NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT **110**

OPTIMIZING STREET OPERATIONS THROUGH TRAFFIC REGULATIONS AND CONTROL

HIGHWAY RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING

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PEAT, MARWICK, MITCHELL & CO.
SAN FRANCISCO, CALIFORNIA

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- HIGHWAY SAFETY
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DIVISION OF ENGINEERING NATIONAL RESEARCH COUNCIL
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Highway Research Board of the National Academy of Sciences-National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn, it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway departments and by committees of AASHO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are responsibilities of the Academy and its Highway Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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This report was prepared by the contracting research agency. It has been reviewed by the appropriate Advisory Panel for clarity, documentation, and fulfillment of the contract It has been accepted by the Highway Research Board and published in the interest of effective dissemination of findings and their application in the formulation of policies, procedures, and practices in the subject problem area

The opinions and conclusions expressed or implied in these reports are those of the research agencies that performed the research. They are not necessarily those of the Highway Research Board, the National Academy of Sciences, the Federal Highway Administration, the American Association of State Highway Officials, nor of the individual states participating in the Program

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FOREWORD

By Staff

Highway Research Board

This report will be of special interest to traffic engineers, public works administrators, and other city officials interested in improving the traffic-carrying ability of city streets. The project is unusual in that it is one of the few research endeavors that has actually demonstrated methods of improving traffic flow on a network of city streets as compared with spot or arterial improvements. In doing this, traffic improvements were carried out with the cooperation of the cities of Sunnyvale and Redwood City, California The results vividly point out the need for a good program of public relations and law enforcement. An appendix to the report includes complete documentation of the newspaper publicity received during the study.

To meet present and future traffic demands, existing streets must be made to operate more efficiently. Streets through heavily developed areas have limited rights-of-way, thus preventing, on an economic basis, their reconstruction for increased capacity. Practical measures for increasing operational efficiency of these streets through the judicious application of traffic regulations and controls should be developed. Numerous studies of isolated or "spot location" traffic engineering treatments have been reported. This piecemeal information has not provided a basis for measuring the operational gains that could be obtained from intensive area-wide traffic engineering improvement programs. Through area-wide improvements in traffic regulations and controls, the interaction between measures and their effect on adjacent locations as well as on the traffic environment of the area as a whole could be determined. It was with these thoughts in mind that this project was initiated during the fall of 1966.

The primary objective of this research was to apply a series of standard traffic regulation and control techniques to an area of urban streets and evaluate the results. For this research, the cities of Sunnyvale and Redwood City, California, were selected as the cooperating demonstration test cities.

In this comprehensive and well-documented study, the consulting firm of Peat, Marwick, Mitchell and Co. established a base-condition traffic operation profile in each city by measuring such parameters as travel time, accidents, etc. The base-condition profile was used as one yardstick to measure the effect of traffic improvements installed in the two cities. In addition, the value of the traffic improvements—based on public acceptance, retail business performance, and driver observance—was also measured.

It should be noted that the study goal was "optimization" of traffic regulation and control. The applied research effort in this study program was undertaken in real time under all the pressures that exist in the real-world environment of the test cities. The effects of various regulation and control techniques could be measured and compared and the best performance identified. Only in this sense could it be implied that "optimization" has been attained.

Further research is needed to clarify the degree of awareness and soundness of judgment of various sectors of the public to operational changes. As the authors point out, a way must be found to effectively incorporate representative public opinion into the decision-making processes associated with improved traffic regulation and control.

CONTENTS

ACKNOWLEDGMENTS

The research reported herein was conducted by the San Francisco office of Peat, Marwick, Mitchell & Co (formerly Traffic Research Corporation), with James H Kell, Partner, as Principal Investigator and Barnard C. Johnson, Manager, as Co-Principal Investigator and Project Director. The research team was composed of consultants Barry L Benioff, T S. Khanna, W. Michael Belrose, and Ahmad Moghaddas Field studies were supervised by Ronald J Repper.

Particular acknowledgments are extended to the following individuals and organizations

Arthur U. Eskelin, Traffic Engineer of Redwood City, Calif , and V Lee Yarborough, Traffic Engineer of Sunnyvale, Calif , for their time and efforts in the planning, design, and implementation of each test stage

Howard Ullrich, City Manager of Redwood City, John Dever, City Manager of Sunnyvale, and their respective staffs

The Mayors and City Council members of Redwood City and Sunnyvale for passing enabling legislation allowing the study to proceed.

The Chambers of Commerce of Redwood City and Sunnyvale for providing staff time and effort to obtain the opinion of merchants on various test stages and helping to collect retail sales data

The Police Departments of Redwood City and Sunnyvale for providing the project with citywide traffic accident records and contributing to the planning of test stages.

The Public Works Departments of Redwood City and Sunnyvale for providing manpower, equipment, and materials for the implementation of each test stage and for the use of their battery chargers and traffic counters.

The local newspapers in Redwood City and Sunnyvale for their thorough press coverage of test stage developments as the study progressed

The California Division of Highways and the Public Works Department of Santa Clara County for providing traffic volume data.

The City of Santa Clara, Calif., for the use of their 20-pen recorder

The citizens of both Redwood City and Sunnyvale for their responses to the public opinion questionnaires and their patience and understanding throughout the study.

OPTIMIZING STREET OPERATIONS THROUGH TRAFFIC REGULATIONS AND CONTROL

SUMMARY

This report presents the findings of a two-year project that determined the relative areawide effectiveness of traffic engineering techniques in the central business districts (CBD) of two small west-coast cities. The cities participated in a program of traffic operations research, and the results were obtained in a real-time and political environment. In addition, many elements of the urban environment were observed, including business performance, public opinion, and political processes.

In the California cities chosen as test sites, Redwood City (pop. 60,000) and Sunnyvale (pop. 90,000), serious planning had been under way for the revitalization of the CBD inasmuch as attractive shopping centers in outlying areas were creating an economic squeeze on the downtown merchants. Traffic access, circulation, and parking were recognized as important elements in the viability of the CBD. City officials and leaders of the business community welcomed the opportunity to participate in a program designed to test the effectiveness of various techniques as a means of maximizing use of existing roadways. With the support of city officials and the downtown community, the Councils of each city enacted broad legislation endorsing the project and offering specific assistance in the form of labor, materials, and equipment.

A base condition traffic operations profile was established for each city and was used for subsequent comparisons as changes in traffic regulations and control were implemented and evaluated through a series of test stages. Operational techniques ranging from relatively simple, but effective, signal timing to extensive left-turn prohibitions and one-way operations were evaluated. Angle parking, no-stopping towaway, and unbalanced traffic flow were also evaluated throughout an area of urban streets. Average speeds, stops, delays, and a variety of other measures were used to determine the relative magnitude of operational efficiency on an areawide basis. Business performance, public acceptance, and driver observance were also measured for each combination of traffic improvement techniques.

The greatest improvement in operational efficiency was found in Redwood City with a combination of one-way and unbalanced flow couplets. From a public opinion and business performance standpoint, this test stage was the least objectionable and is considered the one most suited to the prevailing conditions.

The next best combination of regulation and control techniques was demonstrated in a test stage which incorporated wider lanes on the main shopping street through use of a no-stopping towaway regulation. The areawide performance of this

stage was good, although the adverse effect on operations of additional angle parking on major side streets was apparent.

Two other test stages revealed certain increased efficiencies in areawide measures, but, at the same time, revealed the inherent problems that arise when attempts are made to introduce new traffic patterns without having good alernate routes. In Redwood City, the main shopping street was de-emphasized, through traffic was encouraged to use an adjacent parallel street, and, in effect, two new parking lots were created on major side streets. A continuous left-turn prohibition produced improvements where traffic could be diverted to alternate routes, but it was less efficient where no alternate route was available and the effect of increased vehicle-pedestrian conflicts was evident.

In Sunnyvale, efficiency was considerably increased with an effective unbalanced flow pattern. This stage was concurrent with closing two blocks to through traffic and adding angle parking. In a previous stage, a revised signal timing plan had shown improvement, but not under conditions where the single-lane flow pattern was sensitive to turning movements and parking maneuvers.

The assumption may often be made that a CBD signal system is at peak operating efficiency and that further improvements in traffic flow conditions can be made only by implementing more restrictive types of control. The signal timing should always be reviewed first because this factor has one of the greatest effects on intersection capacity. This study showed that areawide improvements can be attained through signal timing refinements. However, when traffic lanes are relatively narrow and curb parking is present, the effects of signal timing improvements were found to be much less noticeable.

As this research study included the significant areas of business performance and public opinion, greater insight was gained into the political feasibility of a proposed traffic change. The study findings substantiated the proposition that no major traffic improvement plan can be implemented, regardless of the extent to which it may serve the public interest, unless it meets with the support of the general public, especially that of the business community.

Action should be taken now to apply the research results through a series of workshops and seminars that would directly and objectively involve city officials and business leaders in community action programs aimed at maximizing the use of existing street space. It is a crucial time, nationwide, when many cities are undertaking extensive programs to revitalize their CBD areas. The economic viability of these areas will depend on efficient access, circulation, and parking. It is imperative that these cities be made aware of the beneficial areawide effects of sound traffic regulation and control.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

STATEMENT OF PROBLEM

The increasing use of private automobiles as a means of transporting people poses a congestion problem that threatens to strangle business, recreational, and industrial complexes throughout urban areas of the United States. Congestion must be relieved if core areas are to continue to grow and merchants are to continue to prosper and compete with outlying shopping centers. Downtown areas must:

1. Be easily accessible.
2. Provide efficient circulation within the area.
3. Minimize traffic delays.
4. Maintain sufficient readily available parking.
5. Provide convenient pedestrian circulation.
6. Create an amenable shopping atmosphere.

The capacity to handle increasing traffic remains essentially constant in the downtown core areas of most cities because of the fixed right-of-way available. It is usually impossible or, at least, impractical to widen streets in most downtown areas without a major redevelopment program. There are only limited physical alterations possible that increase available street space (e.g., narrowing sidewalks). Therefore, to ease the urban traffic congestion problem it is necessary to make more efficient use of available street space by improving traffic regulation and control techniques

This problem faces almost all small- to medium-size cities. In general, emerging traffic congestion problems are solved only after conditions become intolerable (significant increase in congestion or accident levels). An expedient solution may solve one problem, only to create another. In addition, conditions may necessitate such immediate or drastic solutions that the cost is disproportionate to the level of improvement. Many smaller cities cannot, or do not, maintain a professional traffic engineer, and those that do often have neither the staff nor the budget required for sophisticated planning or extensive traffic improvement programs.

OBJECTIVES

To determine and evaluate areawide effects for a variety of traffic regulation and control measures in the central business district (CBD) of small cities, this project was undertaken.

The project objectives were stated as follows:

1. To develop and demonstrate methods of improving operational efficiency of streets in urban areas.

2. To determine the relative magnitude of increased operational efficiency and safety achieved by application of a model program of traffic regulation and controls throughout an area of urban streets.

3. To evaluate the effect of the area program on driver performance, including observance of traffic laws.

As the project progressed through the test stage planning and approval process, city staff members, leaders of the business community, and Council members became directly involved. Although discussions were oriented toward pursuing the first three objectives, it soon became evident that the following supplemental objective should be considered:

4. To explore the various aspects of the political feasibility of traffic improvement programs and to evaluate the importance of public opinion and business performance relative to the operational features of different traffic regulation and control techniques both before and after implementation.

The effect of these objectives will be to emphasize the effect of the area program not only on driver performance but also on business activity and public acceptance. Public opinion is approached from several viewpoints. During the study, merchants appeared to be acting as a distinct pressure group on the city authorities; hence, their opinions in this project were considered separately.

FIELD TEST SITES

To accomplish the project objectives, two typical urban areas were selected as test sites. The criteria for the selection of test cities included.

1. Physical conditions that would permit a variety of approaches in accomplishing the research tasks.

2. Evidence that major physical features would be relatively stable during the anticipated study period.

3. Sufficient traffic volumes and congestion to provide adequate traffic input to assure meaningful results.

4. Evidence that city staff members and elected public officials were enthusiastic about the proposed project, were willing to accept a progressive approach to solving traffic problems, and were willing to provide services, facilities, and materials needed for the research task.

5. Assurance that the business community and other interested private groups would cooperate with the study.

After careful consideration of many candidate cities, two California cities—Redwood City and Sunnyvale—were selected for the study. Of major importance was the positive attitude of cooperation evidenced by the staffs and legislative bodies of these two cities. The resolutions of the City Councils and letters from staff members and the business communities within the two cities demonstrated their enthusiasm and eagerness to cooperate with this project (see Appendix D).

The two cities selected have many features in common and, also, some significant differences. Both Redwood City and Sunnyvale are situated on the westerly side of the San Francisco Bay (Fig. 1). Both cities operate with a Mayor/Council/City Manager form of government. There is a traffic engineer in each city; however, the effectiveness of each varies, largely because of the organizational structure of each position

From a traffic standpoint, both test sites are affected by some of the same pressures and influences. The Southern Pacific Railroad, which provides major commuter service to San Francisco, runs adjacent to the central business districts (CBD) of both cities. The resulting grade crossings are a part of the traffic congestion picture, especially during the peak commuting periods. Train stations are located in each CBD, with considerable demand for all-day parking in and adjacent to the commuter parking lots.

Characteristic of both cities is the urge toward revitalization of the CBD core areas. Each city has a "new generation" planning department, energetically striving for the

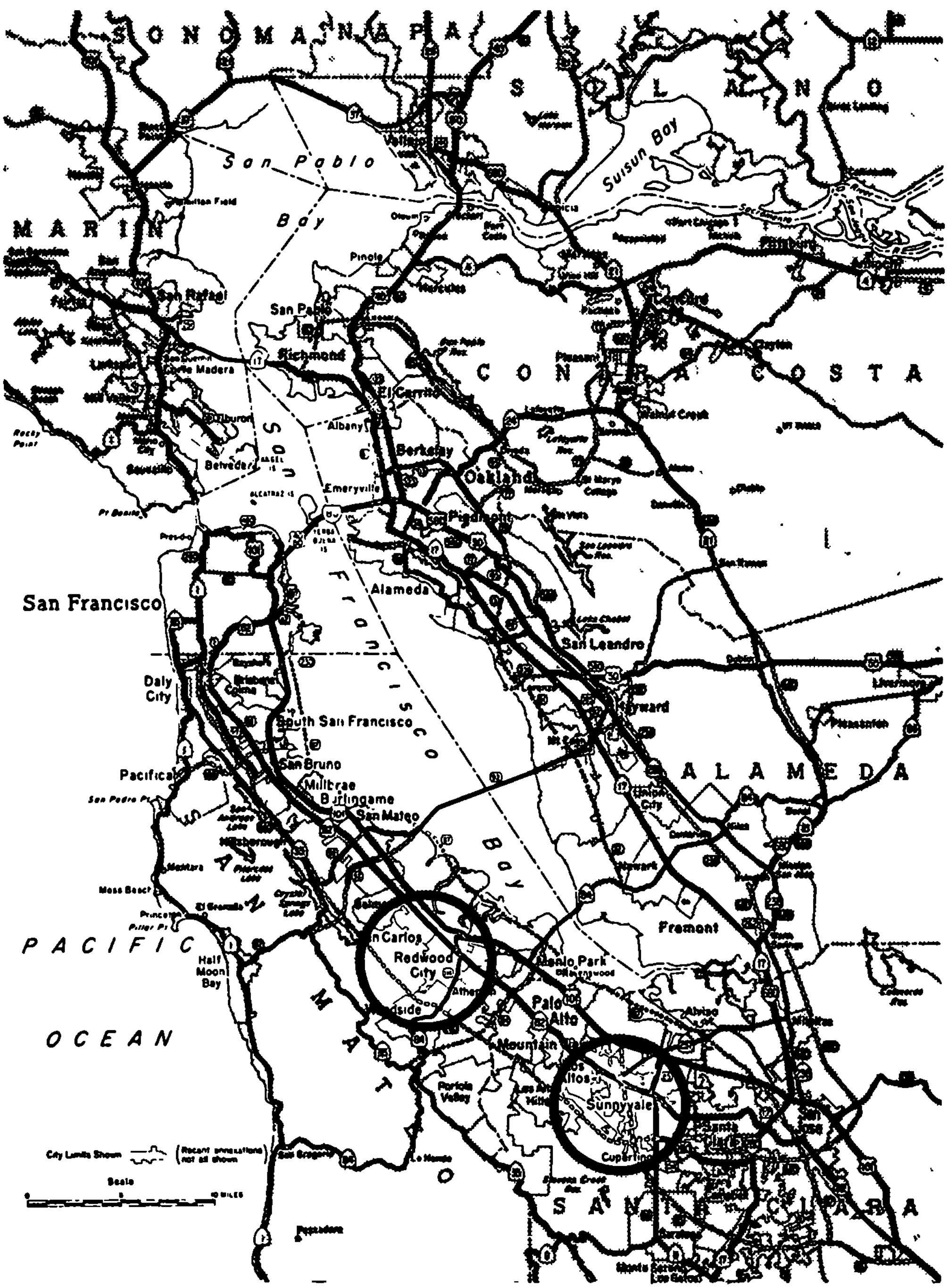

Figure 1. Geographic location of test cities—Redwood City and Sunnyvale, California.

implementation of features contained in recent major planning studies for the downtown areas. Their efforts are also being actively encouraged by progressive committees of businessmen

Although the test cities are similar in the aspects previously described, the differences within the CBD's permitted a wider range of techniques to be evaluated during the same time period. For example, Redwood City has older and denser commercial use in the core area Typical of older cities, there is a main street through the center of the CBD. Sunnyvale, on the other hand, is a newer city with a less dense core, and its through traffic is largely handled on peripheral streets

The concept of using two sites worked well throughout the experimentation phases because field evaluation studies could alternate between the two cities This increased the effort necessary to establish the base conditions, but it also increased the depth, scope, and validity of the study

ORGANIZATION OF DATA

The following final report is organized and presented broadly parallel to the conduct of the study. After a statement of the basic research approach, the framework for the test stage formulation and the description of each specific test stage is presented This chapter defines the measures of effectiveness developed to quantify traffic performance and the analytical procedures used to evaluate the findings. The findings for each test stage are summarized and compared in Chapter Two, including operational performance, business performance, and public opinion As the project progressed, certain aspects of local operations became evident to the impartial research staff that may not have been obvious to local city staff representatives. These supplemental findings are presented in Chapter Two as items that must be considered by any community seeking an effective traffic regulation and control program.

The study conclusions, based on comparative analysis of the findings, appear in Chapter Three. Applications of the study results and suggested research appear in Chapter Four.

The appendices contain the detailed data and associated information developed during the study period

RESEARCH APPROACH

The basic approach used in this project was to quantify and evaluate the effects of a wide range of traffic regulation and control techniques on a specified area of CBD streets in two test cities These techniques ranged from less restrictive items, such as signal timing, to more restrictive techniques, such as parking elimination (towaway) and one-way street operations. Study techniques and alternative solutions to traffic problems in the two test cities could readily be used or adopted to serve as a nationwide model for similar small- to medium-size cities

The initial task was the collection of all pertinent traffic information available from the city staffs, including base maps, accident records, and traffic counts. After initial discussions with city staff members—principally the traffic engineers and Chiefs of Police—a study boundary was established around the CBD of each city. This delineated the area for which a complete data base was to be established for comparison with subsequent experimental test stages As had been anticipated, both cities lacked the quantity and quality of traffic data necessary for this research project

The next step of the work plan was to collect and evaluate base data for existing conditions in the two cities. These data indicated problem areas where traffic operations could be improved, and, preferably, where more than one type of regulation or control could be tested Procedures were organized so that experiments could be implemented in both cities alternately, thereby keeping the field crew occupied to the fullest extent possible

Analyses of traffic conditions and base data were made to.

1. Identify major problems
2. Relate the resulting test plans to identified problems.
3. Determine those situations that are not covered by existing problems and conditions and, therefore, must be artificially created
4. Seek out those significant areas where the resulting test plans can be carried out in greater depth.

As the collection of base data progressed, the formulation of a test stage program began. The original work plan, as set forth in the proposal, called for a separate series of components for each test stage: design, implementation, stabilization, field study, and analysis. It later proved to be more practical—and, in fact, was demanded by the city staffs and merchant groups—to design the major portion of the test stage program (i e., a series of test stages) as a functional unit and have it approved as a complete experimental package The test stage program developed along these lines became a series of components comprising implementation, stabilization, and evaluation field studies Analysis became a continuing process.

Within the time frame available and for the traffic conditions existing in each test site, a series of test stages was implemented and evaluated. A multiplicity of measures of effectiveness was investigated in this study. Standard measures, such as travel time and delay, were evaluated for magnitudes and characteristics of areawide change Incidence of traffic accidents and driver observance as a result of various levels of enforcement were investigated to the extent possible. Other measures providing valuable additions to the study were public opinion and indicators of business activity (sales factors).

Whereas the study goal was "optimization" of traffic regulation and control, the applied research effort in this study program was undertaken in real time under all the pressures that exist in the real-world environment of the test cities. The effects of various regulations and control techniques could be measured and compared and the best performance identified Only in this sense could it be implied that "optimization" has been attained

TEST STAGE FORMULATION

The test stages designed, implemented, and evaluated during the study period were evolved from the base conditions existing in each test city. The following describes the physical characteristics, base conditions, and test stages for both Redwood City and Sunnyvale

Redwood City

Description

The oldest city in San Mateo County, Redwood City celebrated its one hundredth anniversary in 1967. Incorporated in 1867, it has been a county seat since 1856. The city is 25 miles south and east of San Francisco. The present city covers an area of 34 square miles and has a population, currently 60,500, that has been rising at the rate of approximately 10 percent per year. Business activity, measured by retail sales in the city, was approximately $104 million in 1967, compared with the 1963 figure of $93 million. In addition to other typical business and civil functions, county operations for a population of 530,000 are transacted in a building complex located in the CBD. The CBD of Redwood City is shown in Figure 2.

Most of the major streets in the CBD are four lanes wide and have parallel parking. Broadway, the principal street, is the major shopping street as well as an important crosstown arterial. Curb parking is extensive, with some angle parking on minor streets. Over 550 off-street spaces are provided in city lots in the CBD, exclusive of commuter lots Parking meters are installed throughout the CBD, although merchants have requested removal of the curb meters on numerous occasions The merchants are convinced that these meters have a harmful effect on business. In fact, during the Christmas shopping season, on-street meters are removed and the merchants' association compensates the city for the estimated revenue loss.

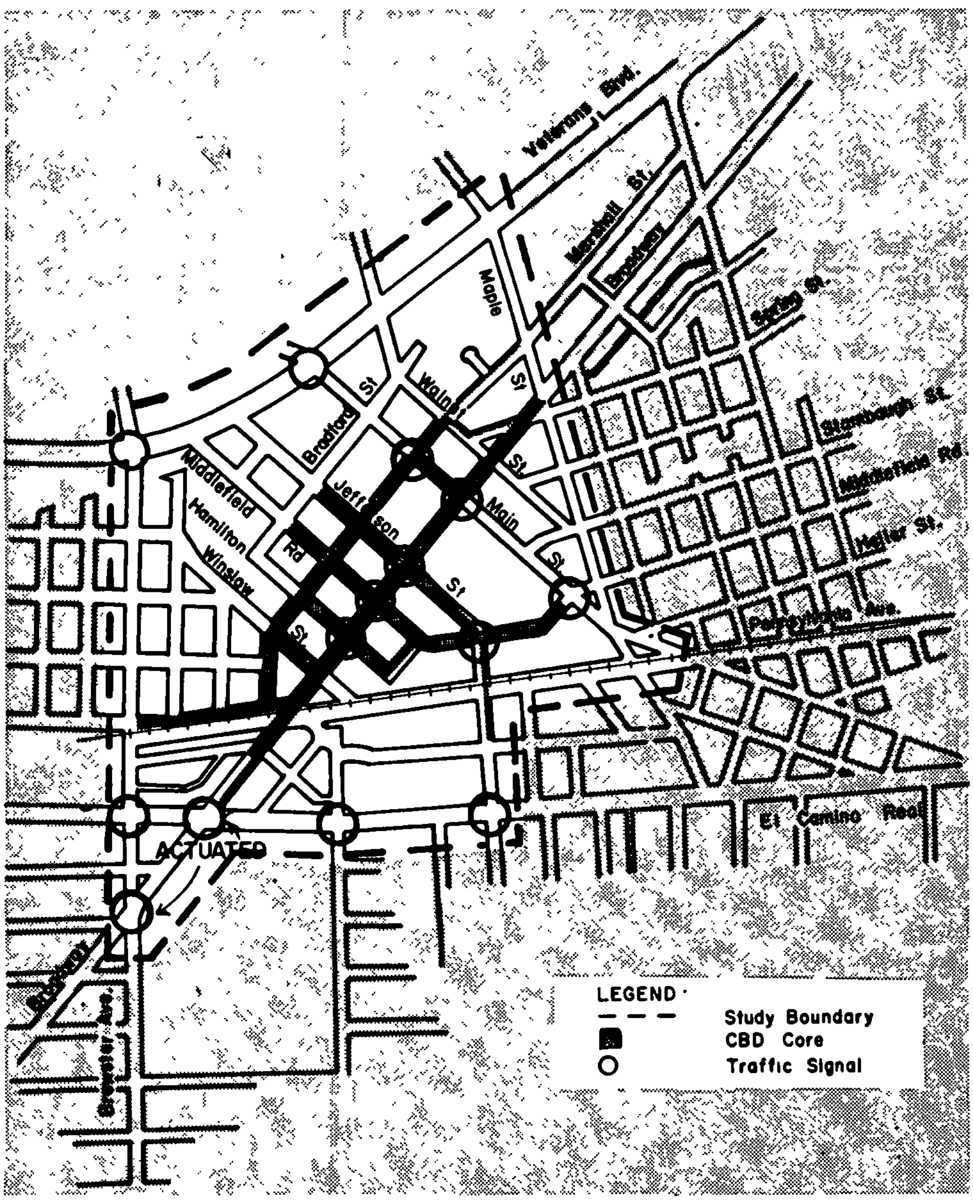

Figure 2. Redwood City central business district.

Base Conditions

Basic traffic data suitable for operational studies in the CBD were sparse. Striping and physical condition drawings were not available. Signal timing records either did not exist or were sketchy and not up to date. Current automatic and manual volume counts were limited to a few spot locations. Speed and delay runs were nonexistent, and descriptions of traffic congestion were largely intuitive and general in nature. Spot speed studies generally were done only for enforcement purposes, using mobile radar units, and then usually on peripheral streets outside of the study limits. There were no volume counts of short duration that were suitable for use with the necessary speed and delay runs (These observations are made in relation to the needs of this particular project and are not intended to reflect in any way on the city staff.)

To develop a valid, in-depth profile of existing traffic parameters that would serve as a basis of comparison for measures of traffic improvement, studies were undertaken by project field teams to obtain the following data:

1. Volume counts—15-min automatic counts and short-interval counts (6 min).
2. Turning movement counts for selected time periods.
3 Pedestrian volumes at critical locations.
4. Speed and delay runs on a block-by-block basis for practically all streets in the study area.
5. Stopped time delays at signalized intersections.

The need for potential traffic improvements is indicated by such factors as low travel speeds, accident rates, and excessive backup at signalized intersections. Broadway, the principal street, exhibited the greatest problems, having a speed range from 26 down to 6 mph (Fig. 3). The street

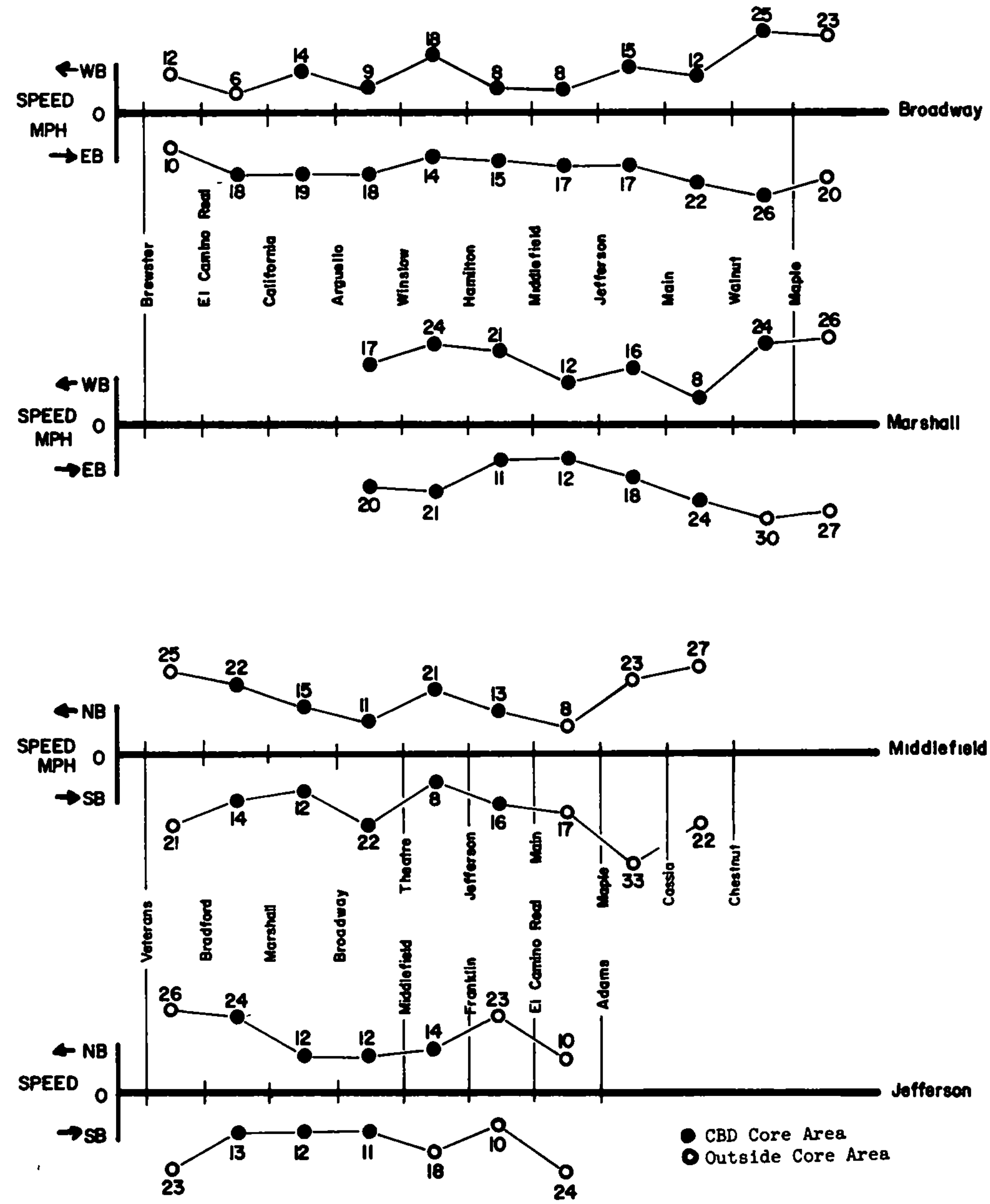

Figure 3. Base condition speed profiles—Redwood City.

carries approximately 12,500 vehicles per day (vpd). Substantial congestion occurs at certain times during the day. The street has an accident rate of 51.6 accidents per million vehicle-miles. This figure is compared with a rate of 12.7 on the adjacent parallel street carrying 6,000 vpd and rates of 22.1 and 15 5, respectively, on the two major cross streets carrying approximately 5,000 vpd each.

Existing problems on Broadway appeared due largely to narrow lanes. The curb-to-curb width of 50 ft was divided into two 7-ft parking lanes and four 9-ft moving lanes. Driver reaction to the narrow lanes and the close proximity of parked vehicles was evident by the obvious reluctance of motorists to use the curb lane until compelled to do so by the pressure of increasing traffic volumes.

Test Stages

Based on an evaluation of the base conditions and the identification of problem areas, test stage programs were established. The procedure that was followed consisted of presenting the test program recommendation to the city traffic engineer for review. Suggestions for modifications were made at this staff level before the program was submitted for approval by the broad-based interdepartmental staff committee and, subsequently, by the City Manager. Numerous changes were made, particularly as a result of the information meetings held by the City Manager with several business and civic leaders who were keenly interested in the revitalization of the downtown area. (This subject is discussed more fully in Chapter Two.)

The various test stages and their sequence are summarized as follows.

R1.0/R2.0—Signal Timing (Fig. 4).—In the CBD, Broadway is controlled by four single-dial, noninterconnected, pretimed signals. The primary objective of these test stages was to test the sensitivity of Broadway traffic to signalization. Stage R1.0 was a timing program designed for morning peak-hour conditions that favored traffic in the eastbound direction. The objective was to improve traffic flow conditions for traffic moving in the peak direction. A secondary objective was to study the effect of the change in progression on each direction of flow and during other time periods of the day. In this case (and most others involving signal timing), the stabilization period was assumed to be practically instantaneous.

The expected result for this stage was an increased speed for the morning peak direction (eastbound) that would more than offset the expected adverse effects on traffic moving in the opposite direction. It was also anticipated

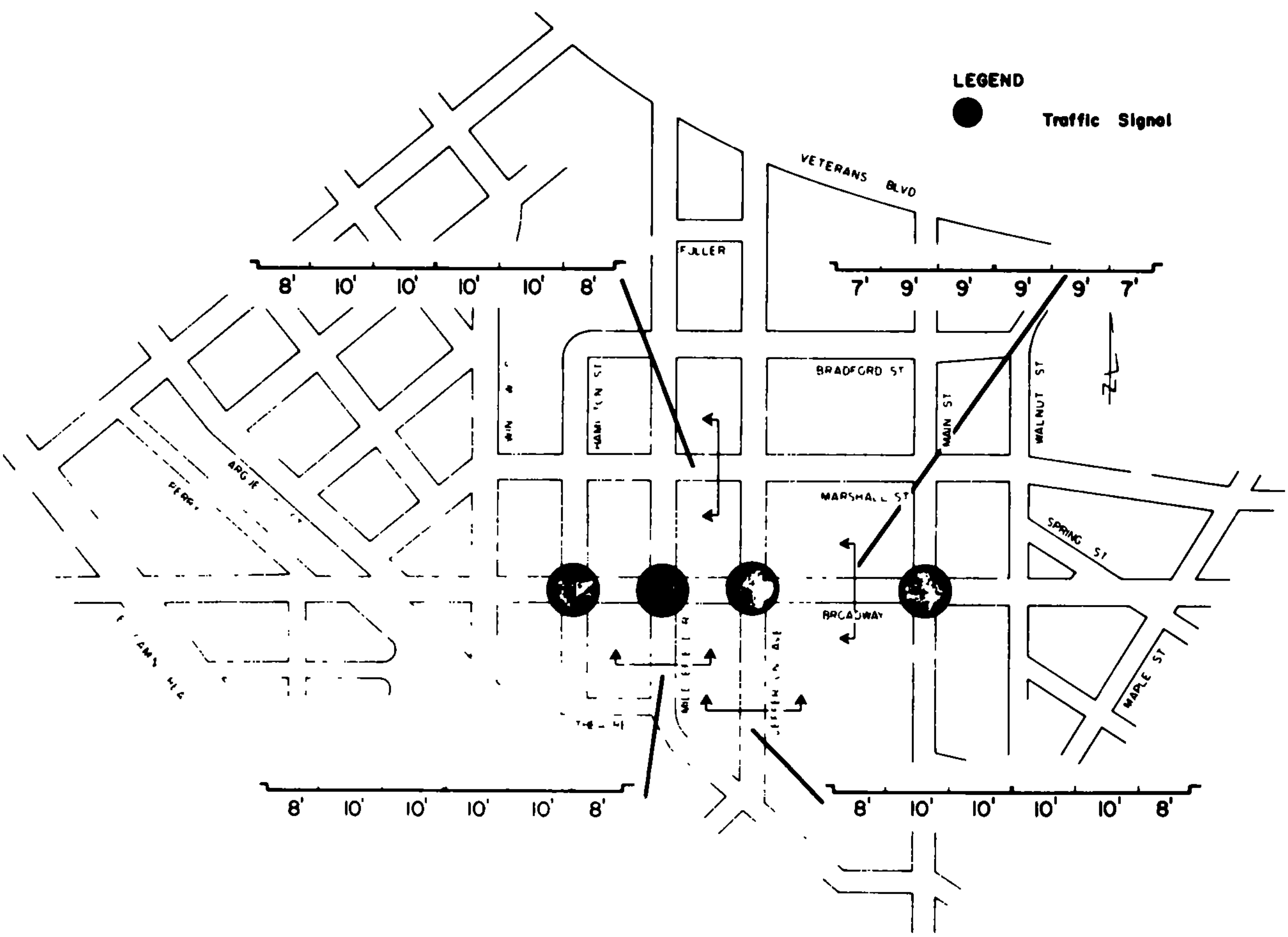

Figure 4. Test stage R1.0/R2.0—signal locations.

that the speed for the evening peak direction (westbound) would be decreased.

Stage R2.0 was designed for conditions for which it would be desirable to treat both directions of traffic flow equally. The settings actually favored the predominant westbound traffic slightly, but only by a ratio of approximately 55 to 45.

By using the morning peak period results from R1.0, combined with results from other time periods of R2.0, a two-offset signal system can be simulated.

R20.0—Left-Turn Prohibition (Fig. 5).—Congestion had been observed behind left-turning vehicles on Broadway at various times during the day. The backups occurred at times when the curb lane was available; however, the general reluctance of drivers to use that lane tended to compound the problem. Left turns were prohibited in both directions on Broadway at the six principal intersections in the core area. The turn prohibition was requested and approved as a 24-hr prohibition in order to establish a habit pattern for all motorists using the street at any time of the day. The objectives of this stage were to improve traffic flow in each direction on Broadway during all time periods and to study the impact of the left-turn prohibitions on other streets in the core area.

Standard NO LEFT TURN signs were installed on the near-right and far-left corners of each intersection. Advance warning signs for motorists approaching the CBD from both directions were posted, informing them of the new prohibitions. In addition, a special sign was installed for the westbound motorists, notifying prospective left-turning drivers of an alternate route via Marshall—an adjacent parallel street one block north of Broadway.

The stabilization period for this stage was originally estimated to be two weeks. Special studies performed to confirm stabilization indicated the need to postpone evaluation field studies for one week to allow more time for left-turn violations to decrease and stabilization to occur. Details of the stabilization pattern appear in Appendix C.

R30.0—Towaway and Angle Parking (Fig. 6).—Test stage R30.0 involved the implementation of the no-stopping towaway regulation from 7:00 AM to 6:00 PM on the south side of Broadway for eastbound traffic in the core area. The left-turn prohibitions were continued. The objective of this stage was to expedite eastbound traffic flow as a result of wider lanes and the elimination of marginal friction. A further objective was to reduce the midblock accident rate on Broadway.

The stabilization period for the towaway regulation was surprisingly short—requiring only a few days and minimum

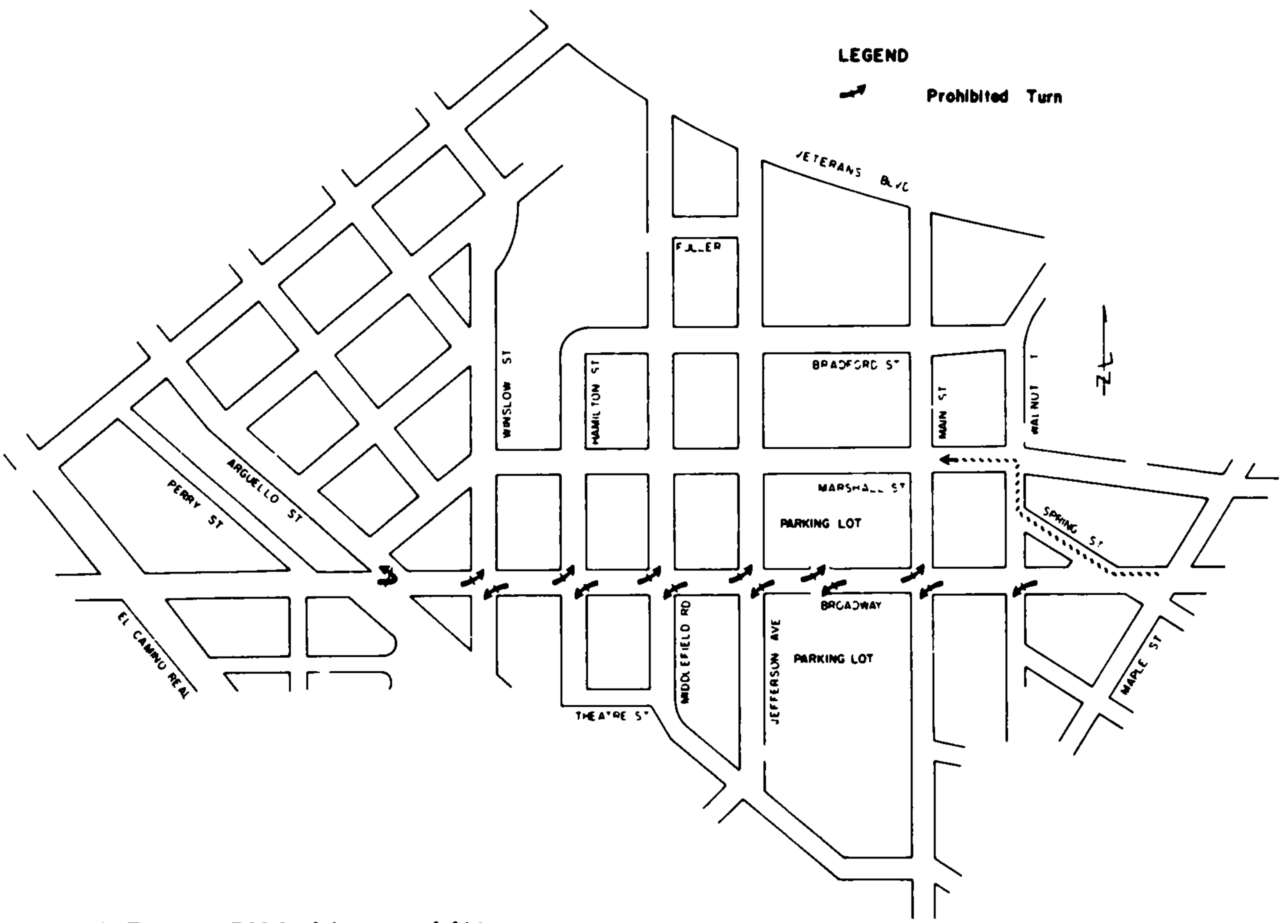

Figure 5. Test stage R20.0—left-turn prohibition.

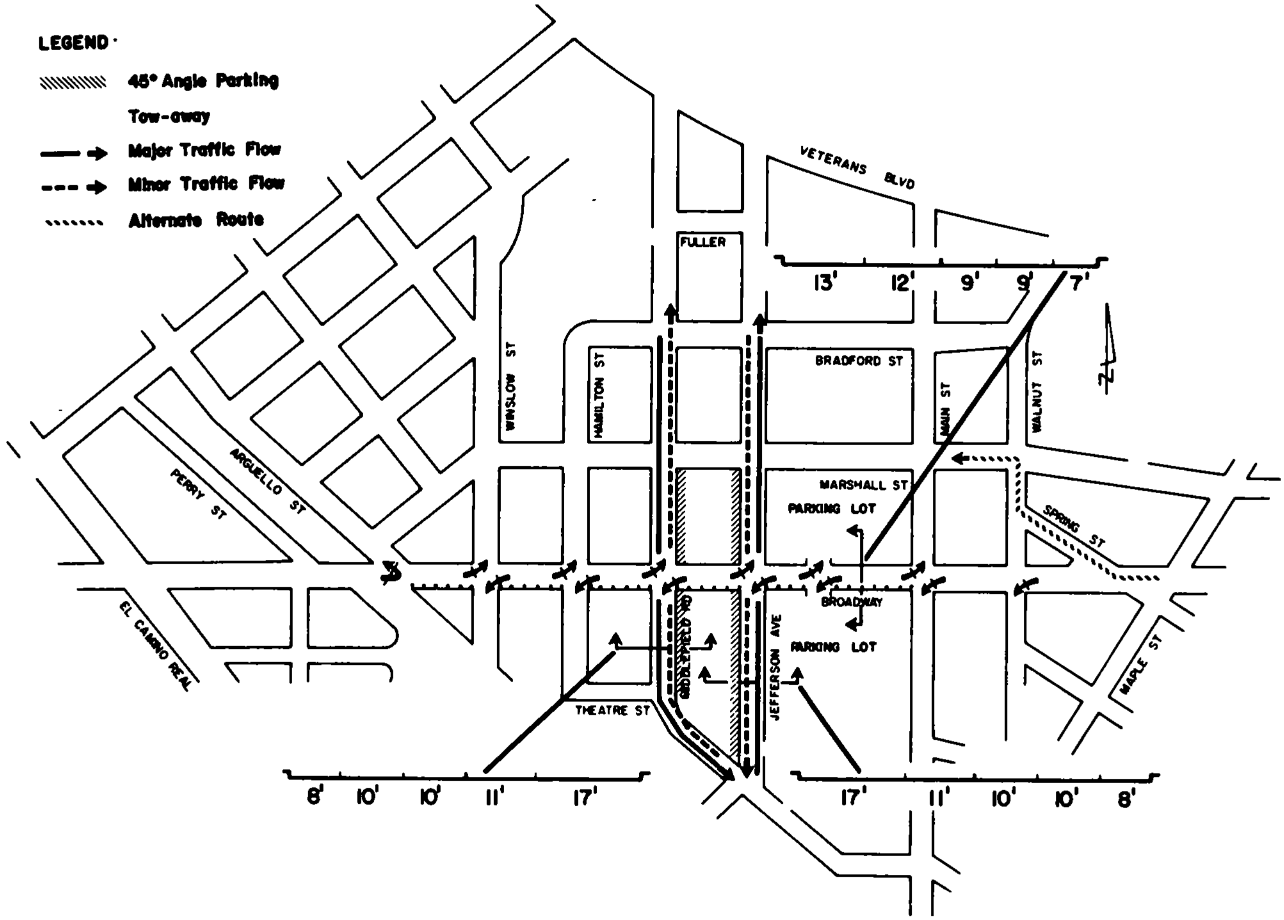

Figure 6. Test stage R30.0—towaway and angle parking. No stopping towaway, 7 AM-6 PM, south side of Broadway.

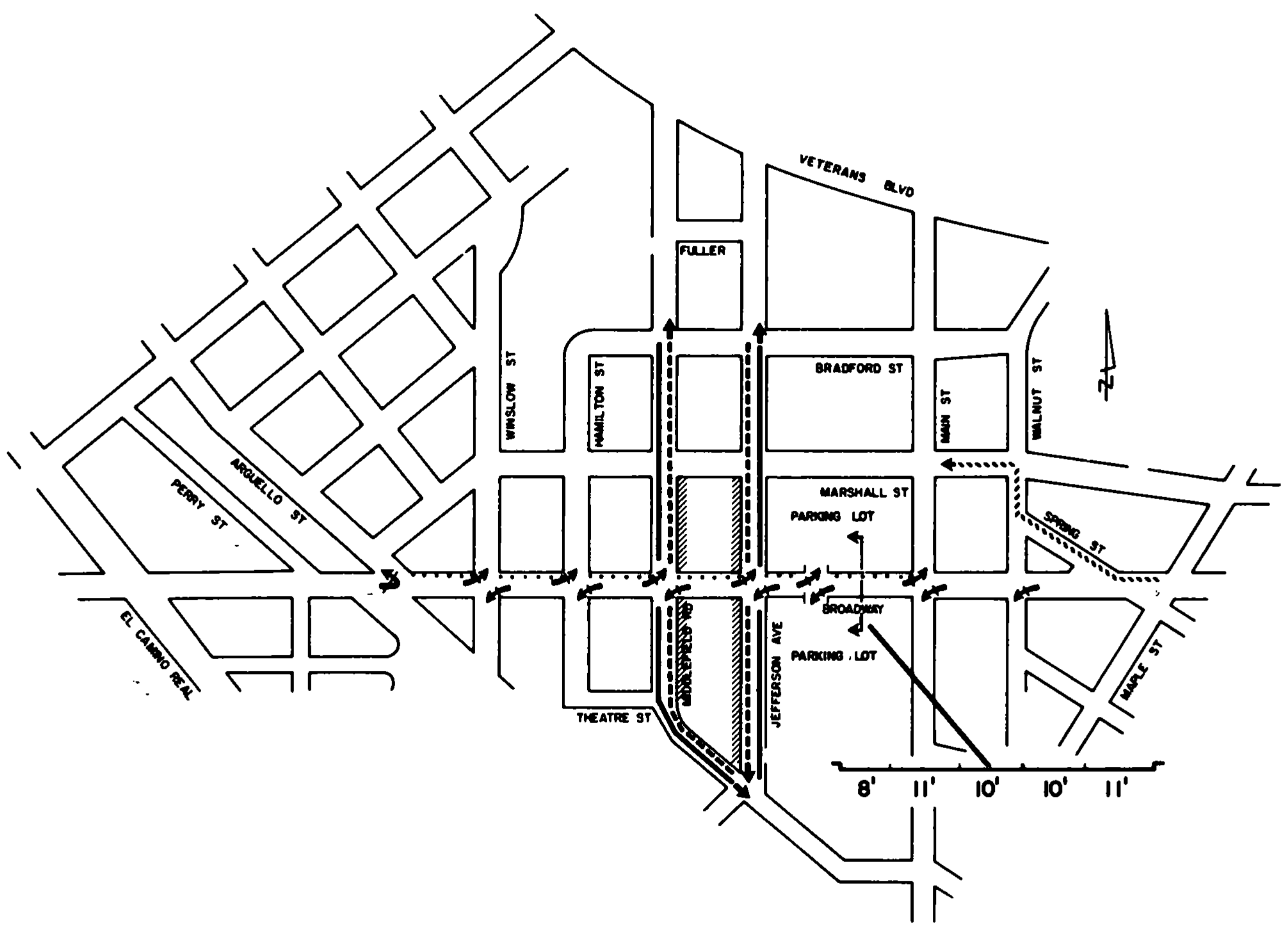

Figure 7. Test stage R40.0—towaway and angle parking. No stopping towaway, 11 AM-6 PM, north side of Broadway.

enforcement. This record was largely due to use of frequently spaced large signs (18 in. × 31 in.) and the removal of parking meters that accentuated the change.

Concomitant with the towaway regulation on Broadway, angle parking was implemented on the east side of Middlefield and the west side of Jefferson. The parking meters, which did not conform to the new stall locations, were removed from their posts, permitting free parking. The new parking configuration reduced the number of lanes from two to one for the directions involved, leaving the two lanes for travel in the opposite direction unchanged. In this way an unbalanced flow pattern was achieved. The objective of this phase of the test stage was to study the effect of angle parking and unbalanced flow on the streets involved.

R40.0—Towaway and Angle Parking (Fig. 7).—Stage R40.0 was similar to that implemented in stage R30.0. The left-turn prohibitions and the sidestreet angle parking were continued. The towaway regulation was changed from the south side to the north side of Broadway. The time period was also changed so that the regulation was in effect only from 11:00 AM to 6:00 PM because the westbound morning traffic was light. Parallel parking was restored on the south side of the street. The street was restriped to make all four lanes approximately 10 ft in width.

The principal objective of this stage was to improve traffic flow conditions for westbound traffic by providing wider lanes and reduced marginal friction as a result of eliminating parking. A secondary objective was to evaluate the effect of wider lanes adjacent to parked vehicles for eastbound traffic.

It was anticipated that more congested conditions for westbound traffic would occur during the morning peak period when the towaway regulation was not in effect and the number of lanes was reduced from two to one. Eastbound traffic was expected to be worse than that in test stage R30.0, but better than in the base condition.

R0 5—Holiday Moratorium.—Stage R0.5 was not a formal test stage, but a two-month period during which the CBD core area street system was returned to the base condition for the Christmas holidays. Measures of travel times and delays were obtained along Broadway during this period as a means of reconfirming base levels of operational efficiency. The factors leading to the moratorium are discussed in Chapter Two, under "Political Feasibility."

R56.0—One-Way and Unbalanced Flow (Fig 8).—Originally, two stages were planned for stage R56.0: an unbalanced flow condition, followed by a more restricted one-way operation. In each stage, two couplets were planned (east-west and north-south). Because of the pressures exerted on the project by some Broadway merchants, a compromise test stage was developed combining the two stages.

As implemented, the combined stage R56.0 consisted of a one-way couplet through the core area, using Broadway eastbound and Marshall westbound. The two major cross streets were restriped for unbalanced flow, with northbound favored on Jefferson and southbound on Middlefield. The objective of this stage was to improve traffic flow conditions on the four major streets in the core area and to study the effect of these extensive changes on an areawide basis.

The one-way flow conditions were the factors used to determine stabilization. Based on reports from the Police Department and observations of driver actions, the evaluation field studies were initiated after approximately one month of stabilization.

The changes made in this stage produced design changes at the intersection of Middlefield and Jefferson. Additional changes in approach-lane configuration were made and the intersection was evaluated as a minor test stage. The objective was to reduce intersection delay.

R70.0—The Downtown Plan (Fig. 9).—Stage R70.0, the final phase in the Redwood City test stages, comprised an areawide combination of techniques that approximated the circulation elements of the Redwood City Downtown Development Plan. Broadway was de-emphasized from a through-traffic standpoint by restriping the street for one lane in each direction between parallel curb parking and left-turn lanes. Motorists were encouraged to use Marshall as a bypass around Broadway. This route was improved by eliminating STOP signs and channelizing flow at transition points.

Middlefield was effectively closed to through traffic by installing angle parking on both sides of three core blocks and by implementing opposing one-way flow in these blocks (each block going in an opposite direction) Jefferson was emphasized as a major two-way street with left-turn lanes and parking prohibitions.

The objectives of this stage were to study areawide effects of this circulation pattern and to evaluate the changes on the individual streets involved.

Midway in the stabilization period, the test stage design had to be changed because the through traffic was not being diverted to the bypass route and intolerable delays were resulting on Broadway. An indignant merchant group and a few councilmen threatened to abort the study if conditions were not improved before the Easter shopping period began. The delays were subsequently reduced by changing the signal timing and adding a right-turn lane. The test stage then continued to the satisfaction of the merchants. Evaluation field studies were conducted after Easter.

The separate study of the intersection of Middlefield and Jefferson continued during this stage. The objective was to determine the effect of the changes made in this stage on intersection delay.

Sunnyvale

Description

Sunnyvale is located in Santa Clara County, 15 miles southeast of Redwood City and 40 miles from San Francisco. The city was incorporated in 1912 and consists of 20.7 square miles The present population is 92,000 and is growing at the rate of 4 percent per year. In 1967, retail sales in Sunnyale were $115 million, as compared to the 1963 figure of $85 million. Retail activities are concentrated along Taaffe Street (not a major arterial) and in an adjacent shopping complex. There is a generous supply of free on- and off-street parking. Figure 10 shows the basic geometric features of the Sunnyvale CBD.

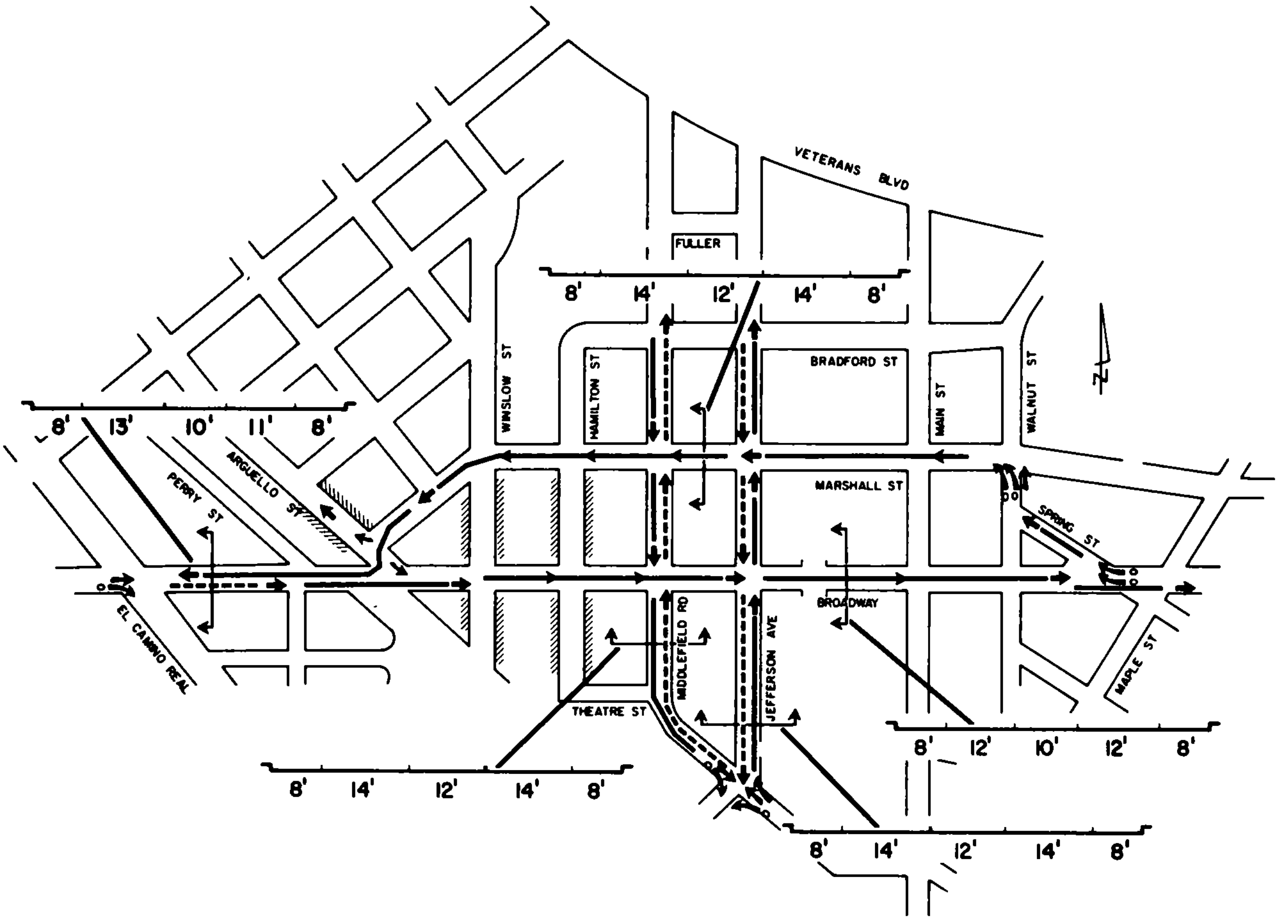

Figure 8. Test stage R56.0—one-way and unbalanced flow.

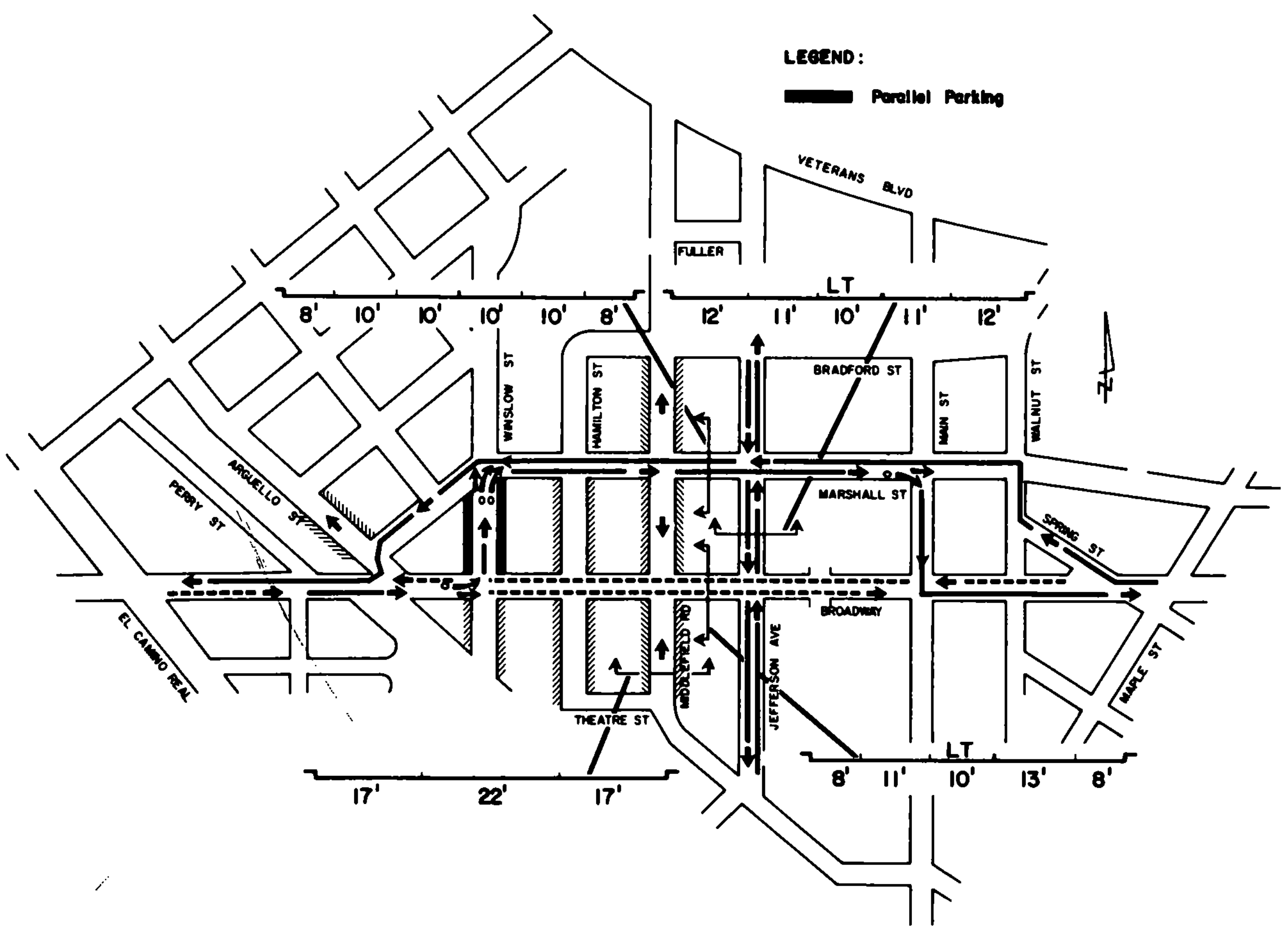

Figure 9. Test stage R70.0—the Downtown Plan. STOP *signs removed for Marshall at Middlefield.*

Major signalized arterials, four lanes or wider, border three sides of the CBD. All streets in the CBD are two lanes wide and, with one exception, have parallel parking with 3-hr time limits. There are no one-way streets, and channelization is limited. Two parallel and adjacent streets within the CBD are controlled by interconnected signals. One street in the shopping complex has angle parking and could easily be converted into a pedestrian shopping mall. In the past, there have been several occasions when the merchants on both sides of the street have arranged to have the central block closed during special sales events for the temporary installation of decorations, booths, exhibits, etc.

Base Conditions

In establishing the data base for the Sunnyvale area, the same procedures were followed as for Redwood City. The

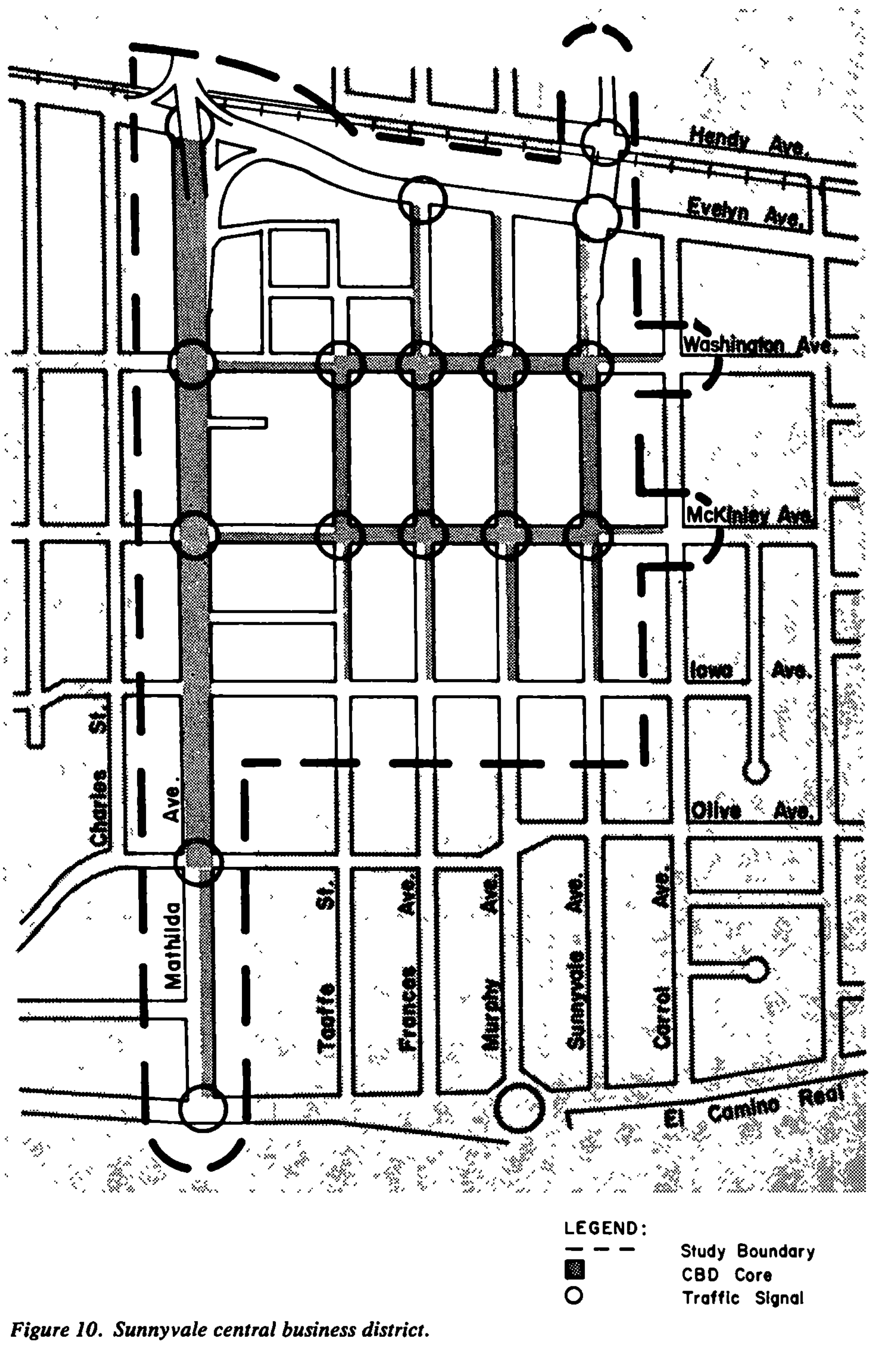

Figure 10. Sunnyvale central business district.

available data, as in Redwood City, did not completely fulfill the requirements of the study program, and similar procedures were followed in Sunnyvale to establish the base conditions.

The speed profiles for the principal streets in the core area are shown in Figure 11 The speeds in some locations were as low as 6 or 7 mph. Accident rates were 11.3 accidents per million vehicle-miles for Mathilda and 32.4 for Sunnyvale Avenue.

It was evident that the CBD could be functionally divided into three problem areas for subsequent evaluation of regulation and control techniques· (1) Mathilda (the major arterial on the western periphery of the CBD) was studied as a signalized system controlling commuter traffic through the area and traffic entering and leaving the core area; (2) the intersection of Sunnyvale and Evelyn also had certain unique characteristics and was handled as a separate problem area, and (3) the core area, controlled by eight pretimed signals and encompassing the shopping district, constituted the third functional problem area.

Test Stages

The first series of test stages in Sunnyvale—S0.5 through S5.0—involved signal timing changes. These tests were considered minor stages in this report, although significant improvements may have been achieved through these changes. (See Fig. 12 for the signal system and base condition cross sections.) The subsequent test stages were broader in scope and dealt primarily with the core area.

S0 5—Fair Oaks Avenue Detour —A major construction project on Fair Oaks Avenue, several blocks east of the CBD, detoured large volumes of traffic to Sunnyvale Avenue, which borders the CBD This changed the base conditions and allowed the evaluation of travel speed changes.

S1 0—Master Dial Replacement —Dial Number 2, controlling traffic during the off-peak periods of the day, had been removed from the master controller for servicing, and a replacement dial had not been installed. The resultant effect on the flow of traffic was studied by having the dial replaced. The objective was to study the effect of the new timing on travel speeds.

S2 0—Eliminate Flash in Morning Peak.—The signals in the core area remained on flashing operation until 8 45 AM, when normal operation began. This timeclock setting was changed so that pretimed signal operation began before the morning peak period. The objective of this stage was to study the effect on traffic flow conditions.

S3 0—Eliminate 24-Hr Flash —Two of the eight signals in the core area had been flashing normally all day. For this and subsequent test stages the signals were operated in a pretimed mode and coordinated with the rest of the system The objectives were to extend the effective grid system to the full eight signals and to study the effect of the change on traffic flow conditions.

S4.0—Improve Vehicle-Actuated Control Settings.—The signal timing settings were refined at the intersection of Mathilda and Washington, a high-volume intersection on the CBD perimeter controlled by vehicle-actuated signal equipment. The objective was to improve the efficiency of vehicular flow through the intersection.

S5.0—Master/Slave Interconnection.—Although equipped with the necessary circuitry, the two signals on Mathilda in the core area did not operate in a coordinated manner. A test stage was implemented whereby a coordinated relationship was established for southbound traffic from the signal at Washington (three-phase, volume density, actuated controller) to the signal at McKinley (modified, pretimed controller). A definite offset was established in the evening peak, but for the morning peak an indefinite relationship was in effect.

The objectives of this stage were to improve flow conditions for southbound traffic during the evening peak hour and to evaluate the performance of the master/slave system as a whole.

Stabilization in this case consisted of a period when the offset relationship between the two signals was refined to maximize the number of vehicles able to clear the system.

S7 0—Signalized Grid Timing (Fig. 12).—Test stage S7.0 involved new timing for the core-area signals in a pattern that established arterial progression along the two major east-west streets and related the timing for each street in a manner favoring one major cross street on the eastern periphery of the core area. The objective of this stage was to improve traffic flow conditions for all three streets.

S8.0—Preferred Route Timing (Fig. 12).—Grid timing was approached in stage S8.0 by implementing offset relationships favoring preferred route for most people driving through the grid, as determined by license-plate studies. The objective of this stage was to improve traffic flow conditions for dominant movements and to study the effects of the change on the core-area street system as a whole

Concurrent with this stage, there was minor rechannelization done at the intersection of Sunnyvale and Evelyn. The effect of this work was to improve the approach- and exit-lane configuration for southbound traffic. The resultant change in intersection delays was then studied and evaluated.

S20 0—Street Closure and Unbalanced Flow (Fig 13). —The regulation and control techniques incorporated in stage S20.0 were originally intended to be implemented as separate stages. It was learned that a major construction project would affect the CBD core area during the last six months of the project. Therefore, a series of five test stages was compressed into two stages, as all the features were considered worth implementing. The two stages were actually formulated as a combination of areawide techniques.

This stage involved closure of Taaffe, the one-block shopping core, to all but pedestrians and emergency vehicles. In addition, an unbalanced flow condition was implemented on each of the major east-west streets, with McKinley favored eastbound and Washington favored westbound. The unbalanced flow was obtained by installing 11:00 AM to 6:00 PM no-stopping regulations and adding a lane stripe in the favored direction.

The observance of the no-stopping regulation was poor and was never stabilized at an acceptable level. Apparently this was due to the use of small signs (14 by 20½ in.) and the lack of enabling legislation for a towaway regulation to accompany the no-stopping prohibition. Conditions were improved slightly by placing on the sidewalk tempo-

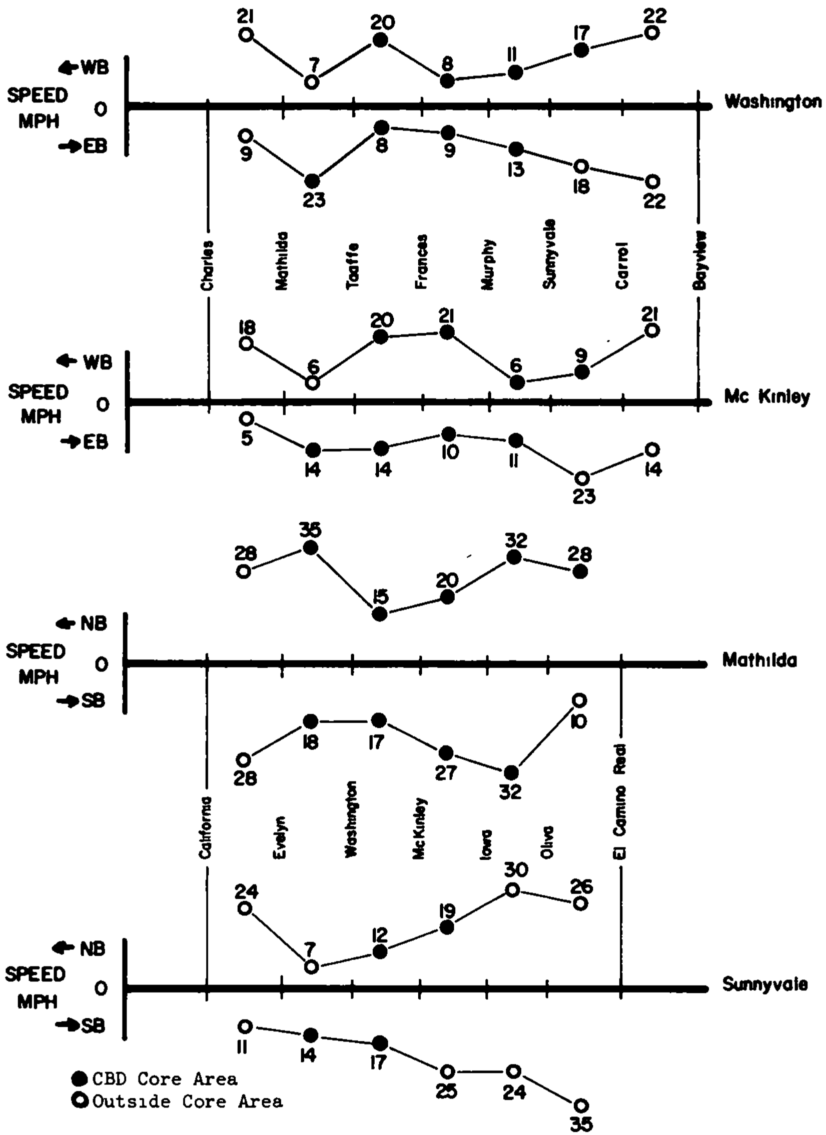

Figure 11. Base condition speed profiles—Sunnyvale.

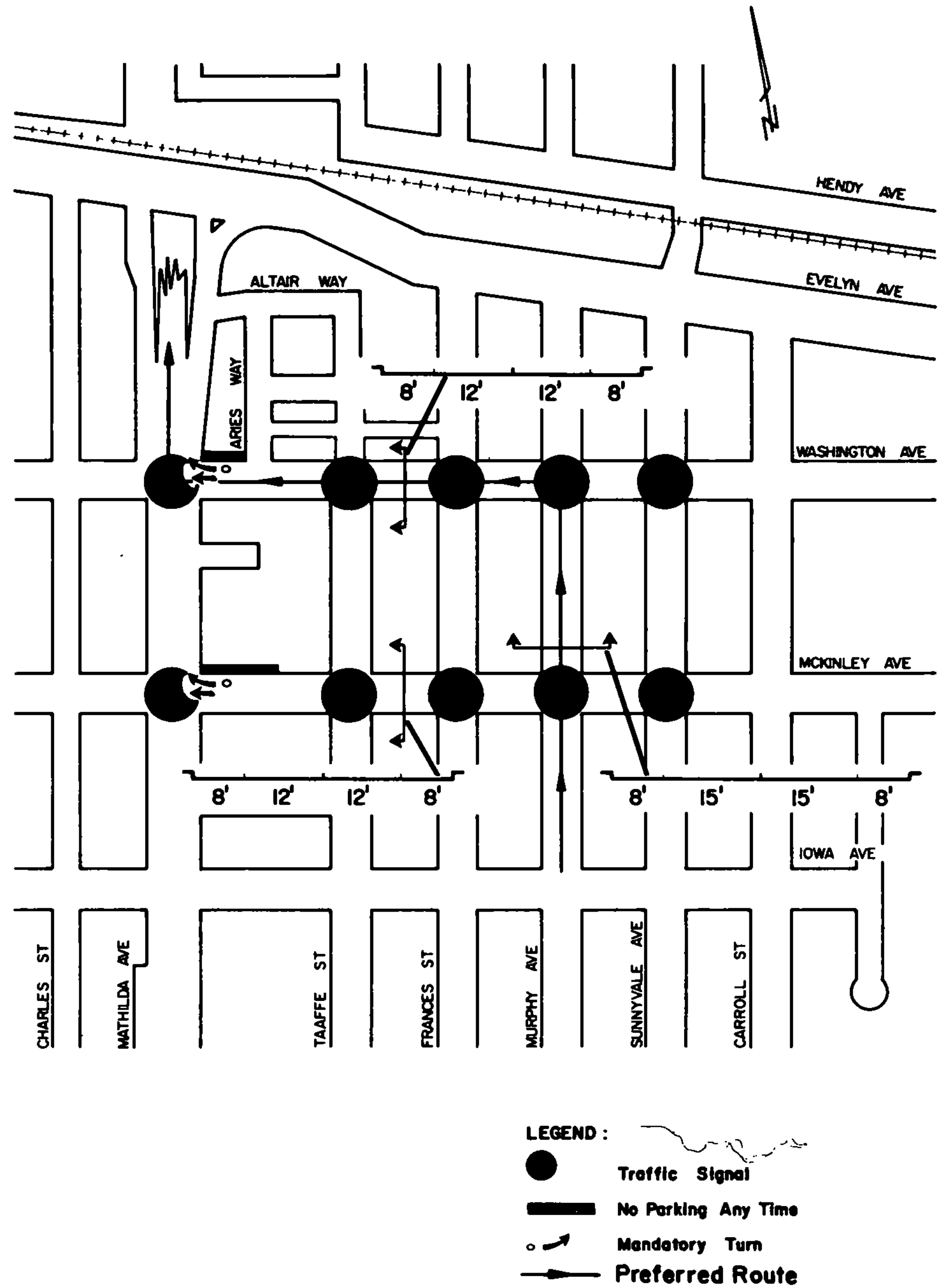

Figure 12. Test stages S1.0 through S8.0—signal locations.

rary barricades bearing signs warning of strict enforcement of the parking regulation. However, on days when evaluation field studies were conducted, special arrangements had to be made with the Sunnyvale Police Department to have the parking regulations frequently and strictly enforced.

Another element in this test stage was a redesign of the intersection of Murphy and McKinley. Parking was prohibited on two approaches and left-turn lanes were installed by restriping the approach roadways. The objective of this stage was to improve traffic flow conditions for all the streets directly involved and to determine the areawide impact of the combined techniques.

S30.0—Street Closure and Unbalanced Flow (Fig. 14). —Stage S30.0, the final test stage in Sunnyvale, involved extension of the unbalanced flow pattern in the CBD core area and street closure of a different type than had been used in the previous stage. Taaffe, closed to vehicles in Stage S20.0, was reopened and Murphy was closed to through traffic, using some of the same techniques applied in Redwood City. Two blocks were made one-way in opposite directions, and angle parking was installed on both sides of the street in a staggered pattern alternating from one side to another.

In addition, the 3-hr parking time limit for on-street parking spaces in the core area was changed to a 1-hr restriction. The no stopping from 11:00 AM to 6:00 PM was changed to no parking at any time. This time the results were more favorable in terms of motorist observance

The objectives of this stage were to further improve traffic flow conditions for the favored direction on Washington, the westbound street in the unbalanced flow couplet, and to improve flow conditions in the core area as a whole as a result of the Murphy Avenue closure.

ANALYTICAL PROCEDURES

The major objective of this project was to quantitatively measure the effectiveness of a series of traffic regulations and control techniques. Therefore, to evaluate the techniques, it was first necessary to choose measures of effectiveness that best quantified the traffic performance.

On a street or an intersection, it is comparatively easy to measure the effectiveness of a change in terms of travel time or speed, number of vehicle stops, and average delay per vehicle. However, measuring the effectiveness of a change on an areawide basis is more complex. When a particular spot improvement on an intersection or a street is made, areawide measures must reflect the possible adverse effects of the spot improvement in other areas. In addition, the areawide effectiveness measures must reflect not only the operational efficiency of the total system, but also the impact on business performance (retail sales) and on public opinion

The measures used to evaluate the test stages were determined from the test stage objectives and expected results. If, for example, an objective was to reduce delays at an intersection, some type of delay determination was chosen as a measure of effectiveness The measures of effectiveness selected determined the type of data required to quantify the measure. In some cases there was more than one way to quantify a specific measure, and the most efficient method had to be determined based on the circumstances and conditions under study.

After the data had been collected and the selected measures of effectiveness had been calculated, the measures were related to the regulation and control techniques and to each other. Two primary methods were used to relate the data: the measures were plotted as a function of test stage chronology for the selected time periods, and measures for each stage in each time period were plotted as a function of some measure of volume to determine the performance of the regulation and control techniques over a range of volume.

The measures of effectiveness chosen to evaluate the test stages of this project are described in the following. Detailed derivations of these measures are given in Appendix A.

Time Periods

After analysis of preliminary volume data, four time periods were selected as representative of various flow conditions in both cities. Data collection and analysis were therefore related to the following time periods:

STANDARD TIME PERIOD [a]	TIME PERIOD IN: REDWOOD CITY	SUNNYVALE
1 Morning peak	7:30-8:30 AM	7:15-8:15 AM
5 Noon	12.30-1:30 PM	12:00-1:00 PM
3 Midafternoon	2.00-3:00 PM	2:00-3:00 PM
4 Evening peak	4:30-5:30 PM	4:30-5:30 PM

[a] Period 2 (10.00 AM to 11:00 AM) was deleted

Volume

In this study, volume served a dual purpose. It was sometimes considered a measure of operational performance, used to determine the effect of a control change on street performance. It also served as an independent variable in evaluating the variation in other measures.

The volume data collected included·

1. Midblock directional counts to obtain hourly, daily, and monthly volume patterns.
2. Intersection turning movement counts.
3. Approach volumes with stopped-time delay studies.
4. Six-min counts with travel time studies.
5. Vehicular volume by lane.
6. Pedestrian flow.

The techniques and objectives of these volume studies are given in detail in Appendix A.

Travel Time and Speed

Travel time and speed are generally considered meaningful measures of operational performance. Travel times, determined from floating-car studies, were obtained for most street lengths between successive intersections in the study areas. These travel times were used to calculate (1) speed on streets between successive intersections, (2) an average speed for a length of street, and (3) an average speed for

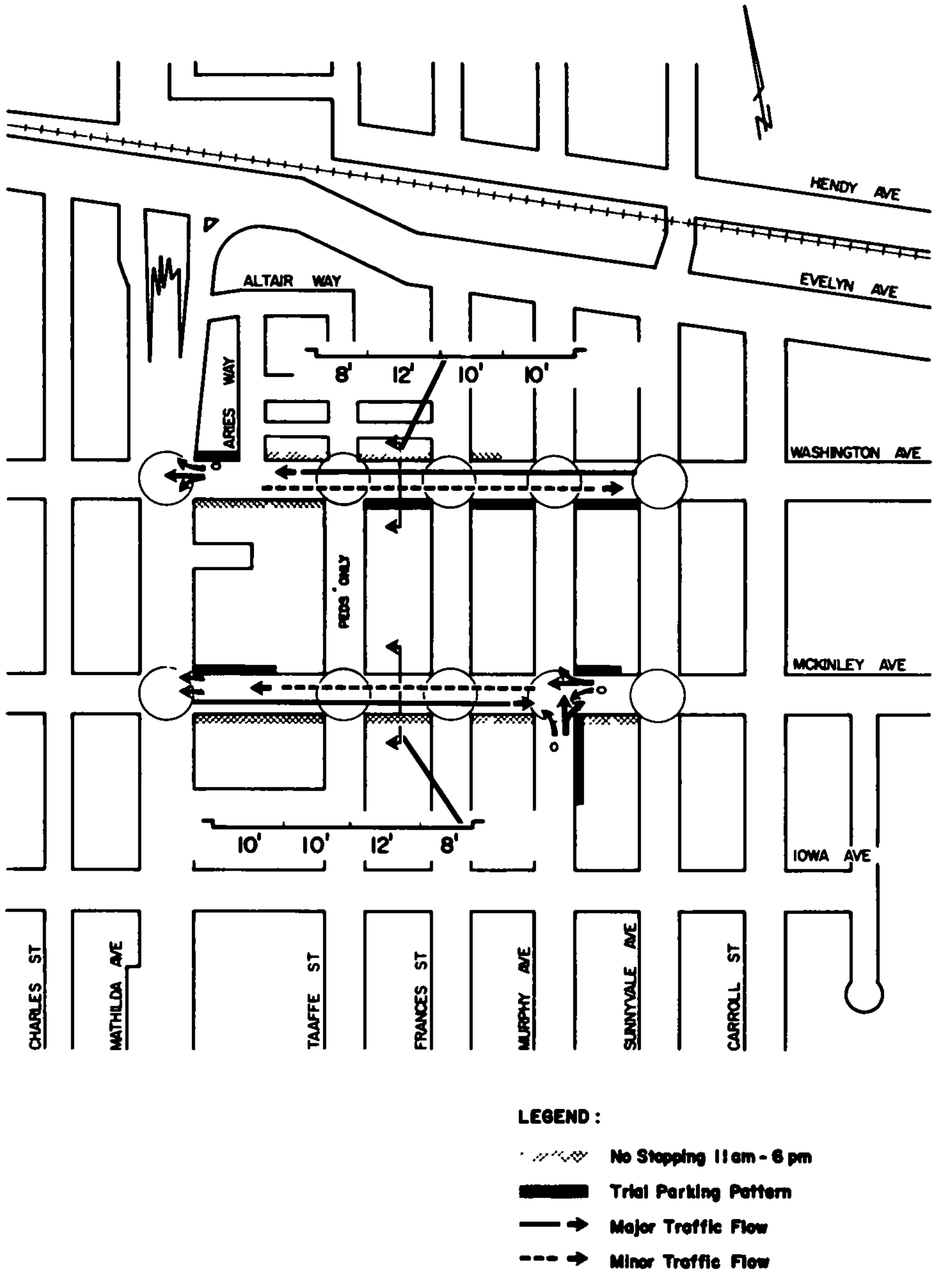

Figure 13. Test stage S20.0—street closure and unbalanced flow Taaffe Street closed to vehicular traffic.

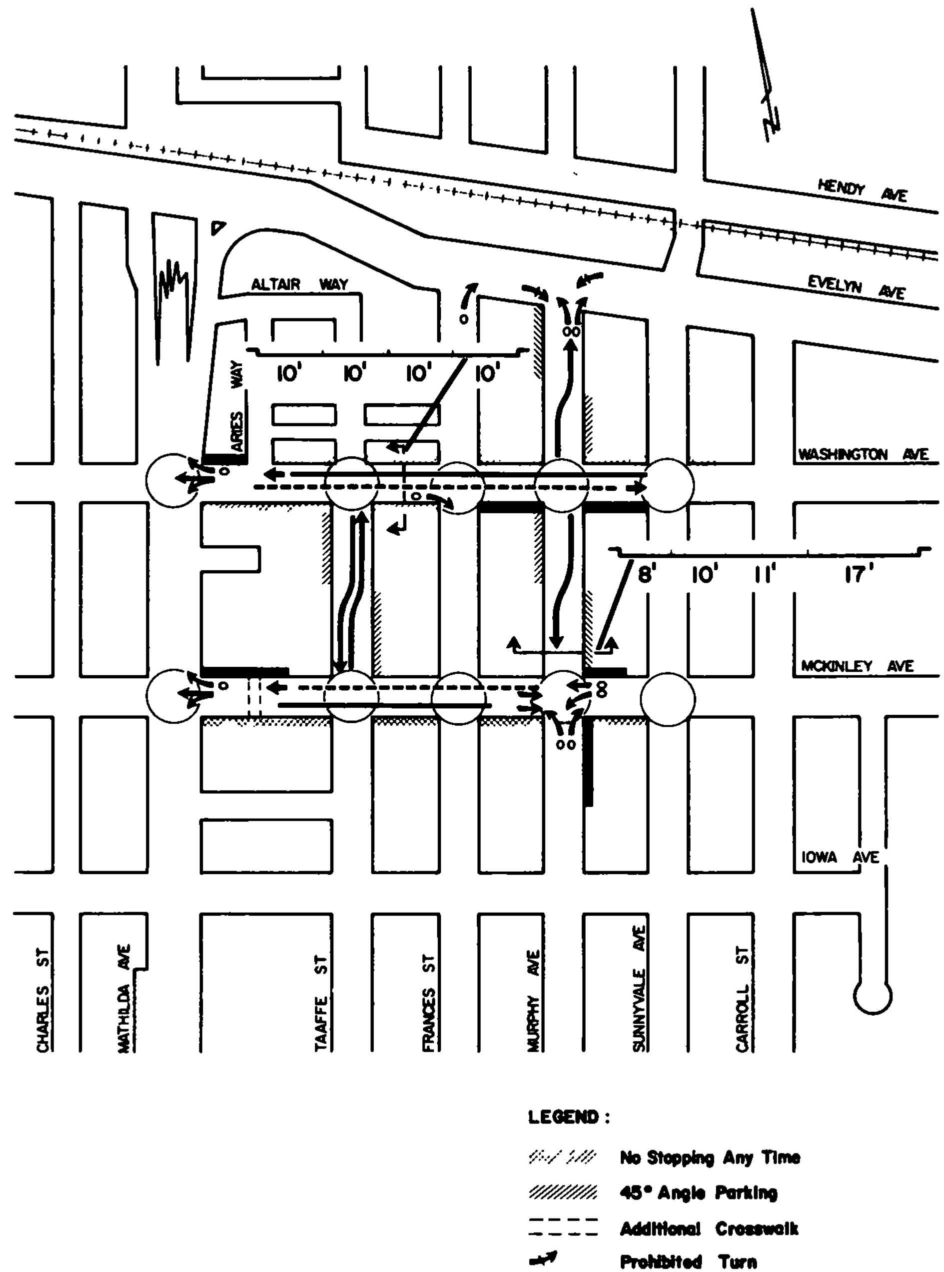

Figure 14. Test stage S30.0—street closure and unbalanced flow. Murphy Avenue closed to through traffic.

several non-colinear streets representing a one-way or unbalanced flow couplet

Travel time data also were used to construct isochronal or time contour maps. These maps show the travel time from major intersections (centroids) to other areas within the study boundaries.

Stops and Delays

Stops and delays were used as measures of effectiveness for both midblock and intersection locations. Two different methods of collecting data for stops and delays were used during the project. floating-car travel-time and delay studies, and intersection interval queue sampling (stopped-time delay studies) Consequently, two slightly different definitions of each measure resulted.

Data for stops and delays, gathered by floating-car studies, were expressed as average stops and delays per test-vehicle run Delay times were recorded by type for major streets between successive intersections and were accumulated for street lengths and for the entire study areas. Data gathered in this manner have been identified as "stops," "control device delay," and "other delay" If the floating car were truly an average vehicle, the results would represent average stops and delay per vehicle using a given street However, the floating car did weave to avoid queues and, therefore, the results probably underestimated total stops and delays.

For data gathered by interval queue sampling, results were expressed as total delay and average delay per approach vehicle. Data gathered in this manner are identified as "total stopped delay," and "average stopped delay." Data gathered by interval queue sampling also were combined for a system of intersections by weighting the average stopped delay for each approach in proportion to approach volume.

Accidents

Accident measures were defined as the number of reported accidents occurring at particular locations within the core area during specific time intervals. Separate summaries were made for midblock or intersection accidents by type or cause. These data were gathered from Police Department reports in the test cities

Special Areawide Measures

One of the major considerations in the formulation of this project was the need for areawide evaluation of operational techniques. This requires that the impact of changes in regulation and control on one or several streets in the CBD core areas be evaluated, not only for the specific street(s), but for the entire system susceptible to change.

Areawide measures of effectiveness were defined as weighted combinations of street link measures. A link was defined as the street segment between two successive intersections for one direction of travel; a two-way street, therefore, had two links between each successive pair of intersections Four special areawide measures used in this project are described as follows.

Weighted Average Speed

Travel speed on a single route was calculated as the weighted average of link speeds. In performing the actual calculations, average speed was found by dividing total vehicle-miles of travel per hour in an area by total vehicle-hours of travel per hour

Weighted Average Link Volume

The areawide measure of volume has the same dual role as the traditional measures of volume described earlier: it serves as a measure of effectiveness in assessing volume changes due to control techniques and serves as an independent variable affecting the other measures. The areawide volume measure for this study was taken as the average of link volumes weighted in proportion to link length.

Kinetic Energy

It has been pointed out by Drew (*1*) that kinetic energy of a traffic stream is a good measure of the stream's performance. By analogy with fluid dynamics, he shows that the product of speed and volume is a measure of the kinetic energy of the system In a similar manner, weighted average speed and weighted average link volume, as described previously, can be multiplied to get an average areawide measure of kinetic energy. As it is desirable to increase speeds without decreasing volumes, this parameter is meaningful as an areawide measure

Density

Density can be considered as a measure of effectiveness because a decrease in density implied an increase in speed for a constant volume. Areawide density was defined as the total number of vehicles in the area divided by the total length of links in the area. To calculate density for this study, an estimate of the number of vehicles on each link was made from travel time and volume data, and the total number of vehicles in the area was accumulated

Distribution of Areawide Measures

When measuring any variable by a sampling technique, it is desirable to know the nature of the statistical distribution of the variable. From this distribution, confidence limits for the sample can be determined and statistical tests of significance can be made.

The determination of areawide measures of effectiveness in this project represented choosing samples from the appropriate populations. Only one determination was made for each test stage in each of the standard time periods. It was impossible to determine the nature of the distributions from such a sample. The distributions of the four areawide measures described previously are mathematically quite complex. The measures are defined as combinations of a number of link volumes and link travel times, each with its own distribution; no attempt was made to derive the distribution functions from statistical theory.

From an examination of areawide measures evaluated when no operational changes were made, however, it was inferred that at least a 10-percent change in a given measure would be necessary to conclude that the change was statistically significant

Business Performance

The impact of changes in traffic regulation and control techniques on the retail sales of a community could be of great concern to local merchants and was considered a significant measure of effectiveness in this study.

The CBD business performance study was carried out to evaluate the effect on retail sales of changes in traffic conditions during the various test stages The study procedure included the following elements·

1. The merchants were approached directly, informed of the purpose of the study, and assured that the information supplied would be kept confidential
2. A base week was established that was free from any influence of the test stages.
3. Instead of actual dollar amounts, the merchants were asked only for percentage variation in weekly retail sales as related to the base week in each city
4. The period for which the weekly retail sales information was sought covered all the weeks during the test stages and corresponding weeks of the previous year.

Data forms for use by the merchants were prepared indicating the selected base week and test stage periods for which weekly retail sales information was required. (Samples of these forms appear in Appendix A.)

With the cooperation of the Chambers of Commerce, the forms were distributed individually to the CBD merchants in Redwood City and Sunnyvale. The distribution involved 25 business establishments in Redwood City and 30 in Sunnyvale. Eleven business establishments from Redwood City and 3 from Sunnyvale responded by supplying the necessary data In some cases the sales factor percentages were erratic or were incomplete for the last few months Data for these stores were either omitted or adjusted to account for the missing data.

To supplement the data from individual stores, an analysis was made of city and county figures. Quarterly retail sales figures for the period from January 1, 1963, through March 31, 1968, were obtained from the State Board of Equalization, and the sales trends for the cities and counties were analyzed. Where possible, these trends were related to the information supplied by the participating businesses.

Two different procedures were used to analyze the retail sales factors obtained in Redwood City: (1) the apparent change between corresponding weeks was analyzed, and (2) the factors were compared with expected values based on trend analysis of citywide figures from the quarterly sales data.

Public Opinion

Public opinion is usually considered a qualitative measure of effectiveness, which is expressed in communications to traffic engineers and lawmakers. Before public opinion is defined, it is important that the meaning of "public" in the context of public opinion is clearly understood.

"Public," as a noun, is defined as people at large. The character of a particular type of public may vary with the type of issue, degree of interest and involvement, quality of education, and general awareness Any single individual may belong to a number of different types of public in a society, depending on the variety of his interests. For example, a motorist may also be a pedestrian in a particular area. Furthermore, because every member of the public may not be equally interested in a particular issue, the more interested people comprise the active group, and the others form the passive group.

For the purposes of this project, public opinion is defined as the expression of prevailing ideas on certain specific questions by members of both active and passive groups of the public.

With advancing technology, public opinion is assuming a progressively greater role as a dynamic factor in our society. It can serve as a fairly sensitive scale for measuring public acceptance of a certain change or issue, reflecting public interests or public ignorance. This measure, in turn, can serve as a useful guide for minimizing the gap between public acceptance and the proposed innovation that directly affects the people.

It is from this point of view that a detailed examination of public opinion as a measuring technique was undertaken. Public-opinion surveys were conducted for the purpose of evaluating.

1. Interest of the public in traffic and parking pattern changes.
2. Public awareness of test stages
3. Subjective experience of the public regarding certain facts and circumstances
4. Public acceptance of the various changes.
5. Difference in the attitude of downtown merchants as an active pressure group compared to the general public.
6. Relation between public opinion and political feasibility.

To obtain a realistic appraisal of public opinion, the survey questionnaire was designed to:

1. Avoid any questions that would be embarrassing, difficult, unclear, long, or biased.
2. Discover content of personal feelings of the respondent by confronting him with both specific questions and free-choice expression.
3. Test the knowledge and interest of the respondent on different aspects of the test stages.
4. Give full confidence of anonymity to the respondent by avoiding qeustions about his name or address
5. Provide sufficient time for the respondent to privately prepare his independent and considered views.
6. Obtain information in a quantifiable form.
7. Arrange the questions in a logical and reasonable order to facilitate responses.

The details of the questionnaires and the distribution procedure are given in Appendix A.

Travel Cost

Travel cost was considered in this project for further insight into test stage performance. Widely used as a measure of effectiveness in transportation studies, travel cost should include: vehicle operating cost; user time cost; traffic accident cost; comfort and convenience cost; and the cost effect on adjacent business and land use. Quantitative values for some of these costs are difficult to determine. Therefore, travel cost is seldom the sole criterion on which engineering decisions are based.

In this project, test stages were too short to quantify the specific cost of traffic accidents or the detailed cost effect on adjacent businesses Therefore, only vehicle operating costs and user time cost were included in the travel cost determination. Comfort and convenience costs were regarded as implicit in these figures.

Total vehicle operating cost was established as $0.07779 per mile, based on data presented in the Final Report of NCHRP Project 2-7 (*2*). User-time cost was established as $1 55 per vehicle-hour, as developed by the American Association of State Highway Officials (AASHO) (*3*).

The Stanford Research Institute conducted one of the more recent studies of travel-time costs (*4*). These studies substantiated the AASHO figures as being reasonable when measuring small time savings. To ensure realistic evaluation of test stage performance, travel costs in this study were calculated from vehicle-miles and vehicle-hours for each time period within each test stage.

Other Measures

Several other measures of effectiveness were used in the study as appropriate to quantify performance. These primarily included measures describing driver observance of new regulations in terms of violations, parking occupancy (both on- and off-street), distance from the curb to the wheels of parallel parked vehicles, and the vehicle maneuvering time associated with different parking stall designs.

In addition to recording the effect of on-street changes in traffic regulations on parking-lot occupancy, the occupancy studies were necessary in Redwood City for another reason. The towaway regulations each caused the loss of about 50 parking spaces on either side of Broadway. This loss was partially regained with the change from parallel to angle parking on Middlefield and Jefferson. However, from a political feasibility standpoint, the towaway regulations were more acceptable to the city staff and business leaders when it was shown that unused parking supply existed in the off-street lots and also in other on-street locations.

CHAPTER TWO

FINDINGS

This chapter defines the principal findings of the project test stages described in Chapter One. Fundamentally, there are three major factors to be considered: relative operational performance, business performance, and public opinion. The relative magnitude of improvement as a function of various traffic regulation and control techniques is discussed in terms of the selected measures of effectiveness developed to quantify the findings.

To attempt to narrow the gap between common belief and the actual facts, no rigid rules of thinking were laid down or followed in arriving at unbiased findings and their quantification. In some cases, new concepts and indices were developed in order to view the facts in a conceptual framework. The process of developing these new concepts and indices involved both a detailed review of the data and an overview of the meaningful interrelationships of the observable facts.

OPERATIONAL PERFORMANCE

The findings relative to operational performance are organized by the relevant measures of effectiveness (speed, stops and delays, and accident rates) for (1) the directional characteristics for the specific street(s) involved with the particular change, (2) the combined characteristics for the specific street(s) involved, and (3) the total street system in the core area. Other measures, such as kinetic energy and density, were investigated and were found to be relatively parallel indicators of improvement; therefore, the discussion here is confined to terms of speed-volume relationships. The detailed relationships that provided the bases for the findings are included in Appendix B.

During the course of the test stage program, and within the study boundaries, there were other opportunities to evaluate changes in traffic regulations and control. Because the primary objective of the study was to evaluate areawide changes, only the pertinent findings are presented. In some cases, these minor test stages have the same control number as for a major stage. The interpretation and evaluation of the findings is not necessarily in relation to accepted standards for certain types of streets in urban areas. Standards can always be challenged as to their applicability in either Redwood City or Sunnyvale, but the end result still would be a comparative analysis of each test stage. Of more importance is answering the basic questions of which types of techniques work best under a variety of conditions. Also, it is important to determine whether the findings in Redwood City and Sunnyvale are in any way applicable to other cities.

Major Test Stages—Redwood City

R1.0/R2.0—Signal Timing

Stage R1.0 incorporated a signal timing pattern favoring the eastbound morning peak flow on Broadway. For the three blocks on Broadway controlled by traffic signals there were only slight variations in travel speeds, contrary to expectations. For both directions and all time periods, the average speed increase was less than 1.0 mph. This indicated that the speeds are relatively insensitive to signal timing changes under conditions where curb parking and narrow lanes are present.

The timing pattern in stage R2.0 treated both directions equally and, in general, did not produce increased speeds, as had been anticipated. The evening peak westbound was improved over both R1.0 and the base condition. The average speeds, however, were not significantly different from the base condition.

The four signalized intersections on Broadway and 14 intersection approaches were considered as a system (Broadway system). This system excluded two minor side-street approaches. The average stopped delay in this system was selected as a measure of system performance. The data showed that the signal timing pattern in stage R2.0 did not change the delay characteristic in the peak commuting periods and appeared to increase the delays during the off-peak periods. A detailed analysis showed a decrease in westbound signal delays; no change in the southbound delays; and an increase in both northbound and eastbound delays.

The areawide speed characteristic for a simulated two-offset system, incorporating the results of stages R1 0 and R2.0 in combination, indicated a slight improvement in flow conditions and a reduction in the sensitivity of Broadway to increases in volume.

The average stopped delays were essentially the same as for the base condition.

During the signal test stages, no accidents occurred at any of the signalized intersections affected by the timing changes.

As the signal stages had minimal effect on the Broadway flow characteristics, it follows that the effect on the areawide measures would also be insignificant.

R20.0—Left-Turn Prohibition

Westbound traffic showed an increase of about 10 mph in the morning peak period and 5 mph for the other time periods. Eastbound traffic, however, showed little change in speed.

The average stopped delay studies taken at the four signalized intersections in the Broadway system showed a considerable reduction in total delay during most time periods. Specifically: delays decreased slightly for northbound and westbound traffic; remained unchanged for southbound; and increased by 30 percent for eastbound during the evening rush hour. These changes reflect the changes in traffic volumes resulting from the left-turn prohibition.

Marshall was available as an alternate route for westbound traffic. Volume data on Marshall showed a marked increase in westbound traffic. This diversion accounted for the reduced westbound delay pattern on Broadway.

A similar alternate route did not exist for eastbound traffic. Delays increased considerably during the evening peak time period. Because eastbound volumes were unchanged, this implied that previous left-turn traffic had been converted to right-turn traffic. Right-turn delays were created by vehicular conflicts with pedestrian crossings on the south side of Broadway. The data indicated that pedestrian volumes in the south crosswalks were two to three times larger than in the north crosswalks.

Northbound delay data for traffic approaching Broadway demonstrated reductions in signal delays, probably due to fewer turning vehicles. The left- and right-turn volumes decreased from 90 and 109 vehicles to 45 and 72 vehicles, respectively

The Broadway system average speed was maintained at a level higher than the base conditions throughout most of the volume range. The analysis indicated an increase in speeds, with increasing volumes, contrary to speed characteristics in previous stages. This speed-volume relationship was probably due to narrow lanes and the influence of pedestrians and parking maneuvers that were evident during midday shopping periods.

For the Broadway system, the number of stops was reduced only slightly below the previous stages. The control device delay was considerably higher, especially in the lower-volume time periods.

The effect of the left-turn prohibition on traffic conditions throughout the total core area system of streets also was investigated. The system average speed for this test stage was slightly above the base condition throughout the volume range. The left-turn prohibition had little effect on stops but produced an increase in areawide control device delay. The delay due to other causes was insignificant (on the order of 10 percent of control device delay) and was not considered further.

The number of core-area accidents remained unchanged when compared with corresponding periods in previous years.

R30.0—Towaway and Angle Parking

Stage R30.0 was the first stage to investigate the effect of lane width on traffic flow. The no-stopping towaway regulation from 7:00 AM to 6:00 PM on the south side of Broadway eliminated parking conflicts and allowed restriping the street for wider lanes in the eastbound direction (13 ft at the curb and 12 ft next to the unchanged centerline). At the same time, angle parking patterns on two major side streets were implemented.

The eastbound speeds increased about 3 mph (20 percent) over stage R20.0, as expected. However, the westbound speeds also increased slightly. This increase was probably due to a continuing stabilization process from stage R20.0 (left-turn prohibition) which was still in effect.

For the two side streets, Middlefield showed an increase in speed, but Jefferson showed no change.

In the Broadway system, wide lanes in the eastbound direction, combined with unbalanced flow and angle parking in the north-south direction, showed an increase in the average stopped delays over R20 0, but still showed a decrease over base conditions. The impact of this test stage on delays was investigated for eastbound and north-south traffic There was a reduction in the eastbound delays during the noon, afternoon, and evening periods due to the wide lanes Southbound delay on Middlefield and Jefferson, combined, increased by 60 percent during the evening peak hour. Data analysis by individual street showed no change in the southbound Middlefield delays, but stopped delays for southbound Jefferson increased from 8.5 to 20 9 sec per vehicle as a result of the elimination of one of the southbound lanes. This large increase indicated that evening southbound commuter traffic was not diverted from Jefferson to Middlefield, as had been expected.

The combined measures of effectiveness for the Broadway area showed substantial improvements over the base conditions and previous test stages. An increase of up to 4 mph was realized over the entire volume range The speed-volume relationship was less sensitive to increases in volume than the previous test stages, showing the effect of the parking removal The number of stops and amount of control device delay was less than for any previous stage.

For the entire core area, this test stage did not show up as favorably as when considering the Broadway area alone. The effect of the Broadway improvement on the total system average speed is noticeable, but is not greatly different from the base condition or the previous stage. Essentially, there was no change in stops from the base condition and R20.0. The control device delays were lower than the previous conditions in the low-volume ranges.

There was a pronounced reduction in midblock accidents on Broadway. No midblock accidents occurred during the test stage, as compared with an average of five accidents during corresponding time periods for the previous two years There was no change in the midblock accident rate on Middlefield and Jefferson despite the installation of angle parking. This is in marked contrast to the performance of the remainder of the core area where eight midblock accidents were recorded.

R40.0—Towaway and Angle Parking

The effect of the loss of one lane westbound in the morning peak was a reduction in speed of about 6 mph. For the other time periods, the westbound speeds remained unchanged. For eastbound traffic, speed decreased in some time periods and increased in others

Stage 40 0 did not change average stopped delay for the Broadway signal system during the peak period, but reduced midday delays. Westbound delays increased during all four time periods, southbound delays were unchanged; and the eastbound and northbound delays were reduced. The continued high southbound delays indicated the reluctance of drivers to adjust to the unbalanced flow pattern. This implies that traffic did not stabilize through two complete test stages.

The Broadway area showed a reduction in speed compared with the previous stage, but was still higher than the base condition. Stops remained essentially the same as the base condition and the previous stages. Control device delay was reduced appreciably, compared with previous stages.

This stage was not evaluated from an areawide standpoint, as the changes affected the flow on Broadway only. As in R30.0, no midblock accidents were recorded on Broadway.

R0 5—Holiday Moratorium

Stage R0 5 produced reductions in speed when base conditions were restored for a two-month period that included the holiday shopping season and higher-volume conditions. The speeds dropped to less than 10 mph during all time periods except the morning peak.

R56.0—One Way and Unbalanced Flow

Stage R56.0 produced the highest eastbound speeds on Broadway of any previous or subsequent stage, considering all time periods. An average speed of more than 18 mph was obtained. Speeds on Jefferson increased somewhat, particularly during the morning peak in the favored northbound direction, while speeds on Middlefield were reduced.

Speeds for the Broadway area were the highest observed in the high-volume range Speed seemed to increase with volume, however, this is heavily weighted by the morning peak when few conflicts exist with pedestrians and parking vehicles.

Both stops and control device delay were significantly lower than in previous stages.

The combination of the one-way couplet on Broadway and Marshall and the unbalanced flow couplet on Middlefield and Jefferson had a profound effect on the core area speed-volume relationship. A substantial increase in speeds was maintained for all time periods. The same effect was observed on stops and delays, which were decreased considerably.

Accidents in the core area, compared with the same period of the previous year, rose from 7 to 15. Thirteen of the 15 were intersection accidents, and a breakdown reveals that six of 13 were sideswipe type. These seem to be a result of turning movements made from the wrong lanes, possibly due to the frequent changes on Broadway. Were it not for the intersection sideswipes, the number of accidents would have remained the same as the average for the two previous years. Once again, there were no parking accidents on Broadway, and total midblock accidents were reduced. This was in spite of the higher speeds that sometimes contribute to increased accident rates.

R70.0—The Downtown Plan

Stage R70.0, the final test stage, resulted in travel speeds on Broadway that were generally lower than those for the three stages before the holiday moratorium. This was due to having only one through lane in each direction. The improved signal timing kept the speeds from going even lower.

Even with the installation of a left-turn lane at Broadway, the northbound speed dropped by 6 mph as a result of the signal timing change favoring Broadway and a volume increase of 60 percent The speeds for the other times and directions increased only slightly. On Marshall, the STOP-sign removal resulted in speeds slightly higher than for previous conditions.

The Broadway system had slightly less peak-hour delay in the lower volume range; however, these delays increased rapidly as volume increased.

Speeds for the Broadway area were reduced to below the base levels. As volume increased, the speed was reduced at a higher rate than for other test stages This increased sensitivity is probably related to the availability of only one lane for continuous travel The number of stops was higher and rose with increases in volume, as compared with previous stages that showed stops being relatively constant throughout the volume range. Control device delays were slightly higher than for previous stages and extremely sensitive to increases in volume.

The areawide speeds were slightly greater than the base condition in the low-volume range. However, speed was sensitive to increases in volume and was less than the base condition in the higher-volume range.

Stops and control device delay were considerably less than for the base conditions and about the same as for R56.0. The removal of STOP signs for Marshall at Middlefield largely accounted for this reduction.

This stage produced the most significant reduction in number of accidents of any of the test stages. No midblock accidents of any type were recorded on Broadway throughout the test stage. For the total core area, only three accidents occurred—two at intersections and one midblock, a significant decrease in both types. During this stage, the three core-area accidents represented a decrease of more than 70 percent from the average (11.5) of comparable periods in the two previous years.

Minor Test Stages—Redwood City

R56 0—Middlefield and Jefferson Intersection

The unbalanced flow pattern on Middlefield (eastbound) and Jefferson (southbound) allowed the evaluation of these two approaches. Middlefield, westbound, was also altered by prohibiting parking at the curb and adding a left-turn lane. Stopped-time delay was the measure of effectiveness.

As Table 1 indicates, no improvement in westbound delay resulted from the separate left-turn lane for stage R56.0. The left turn was approximately 60 percent of the evening peak approach volume and, prior to the change, the inside lane was essentially operating as a left-turn lane.

The reduction in delay for the eastbound Middlefield approach was probably due to the realignment of traffic lanes to obtain a 9-ft increase in right-turn radius. There was a reduction in delay in the high-volume range of about 20 percent. The approach was able to handle an increase in peak-hour approach volume of 100 vph and retain the same level of total delay.

The southbound Jefferson approach delay was increased considerably in the high-volume range when the approach was reduced from two lanes to one lane.

R70.0—Middlefield and Jefferson Intersection

The two intersecting streets have different roles in the Downtown Plan (R70.0). Jefferson was emphasized as the main crosstown arterial. Middlefield was de-emphasized by making portions one way. At this intersection, volume patterns were extensively altered. Southbound volumes increased substantially; eastbound volumes were drastically reduced.

Stopped-time delay (Table 1) remained relatively the same for low-volume conditions, compared with the previous stage. Under high-volume conditions, the effect of two lanes on stopped delay is pronounced. At a volume rate of 600, total stopped delay was reduced from 12,000 to 7,000 vehicle-sec. A higher volume rate was observed in this stage than in any other (e.g, the volume rate increased 33 percent over the unbalanced flow couplet while the delay was the same).

Major Test Stages—Sunnyvale

S7.0—Arterial Signal Timing

The travel speeds on Washington and McKinley increased in the westbound directions for the morning peak. During the other periods of the day, the arterial progression was not an efficient timing pattern, as speeds generally decreased.

The analysis of Washington and McKinley as an unbalanced flow couplet did not reveal any improvement in speeds. The stops and control device delays increased, which offset the slight improvements in speed.

The core-area speeds were slightly lower than for the base condition when all eight signals were in operation. The speed-volume relationship tended to be more sensitive than that for S3.0.

The core-area stops were about the same as for the base condition; however, the control device delays tended to be less as volume increased. The number of traffic accidents remained unchanged during this stage.

S8.0—Preferred Route Timing

McKinley showed sharp increases in speed eastbound during the peak periods, as did Washington in the morning.

TABLE 1

STOPPED DELAY AT MIDDLEFIELD AND JEFFERSON

APPROACH	HOURLY VOLUME RATE (VPH)	TOTAL STOPPED DELAY (VEHICLE-SEC) R0.5 BASE	R56.0 UN-BALANCED	R70.0 DOWN-TOWN
Westbound Middlefield	450	4,000	4,000	2,000
	620	11,000	No data	3,600
Eastbound Middlefield	250	3,300	3,800	3,000
	560	13,000	10,000	No data
	660	No data	13,000	No data
Southbound Jefferson	300	3,000	3,000	3,000
	600	8,000	12,000	7,000
	800	No data	No data	12,000

The couplet analysis for these two streets showed only a slight speed increase in the morning peak.

The signal system was analyzed in the same manner for all test stages. In this case, therefore, the preferred route timing for traffic following an indirect route through the system should have produced favorable results for the usual core-area figures.

Areawide speeds increased significantly to 20 mph in the lower-volume morning peak period. In the higher-volume ranges the speeds were back to the base-condition levels of about 13 mph. This signal timing stage showed an even more sensitive speed-volume relationship than for the previous stages.

Stops and delays were about 10 percent lower than for the base condition, but somewhat higher in the higher-volume ranges than for the previous stage.

As in the previous signal timing stages, traffic accidents showed no significant change during this period.

S20.0—Street Closure and Unbalanced Flow

This stage combined several test stage elements. The lower speeds on the major east-west streets were primarily due to an ineffective no-stopping regulation, plus the closing of one block in the core area.

For the Washington and McKinley couplet, the stops and delays were higher and speeds were generally lower than for previous stages.

The areawide measure of speed was less than that for the base condition. The combined effect of the street closure, the confusion caused by the ineffective parking regulation, and a new pattern of entry and exit turning movements associated with midblock access to parking lots apparently accounted for the lack of improvement. The reduction in speed, with increases in volume, tended to be less than for previous stages The areawide stops and delays were less, particularly in the higher-volume range.

Accidents in the core area dropped from nine to six.

S30.0—Street Closure and Unbalanced Flow

The final test stage in Sunnyvale offered the most efficient traffic flow pattern of those implemented Speeds increased significantly on Washington and McKinley for most time periods and directions. A factor that influenced speed was the improved observance of the no-stopping regulation when made effective for 24 hr instead of only from 11:00 AM to 6:00 PM.

The change in the curb parking time limit from 3 hr to 1 hr was not evaluated in terms of operational performance. However, the change did have a positive effect on the core-area parking characteristics by reducing curb parking occupancy and increasing lot occupancy. Therefore, curb parking spaces were made available for short-time parkers in front of business establishments where formerly this space was used by all-day parkers.

The couplet analysis showed reduced stops and delays and increased speeds of up to 6 mph. Midblock delays were sharply reduced.

The areawide speed increased considerably over the base condition and the previous stages. Stops and delays were greatly reduced below previous stages.

The core-area accident rate did not change during this stage.

Minor Test Stages—Sunnyvale

S0.5—Fair Oaks Avenue Detour

On January 9, 1967, Fair Oaks Avenue, a major road to the east of the CBD in Sunnyvale, was closed to permit the construction of a railroad grade crossing. The detour necessitated by the closure caused increases in the traffic on Sunnyvale Avenue, the next available through street to the west. The results of the closure indicated a significant increase in volume in the direction of the peak movements.

In this case, the volume increased in the evening peak hour by 420 vph (57 percent) and resulted in a decrease in speed from 16.1 mph to 12.9 mph. Northbound in the morning, an increase of 18 percent in volume changed the travel speed from 20.6 to 16.3 mph. This was one of the strongest relationships found between speed and volume.

S1.0—Master Dial Replacement

Shortly after the project was initiated, field investigations indicated deficiencies in operation of the downtown signal system. A major problem was created by the removal of the No 2 master dial unit controlling off-peak flow. The subsequent replacement of this dial allowed display of the correct signal timing intended by the city.

The travel speeds on Washington and McKinley increased considerably from an average of 10.5 mph to 14 1 mph. The areawide average speed showed a slight increase of 1.0 mph over the base-condition speed of 12.8 mph. This change and that for Washington and McKinley, in particular, is probably due entirely to the restoration of proper signal equipment operation.

S2.0—Pretimed Morning Peak Control

Normal and flashing signal operations were compared by setting the core signals to operate in a pretimed mode during the morning peak, rather than in the flashing mode previously used by the city.

The speeds on Washington and McKinley were only slightly reduced. On Murphy and Sunnyvale, which carried higher volumes, the speeds were reduced from 22.3 mph to 15.7 mph. These different effects were probably due to the flashing mode before the change which displayed yellow at three of the four signals controlling Murphy and Sunnyvale.

The speed for the core area was reduced only slightly for the morning peak hour.

The combined measures indicate that flow conditions had been made somewhat worse. The pretimed control caused 12 approaches to six intersections, which previously had a flashing yellow light, to have alternating periods of stop-and-go flow. The increased delay probably resulted from imperfect signal progression at these approaches. It was not offset by a delay reduction at approaches that previously had a flashing red signal.

S3.0—Signal System Extension

The two signals on the major shopping street, Taaffe, were changed from a 24-hr flashing mode to pretimed operation during the day. This extended the core-area signal system to eight signals. A full week was required before the signals were consistently observed by the motorists and violations of the red light no longer occurred.

The travel speeds on Washington and McKinley generally decreased during all time periods, with several of the decreases being significant.

The major change in system performance was increased delay (as measured by floating-car travel-time studies) on the approaches to the two signals.

S4.0—Actuated Signal Timing

The Mathilda signals at Washington and McKinley not only controlled the major volumes through the CBD, but also metered traffic into the shopping core. The timing settings on the actuated volume density controller at Mathilda and Washington were fine-tuned for a greater efficiency of operation. Average stopped delay, the primary measure of effectiveness, was significantly reduced during the peak time periods and reduced to a lesser degree during the noon and midafternoon time periods, when the effect of pedestrian time requirements became more pronounced. The specific reductions were from 22.0 to 14.5 sec per vehicle in the morning peak and from 25.0 to 20.0 sec per vehicle in the evening peak.

S5.0—Master/Slave Signal Interconnection

The second major signal on Mathilda in the study area was a pretimed controller modified so that only sidestreet actuations activated the McKinley timing circuitry. This signal was also equipped with circuitry to allow its interconnection with the signal at Mathilda and Washington. The interconnection was timeclock controlled and was in effect for the morning and evening peak time periods only. The resulting interconnected operation was most effective for southbound traffic leaving the "master" signal at Washington.

The intersection delays at Washington and Mathilda increased during the morning time period. Detailed investigation of average stopped delays showed that the largest delays were experienced by eastbound traffic during the morning rush hour. Intersection delays, however, decreased during the evening period, and the largest decrease occurred in the southbound direction, dropping from about 33 to 13 sec per vehicle.

S8.0—Sunnyvale and Evelyn Intersection

At the intersection of Sunnyvale and Evelyn, the southbound exit lane was widened to two lanes by removing the center island. The approach right-turn-only lane was changed to an optional turn lane. The expected results did not materialize in this test because the entire modification package, including other upstream improvements, could not be implemented by the city until a later date. The net effect of the change was to increase the delay per vehicle because through traffic in the right-turn lane would prevent a right turn on red, which could take place more frequently before the change.

S30.0—Sunnyvale and Evelyn

During stage S30.0 the eastbound approach to the intersection was improved by lengthening the left-turn lane to almost one block in length. The resultant effect on delay was striking, particularly in the high-volume range above a 600-vph approach rate. The reduction in delay was almost 50 percent at a rate of 1,000 vph. Part of this decrease was probably due to a diversion of traffic from Murphy to Sunnyvale as a result of the one-way operation on Murphy.

There were no significant changes in accidents at this intersection.

S20 0—McKinley and Murphy

Exclusive left-turn lanes were installed on the northbound and westbound approaches to this intersection. Curb parking was removed to provide space for the left-turn bays.

The new left-turn lane reduced stopped delay by up to 30 percent during all time periods except the morning peak, when there was a small number of left turns.

The northbound left-turn lane had a negative effect on the operation of the southbound approach. Increases in southbound delay might be due to the platooning of northbound left-turning vehicles, which on some occasions would force the opposing traffic to a complete stop.

The effect of the westbound left-turn lane on traffic operation in the east-west direction is not clear. This is partly due to the low east-west approach volumes and partly due to the operation of traffic signals on McKinley Avenue. Traffic is signal controlled, and the location of the intersection of eastbound and westbound through-bands from a time-space diagram controls the gap availability and the operation of the westbound left-turn lane. The left-turn lane may be found ineffective under certain patterns of traffic signal timing.

S30.0—McKinley and Murphy

A further modification was made when the southbound approach was made one-way. The through-traffic volume in the evening peak reduced from 381 to 226 vph, whereas other approaches remained the same or increased slightly. The net result of this change was to hold total intersection delay at about the same level as in stage S20.0.

BUSINESS PERFORMANCE

Redwood City

Two procedures were employed in the retail sales analysis. In both cases, the week ending August 27, 1966, was used as a base, and the sales for that period were given a factor of 100 percent. The sales factors were then provided by the merchants for each week during the test stage program and for each corresponding week of the previous year. Additional weekly sales factors were provided before and after the test stage periods for comparative purposes. The actual factors during the test stage periods were compared directly with corresponding weeks of the previous year (actual difference). The actual factors were also compared with a projected sales factor (projected difference). The projected sales factor was estimated using figures from previous years and sales change trend factors developed from the quarterly figures for the respective store category (general merchandise or apparel).

For all stores combined, these data indicated:

1. For the stores investigated, the average weekly sales figure just prior to the beginning of the test stage program was lower than for the base week in the previous year.

2. During stage R20 0, the actual sales showed an increase over both the previous year and the projected sales factors. From this point, the factors ranged downward.

3. A low point was reached at the end of stage R30.0, after which the trend reversed and moved upward through the balance of the test stages.

4 At the conclusion of the test stage program, the trend reversed and dropped to a point lower than before the test stage program began

The sales trend for an apparel store located outside the physical limits of the major test stage changes was investigated separately for comparative purposes. In this case, the actual sales were lower than projected sales and were about the same as the previous year. This record was not as favorable as the records for the stores in the CBD core area.

Another comparison related the business performance of stores on the north and south side of Broadway during the two towaway stages (R30.0 and R40.0) The southside performance was relatively stable during both stages, whereas northside performance declined during southside towaway (R30 0) and increased during the northside restriction (R40.0) This is a record contrary to the claims of many businessmen.

The relative positioning of sales factor changes for all stores was analyzed during the last two weeks of each test stage period to be sure that conditions had stabilized. In terms of either actual sales changes or projected changes, the Downtown Plan, stage R70 0, appeared to perform best However, it was very difficult to determine a direct effect of any specific traffic regulation on retail sales, with the possible exception of the left-turn prohibition.

Sunnyvale

From Sunnyvale, two apparel stores and one tavern supplied the required data. The data analysis procedure was similar to that for Redwood City.

The results for one apparel store showed the following:

1. During stage S20 0, average sales were 5 percent higher than for the same periods of the previous year; the average sales were 12 percent higher than the projected values because of the previous downward citywide trend.

2. During stage S30.0, the average sales were 3 percent lower than for the same period of the previous year; however, the average sales were 30 percent higher than the projected sales.

These observations indicate that neither of the test stages had any adverse effect on the sales of this store. On the contrary, the sales were better than expected. For the other apparel store, it was clear that:

1. During stage S20.0, the average sales were 5 percent lower than during the same period of the previous year; the sales were the same as the projected values.

2. During stage S30 0, the average sales were 25 percent lower than for the same period of the previous year; the average sales were 8 percent higher than projected.

Although the actual sales were lower than those of the same period of the previous year, they were higher than projected.

For the tavern, comparisons were made only for the actual sales, as a lack of data prevented the development of projected sales values. The analysis showed that:

1. During stage S20.0, the average sales were 15 percent higher than during the same period of the previous year.

2. During stage S30.0, the average sales were 28 percent higher than for the previous year.

PUBLIC OPINION

Toward the end of each test stage, when conditions had stabilized, the opinion questionnaires were distributed. Following each survey, cutoff dates were established based on the chronological distribution of returns. Responses received after the cutoff dates were not included in the analysis, other than the response evaluation. Cutoff dates were imposed to eliminate possible inaccuracies arising from memory fallibility.

Under the categories of "merchants" and "nonmerchants," returns from the frequent drivers (i e., those driving in the CBD once a day or more) were sorted out and subjected to a rigorous analysis.

Redwood City

Response Level

The response level for selected test stages expressed as a percentage of total questionnaires distributed indicated that:

1. The response level was relatively high for questionnaires of this kind.

2. Merchants, as a group, showed a much higher response level than nonmerchants.

Public Acceptance

Support of, opposition to, and apathy toward three major stages of the project were tested to assess public acceptance by analyzing the answers to the question especially designed for this purpose. In this analysis, support content reflected favorable comments; unfavorable comments indicated opposition; and no comment indicated apathy.

A public acceptance index was developed for a quantitative evaluation of each test stage. It is defined as support content minus opposition content divided by total respondents. The public acceptance index for three different stages showed that:

1. Merchants showed more interest in returning the

questionnaires, but their apathy was higher than that of nonmerchants

2. For all three surveys, the opposition exceeded the support.

3. The one-way test stage (R56.0) was the least opposed, and the Downtown Plan (R70.0) was the most opposed.

Acceptance of conditions on different streets in stage R70.0 was tested and evaluated. Maximum opposition was directed toward changes made on Broadway.

Public Awareness

Questions were designed to test the public awareness regarding the regulations in force for stages R40.0 and R70.0 The data collected indicated:

1. On the turning regulation (R40 0) essentially all respondents answered correctly.

2. On the parking regulation (R40 0) approximately two-thirds of the respondents answered correctly.

3. Awareness of the existence of one-way streets (R70 0) was generally low.

Public Judgment

The soundness of public judgment was tested by comparing actual facts with opinions. A concept for quantifying public judgment of a situation was developed This concept may be defined as. sound judgment measure equals 100 minus the absolute difference between the percentage of respondents giving a certain judgment and the percentage estimated to give that judgment. (The percentage estimated is based on directional volume distribution in relation to directional speed change.) In other words, the higher the value, the sounder the public judgment.

The data indicated that the judgments of both merchants and nonmerchants were essentially the same.

Merchants' Preference

The Chamber of Commerce conducted an opinion survey of 88 merchants during test stage R70.0. The survey showed:

1 49 percent would like the CBD to return to the base condition.

2. 31 percent preferred the one-way traffic on Broadway and Marshall.

3. 14 percent preferred the Broadway traffic pattern in the Downtown Plan (R70.0).

4. 6 percent had other preferences or no opinion.

Sunnyvale

Response Level

Response level for opinion surveys in Sunnyvale was similar to that experienced in Redwood City. The level of response from merchants was higher than that from nonmerchants.

Public Acceptance

Public acceptance of the two test stages in Sunnyvale was calculated the same way as for the three test stages in Redwood City

The Public Acceptance Index (PAI) showed least opposition to test stage S20.0; as a group, merchants preferred S30.0

Public acceptance of the closure of Taaffe to vehicular traffic and creation of a pedestrian mall was tested from the viewpoints of traffic conditions, parking facilities, and shopping attractiveness. This study showed that.

1. Nonmerchants' acceptance was much more than that of merchants for all three viewpoints.

2. Nonmerchants indicated a positive acceptance of shopping and traffic conditions, implying that, in their opinion, shopping attractiveness and traffic conditions had improved. On the other hand, merchants did not think that shopping attractiveness and traffic conditions had improved.

3. Both groups were opposed to the loss of parking spaces on Taaffe Street.

Public acceptance of Murphy, with one-way traffic away from Washington, was also tested. It was found that merchants were opposed to one-way traffic on Murphy from all the three viewpoints. Nonmerchants supported the one-way pattern on Murphy from the viewpoint of additional parking, but felt that it was less attractive from a shopping viewpoint

Public Awareness

The results of the analysis of public awareness showed merchants had a better awareness of the regulations in force; however, both groups had a relatively low awareness level.

Public Judgment

As in Redwood City ,the sound judgment measurement was obtained by comparing public opinion with actual facts The sound judgment measure was developed for traffic flow conditions on Washington Street when parking was removed. For both directions of flow, merchants' judgment was found to be essentially the same as that of nonmerchants—a finding similar to that in Redwood City.

TRAVEL COST

The simplified areawide travel cost determination used in this project gave further insight into test stage performance. Travel cost is the summation of vehicle operating cost (vehicle-miles times $0.07779 per mile) and user time cost (vehicle-hours times $1.55 per hour).

The lowest travel cost for the Redwood City core area was found in stage R56.0. Stage R70.0 showed the next lowest cost; stages R20.0 and R30.0 had costs slightly below the base figures.

In Sunnyvale, the lowest core area travel cost was found for stage S30 0, with Murphy effectively closed and unbalanced flow on Washington and McKinley. Stage S20.0, with Taaffe Street closed and a limited unbalanced flow pattern, gave the next lowest cost. The signal timing stages, S7.0 and S8.0, gave slightly higher travel costs than the base data.

The value determination of a traffic improvement measure is often fairly subjective for improvements involving relatively small expenditures. Traffic engineers can predict improvement benefits from experience and published research. Benefit/cost analyses or other objective approaches are usually not required unless large capital expenditures are required for traffic improvement.

In this project, an objective approach was used to quantify the benefits gained from traffic engineering techniques. The net benefit of each stage was calculated by subtracting the user and implementation costs for that stage from the user cost during the base condition. For all stages, the benefits (equivalent to the costs of *not* implementing the test stages) are shown as functions of weighted average link volume in Figure 15.

In Redwood City, stage R56.0 proved the most valuable in terms of operational traffic improvement. Between $70 and $90 per hour were saved during the daytime hours. Stage R70.0 allowed a savings of $24 to $30 per hour during daytime hours. Stages R20.0 and R30.0 produced only moderate benefits.

In Sunnyvale, the highest benefits were found in stage S30.0. Stage S20.0 was next highest, although benefits were nil when average link volume dropped below 150 vehicles per hour. The signal timing stages were not advantageous.

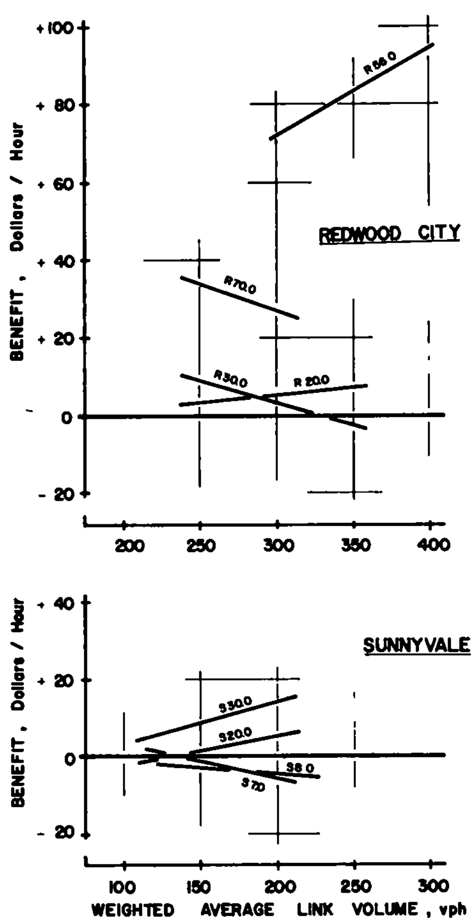

Figure 15. Test stage benefits.

COMPARISON SUMMARY

The purpose of this section is to summarize the findings in comparative form. By so doing, the full impact of the variety of experimentation and analysis becomes clear. The experimentation included the design and implementation of a program of areawide regulations and controls that, under normal circumstances, would have taken at least 10 years to accomplish. Through this research, these findings have been developed in the relatively short span of two years.

Summary charts have been prepared that show the relative positioning of a particular test stage on a value scale of areawide performance for each of several measures. Kinetic energy and travel time measures have been included to broaden the presentation. Five of the measures are plotted against weighted average link volume, and two basic characteristics should be noted when studying these graphs. For example, there is the vertical positioning of a particular stage in terms of higher or lower delay. There is also a characteristic showing how rapidly this same delay will increase as traffic volume increases. In general, the most efficient test stage, from the standpoint of areawide control device delay, would be the one with the lowest delay and showing the least change with increased volume.

The first four sections of this chapter cover the entire range of effectiveness measures, with few exceptions. The kinetic energy and density relationships are not discussed repeatedly because they tend to show the same comparative relationships as when considering speed. Also, the travel time contours are not discussed, but are available in Appendix B for inspection. The other measures are discussed for each individual major test stage in each test city.

The graphs for retail sales show the sales change factors for the last two weeks of each test stage with the pre- and post-study performance as base. The public opinion measure is the Public Acceptance Index for each stage, with the combined response of both merchants and nonmerchants emphasized.

Redwood City

The comparative summary of test stage findings for Redwood City is shown in Figure 16. With this figure as a guide, the general comparisons for each test stage can be observed. No attempt has been made to assign relative weights to the measure.

Stage R56.0, with the concurrent installation of one-way and unbalanced couplets, produced substantially better operational performance than the other test stages in Redwood City, as indicated by most measures of effectiveness.

The remaining test stages are not as favorable in areawide performance, although they all show levels of performance between the base condition and that achieved in stage R56.0. In particular, stage R70.0 revealed additional areawide characteristics that are significant for Redwood City. These same characteristics can benefit CBD traffic planning in other cities with similar problems.

The increased traffic pressure on the main street with only one through lane did not cause any parking accidents because the 12-ft lanes were relatively wide. Also, the removal of only two STOP signs in the core area produced a sharp reduction in areawide stops and delays, despite an increase in both on Broadway. And, finally, it was demonstrated that, with appropriate improvements on Jefferson to handle both through and circulating traffic, three blocks of Middlefield could be effectively closed to through traffic and provided with angle parking on both sides of the street. This test stage element undoubtedly was a major factor in favorable business performance during this stage.

Another factor should be considered in this overview summary of Redwood City test stage findings. A major point in favor of stages R30.0 and R40.0 is the striking effect of the parking prohibitions on reduction of the mid-block accident rate. The trend continued during stages R56.0 and R70.0. This leads to the conclusion that either parking should be partially prohibited and the traffic lanes widened, or at least there should be a wide lane adjacent to any parallel parking on a street like Broadway. There does not appear to be any sound argument against the parking prohibition, especially if the loss of parking is restored on adjacent side streets.

Sunnyvale

The comparative summary of test stage findings for Sunnyvale is shown in Figure 17. With stages S7.0 and S8.0 it was found, as expected, that changes in the operation of a grid system of interconnected signals can improve areawide operational characteristics, especially where lane width is sufficient to preclude frequent conflicts with parked vehicles.

Stage S30.0, with a complete and well-enforced unbalanced flow couplet in effect, was better than the other stages in practically every measure of operational performance. This was particularly true in the higher-volume range. It is also apparent that multiple-lane streets, regardless of how the extra lane(s) are obtained, provide very desirable characteristics in the areawide measures of effectiveness. The resulting system of streets becomes much less sensitive to increases in volume.

This is apparent when comparing the characteristics of the multiple-lane stages S20.0 and S30.0 with the single-lane stages S3.0, S7.0, and S8.0. The same comparison can be made in Redwood City findings and also by comparing the two cities.

Stage S20.0 undoubtedly would have performed better with a strict observance of the no-stopping regulation. Any detrimental effects of the Taaffe Street closure would have been more than offset by the efficiencies of the unbalanced flow system. This was demonstrated with stage S30.0 when two blocks were effectively closed to through traffic.

SUPPLEMENTAL FINDINGS

This project was directed primarily toward specific test stages and the resulting direct findings and comparisons. However, as the project progressed it became apparent that there were supplemental findings that should be presented and discussed as an integral part of the project. These observations are presented in a constructive sense as items that must be considered in any community seeking an effective traffic regulation and control program.

Traffic Problem Relativity

Traffic problems can be found in any city, regardless of size. The severity of the problems may vary with population, but the relative importance to the local community does not. From a comparative standpoint, the large metropolitan center may have problems many times as severe as the smaller city; yet the smaller city can point to congestion, delays, and accidents that are intolerable from their point of view. To compound the problem, the small cities often operate without the services of a professional traffic engineer, whereas the large cities usually have qualified professional staffs.

There is no direct comparison of the severity of traffic problems between large and small cities. Items of minor consequences to major cities often become points of controversy in the smaller community. Similarly, the impact of a specific traffic control measure is greater within the confines of a smaller business district and is therefore of greater local concern.

The relativity of traffic problems depends on the individual characteristics of the area under consideration.

Political Feasibility

This project encountered much public opposition before reaching completion. Despite prior pledges of cooperation from officials, governing bodies, and interested merchants of the selected test cities (see Appendix D), some of the test stages became controversial public issues. The problems encountered and their resultant impact on the study are summarized as follows.

In Redwood City, the first major problem became apparent during stage R30.0 involving continuous left-turn prohibitions for both directions on Broadway. Pressure from complainants increased until a group of merchants and their supporters filed an official objection with the City Manager, requesting termination of the project.

A meeting was arranged between the researchers and the opposing group, in which the researchers requested that the test stages be continued. The researchers pointed out that the plans of each test stage and the period for which they were to remain in force were previously examined and accepted by a majority of the opposing merchants, as well as the city staff and the Council members. The pressure group of merchants, however, succeeded in persuading the City Council to pass a resolution returning the CBD to the base conditions for a two-month "holiday moratorium" (R0.5), starting November 18, 1967.

During the first week of January 1968, before the test program resumed, the City Council again concurred with the opposing group and moved that the remaining test stages (R50.0, R60.0, and R70.0), as previously approved, either be canceled or be modified to satisfy the objections of the merchants. The researchers agreed to modify the balance of the test stages as a condition for reinstating the program. In an effort to preserve the test content of the remaining stages, R50.0 and R60.0 were combined as R56.0, and the combined tests were implemented on

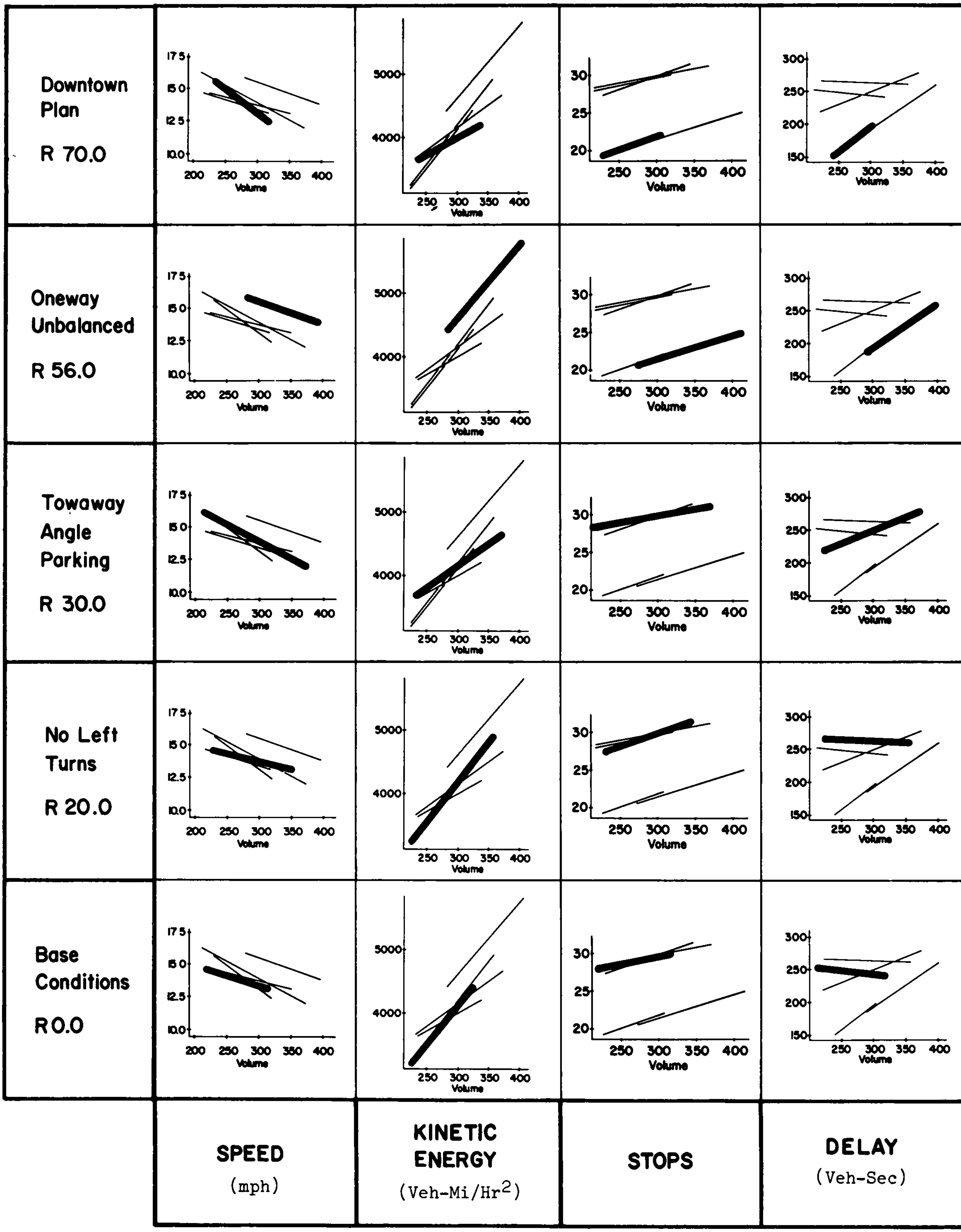

Figure 16. Summary of major test stage findings—Redwood City.

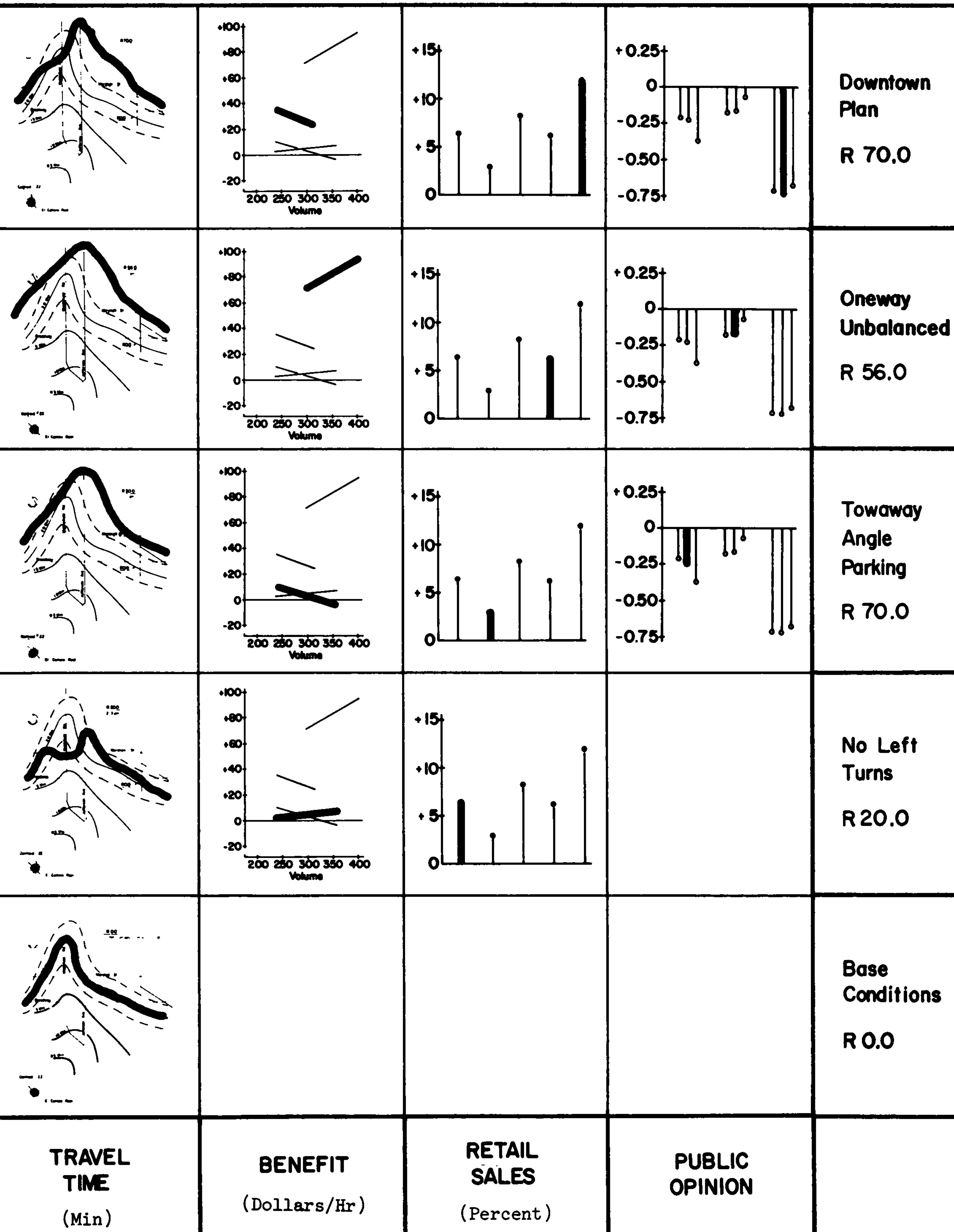

Figure 16. (continued).

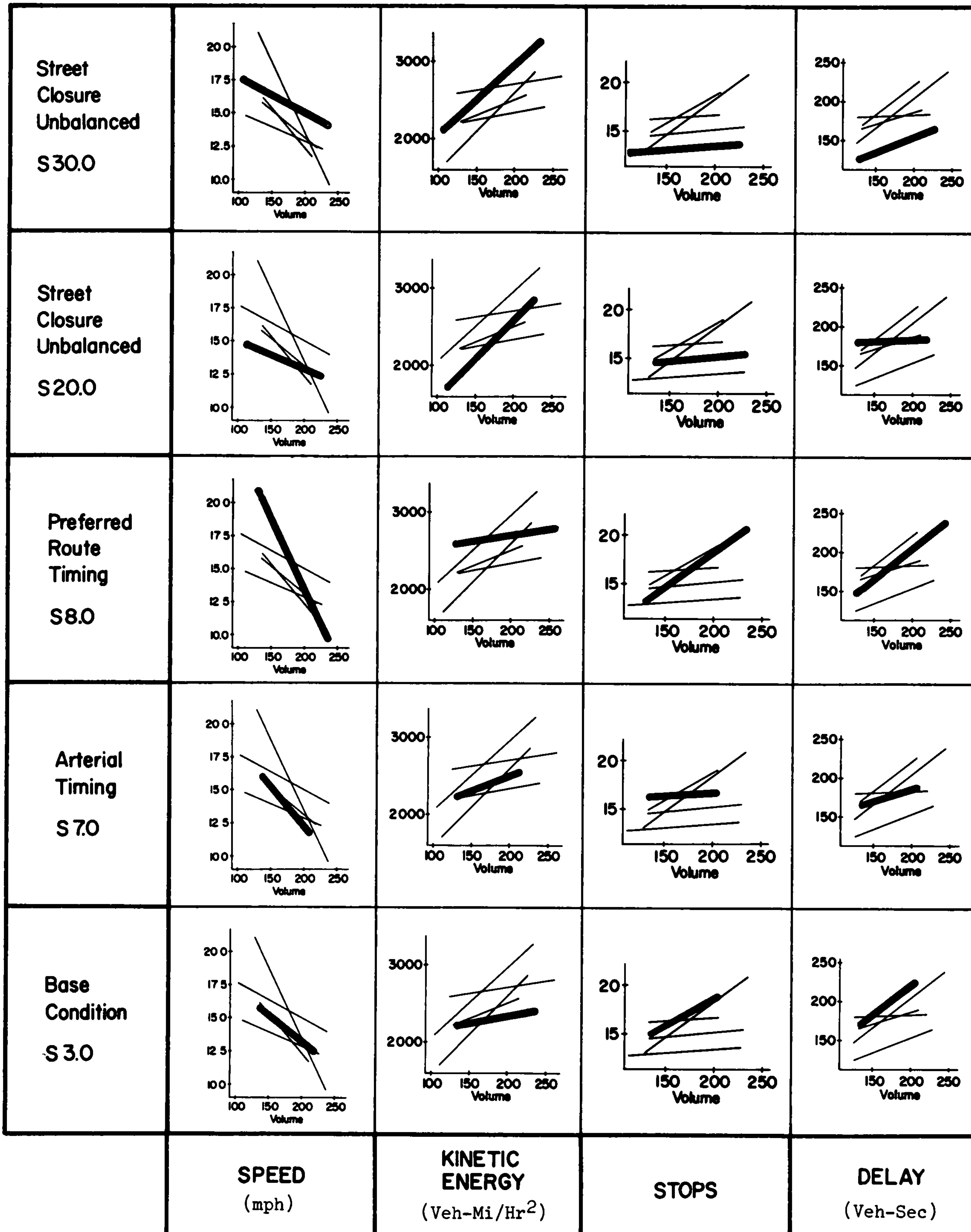

Figure 17. Summary of major test stage findings—Sunnyvale.

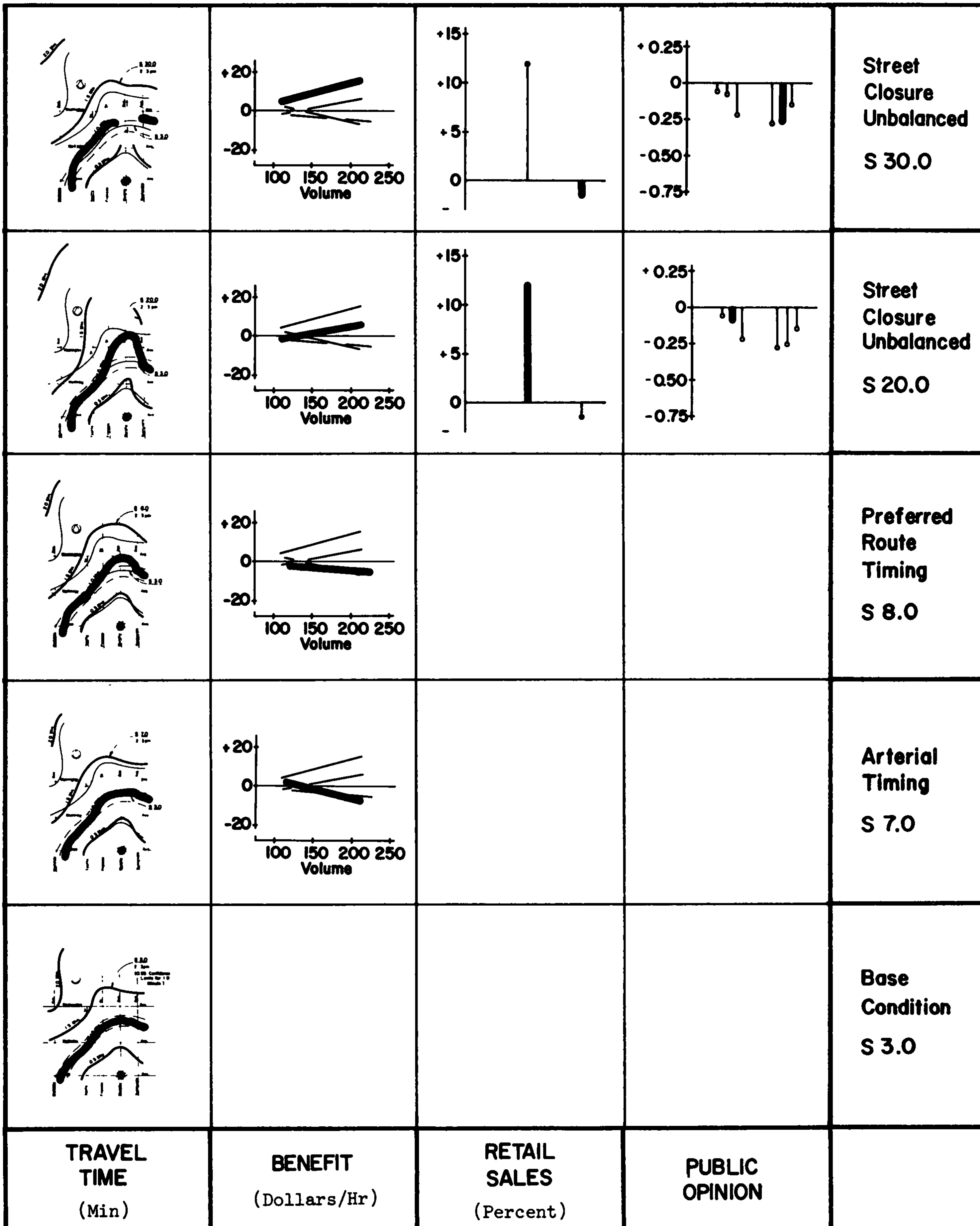

Figure 17. (continued).

January 29, 1968. This modification created a problem for the project in terms of time and test stage evaluation.

Test stage R70.0 was accepted by the city staff and the City Council without much opposition or postponement. This test stage was implemented on March 16, 1968. Soon after the implementation the merchants' group began to exert pressure on the city staff and the Council members to cancel the test stage and return the city to the base conditions. In this case, the researchers made a slight alteration to the stage and successfully persuaded the city staff, Council members, and the opposing merchants to let this test stage remain in force through the six-weeks period ending on April 27, 1968.

In Sunnyvale, no political situation arose from the implementation of different test stages, with the exception of some opposition from merchants concerning the closure of Taaffe Street to vehicular traffic. The city staff successfully persuaded the opposing merchants to accept the closure of Taaffe on a temporary basis

It should be noted that this discussion does not imply a comparison of the activities of pressure groups within the two test cities. The test stages implemented in Redwood City were more restrictive in nature. In addition, more stages were implemented for a longer period of time. Therefore, it would be meaningless to relate the political feasibility for two such diverse conditions.

Staff Organization

The planning and implementation of a traffic regulation and control program is highly dependent on the city staff and organization. The staff organizational structures in the two cities evaluated were similar in many respects. However, the traffic engineering functions were handled differently, resulting in differing levels of effectiveness

In one city the traffic engineer was in a direct line with the Director of Public Works and was responsible for a staff of four assistants He handled practically all items pertaining to traffic, including the writing of implementation work orders for signs, markings, etc. The organization served his interests efficiently and effectively.

The traffic engineer in the other city operated as staff assistant to the Chief of Police. Being placed in the Police Department served the traffic engineering function only by having traffic accident reports readily available. Instead of furthering the effective operation of the traffic engineer, the city staff organization hampered the efficient implementation of traffic regulation and control programs. Traffic signal timing changes, signal maintenance, sign installation, and pavement painting could be accomplished only on approval from the Police Chief, the City Manager, and the Director of Public Works. This awkward relationship often led to ineffective implementation of traffic control measures.

Signal Maintenance

Traffic signal maintenance proved to be an unexpected problem on more than one occasion in both Redwood City and Sunnyvale. A staff assignment had been made in each city for maintenance of the signals, but the task was regarded as low priority. In addition, one city had an annual signal maintenance contract with a local electrical company that did not provide adequate maintenance. The resultant ineffective maintenance led to signal malfunctions that adversely affected the indications displayed to motorists.

The problems resulting from ineffective maintenance were the result of a failure repair philosophy. These problems could be avoided by proper preventive maintenance. For example, the equipment for a number of pretimed signal controllers was oiled in areas that either were permanently lubricated at the factory or did not require any oil This error resulted in sluggish dial operation with unpredictable timing splits, or erratic drum operation causing 3-sec green intervals, 20-sec yellow intervals, or a direct sequential change from green to red.

Proper signal maintenance is necessary for efficient signal operation. Both factors are critical in ensuring a safe traffic environment. The maintenance personnel must be trained in the use of signal equipment.

Traffic Markings

Pavement markings are guidelines for motorists and important elements of traffic regulation and control. Parking spaces and traffic lanes must be clearly marked to obtain desired observance and uniformity of flow.

The test cities selected their own methods of changing pavement markings to implement the test stage geometric patterns Redwood City chose to paint over the old traffic markings Considerable effort was expended to ensure that the paint was carefully matched to the dark grey color of the pavement. However, due to the differing textures of paint and pavement, the old markings remained visible. Under certain lighting conditions it was difficult to distinguish between the new and the old pavement markings. This unfortunate occurrence, coupled with the number and frequency of marking changes, resulted in some confusion and frustration for motorists.

In Sunnyvale the painting work was primarily to add new stripes for the unbalanced flow pattern and to mark parking stalls. In some cases, where subsequent removal of a stripe was more likely, a 4-in.-wide white or yellow adhesive-backed tape was used. This allowed rapid and complete removal when desired.

Post-Study Action

On completion of the final field tests, each city made decisions regarding the retention of regulations and control techniques tested. The two courses of action, summarized as follows, provide insight into the efficacy of the test stage program.

In Sunnyvale, at the request of the traffic engineer, the City Council passed a resolution authorizing retention of most features of the last test stage, S30.0. The Murphy Avenue one way, angle parking, and temporary landscaping were removed because the street was needed for traffic routing during reconstruction of Sunnyvale Avenue. The angle parking probably will be restored at a later date. It is also planned that Taaffe Street, closed during stage S20.0, will be closed permanently and converted to a pedestrian mall when equitable financing arrangements can be completed.

In Redwood City, the CBD was returned to the original base conditions with minor exception. Major sewer and water-main construction was then allowed to begin in the core area where work had been prohibited pending completion of the field testing for this project. The city apparently intends to modify its downtown traffic flow pattern based on the findings and conclusions of this study. On completion of the construction, the CBD streets will be resurfaced and restriped according to a new plan. It is not known at this time which combination of traffic regulation and control techniques will be adopted. It was clear, however, from the Chamber of Commerce opinion survey of 88 merchants that, although 49 percent favored the original traffic pattern, another 49 percent preferred change.

CHAPTER THREE

CONCLUSIONS

The primary objectives of this project have been reached through a concentrated program of research test stages. Contrary to most types of engineering-oriented research, the test stage program in this project dealt with real-time political feasibility. From the Council resolutions that first endorsed the project to the last floating-car travel-time run, a complex interrelationship has been observed and recorded. The research findings have been quantified and evaluated within a total environment, including operational performance, business performance, public opinion, and driver observance. The interrelationship was further compounded by other environmental factors such as travel demand and political processes. However, it is only within this total environment that the fundamental role of traffic engineering becomes clear.

As shown in Figure 18, there are many dependent relationships that comprise the environment from which the major project findings are drawn. There is a multiplicity of variables that are manifest as qualifications on the conclusions resulting from study of the findings. For example, a no-stopping towaway regulation cannot be evaluated strictly on operational performance. The impact on business and public opinion must also be considered. If not, a highly effective traffic regulation may not have a chance for further application when debated in the public forum.

STUDY CONCLUSIONS

Signal Timing

1. Signal timing is not a controlling factor when narrow lanes, curb parking, and left-turn conflicts exist; where signal timing does control, timing refinements can improve flow.

2. In small cities, signal maintenance is often inadequate. For effective signal performance, either a city staff technician must be adequately trained and the maintenance task assigned appropriate priority, or the task must be contracted to a fully qualified outside firm.

3. Greater operational efficiency can be achieved by careful timing of actuated signals, especially on major commuter routes through or adjacent to CBD's.

4. Preferred route timing improves the flow of commuter traffic.

Left-Turn Prohibition

1. When left turns are prohibited at all intersections along a major street within the core area, left-turning traffic can be successfully diverted if a convenient alternate route is available. Traffic flow on the major streets is improved because of reduced volume in addition to the elimination of turning delays.

2. When no alternate route is available, left-turning traffic must turn right to circle the block. Traffic flow is improved only if pedestrian interference with right-turning vehicles does not increase turning delay. Traffic volume on the major street generally is not reduced.

3. Drivers can be expected to observe the continuous left-turn prohibition when an alternate route is available; conversely, drivers can be expected to resist these prohibitions unless strictly enforced when another route is not convenient.

Parking Removal

1. Parking removal is more effective when accompanied by towaway regulations than when simple no-parking or no-stopping regulations are employed. These regulations require strict enforcement for driver observance.

2. A 24-hr parking restriction is more effective in terms of driver observance than limited time-period restrictions.

3. Parking removal is one method of increasing street capacity by permitting either additional or wider lanes.

4. Opposition to parking removal can be expected from merchants, particularly if other additional convenient parking is not readily available.

Lane Width

1. Wider lanes facilitate traffic flow by reducing marginal friction with parked vehicles and adjacent moving vehicles.

2. Wider lanes, when combined with parking removal, maximize traffic flow.

3. To avoid confusing the motorist, it is preferable to physically remove the paint of old lane markings when restriping a street.

Parking

1. Installation of angle parking reduces the effective street width, limits capacity, and, unless through traffic is diverted, increases intersection delay.

2. A change to a short-time limit for curb parking in the shopping core can produce the desired results of increasing off-street occupancy and freeing curb space for shoppers.

One-Way Street

1. A one-way couplet made up of a major street and a lesser traveled parallel street equalizes the use of both streets.

2. One-way streets provide smoother flow, facilitate turning movements, and decrease intersection delays.

3. One-way street couplets produced substantially better operational performance than the other traffic regulation and control techniques employed in this research.

4. Convenient terminals contribute to the successful operation of one-way couplets.

Unbalanced Flow

1. Stabilization periods for new installations of unbalanced flow can be lengthy unless means are developed to divert traffic to the preferred route.

2. Unbalanced flow provides a decided improvement in the favored direction after motorists become accustomed to the altered traffic pattern.

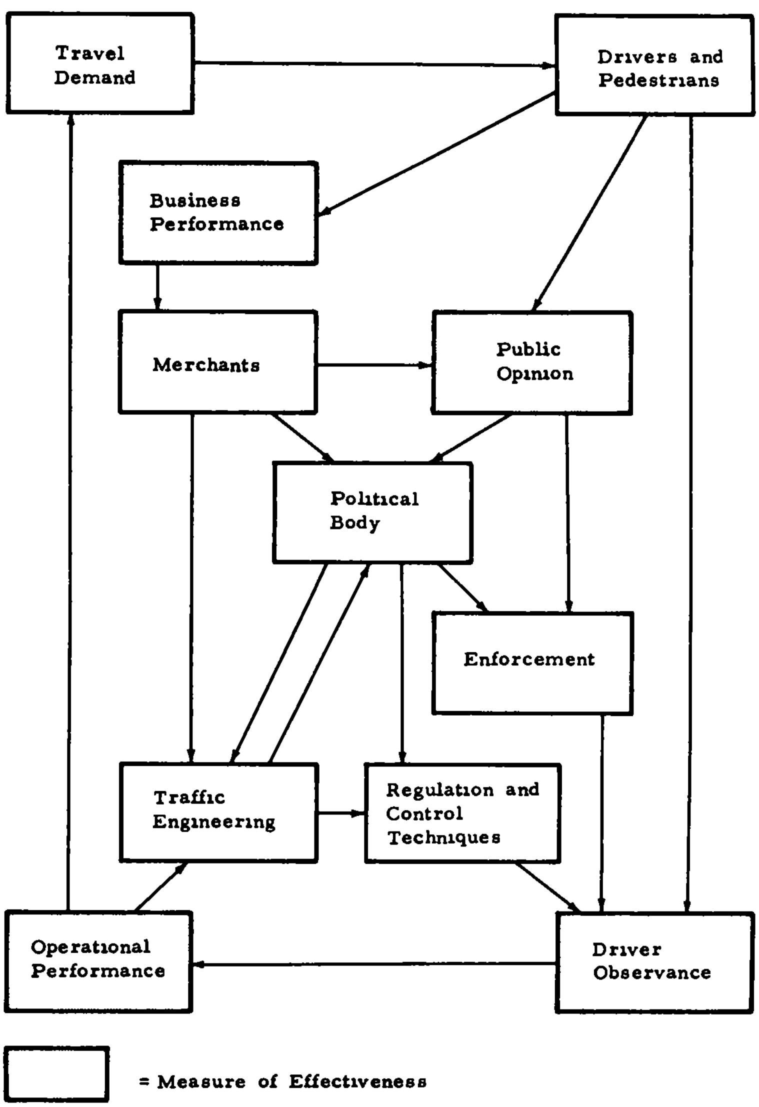

Figure 18. Interrelationship of measures of effectiveness.

Street De-Emphasis or Closure

1. A major CBD arterial cannot be successfully de-emphasized by reducing capacity unless an exceptionally attractive bypass route is provided. Driver habit patterns strongly resist this type of change, despite increased congestion, delays, and driver inconvenience.

2. CBD side streets can be closed to through traffic and virtually turned into parking areas by installing opposing one-way streets, angle parking, and one-lane flow, providing through traffic can be handled adequately on other streets.

3. A shopping street can be essentially closed to through traffic by converting the street to one-way operation in opposite directions from a central intersection with appropriately located parking, adequate circulation, and attractive landscaping. A shopping mall atmosphere can be created that will contribute to the viability of the retail establishments fronting on the street.

4. Complete closure can be accomplished only when the street link is not a major element in the circulation network.

Areawide Measures

As stated earlier, a solution to one traffic problem may create another in an adjacent area. Therefore, a major objective of the study was to determine the effects of a variety of traffic regulations and control techniques not only on the immediate street(s) involved, but also on the area as a whole. This admittedly complex task involved establishing new methods of quantifying and measuring the areawide impact.

The findings of the various test stages indicate that the control measures implemented had little far-reaching effect on the total area, with the exception of the one-way street unbalanced flow pattern which showed considerable overall improvement areawide.

The specific test stages as implemented in this project tended to dilute the areawide effects. The time allotted to each test stage and the allowed stabilization periods proved inadequate in some instances. Moreover, the volume levels in the affected area were not high enough to create the necessary pressure required for this type of measurement. In addition, many test programs were combined because of political expediency that prevented individual measurements. Therefore, a definitive statement cannot be made concerning the relative efficacy of the areawide measures.

Political Feasibility

The attitudes of interested parties concerning a single traffic control regulation can exert significant influence on its satisfactory implementation. In small cities, more than in major metropolitan areas, traffic control legislation is often an important agenda item, and seemingly minor traffic changes can become the subject of prolonged discussion and controversy. Under these conditions, any traffic control program can become vulnerable to the threat of political extermination.

When the attention of community members, as expressed by city officials, Chambers of Commerce, merchant groups, and other vocal citizens, is focused on the immediate effects of a specific traffic control technique, its feasibility is of major concern. If the community involved demonstrates an adverse reaction, pressure may be exerted to eradicate the offending regulation, regardless of its operational benefits. If authorities comply with the requests of the public, implementation can be delayed or, more serious, abandoned.

Although absolute agreement may be expressed by all interested parties at the beginning of a traffic improvement program, public attitudes may change to the extent that they threaten to jeopardize the effectiveness of the program. Community residents may first be attracted to initial publicity and obvious benefits of traffic improvement measures, but later their inherent resistance to change may express itself. Merchants become wary if customer patterns vary; law-enforcement officers are faced with increased problems. The population of the city, once responsive to innovation, will then respond to the discomfort and stress of change.

No traffic improvement program can succeed without the broad-based involvement of all factors in the community environment. Each factor presents a different viewpoint and should be given adequate hearing in the public forum. No one factor should be allowed to dominate. It has been shown in this study that the judgment of the nonmerchant group regarding the operational performance of a traffic regulation is as sound as, if not sounder than, that of the merchant group. The nonmerchant group is by far the more numerous, and the merchants depend on these people for their livelihood. Yet, it is the nonmerchant motorists and shoppers who are generally not represented in the public forum.

The conclusion is that the representation of all factors must be obtained and must be duly considered. Unless the voice of the motoring and shopping public is heard, the downtown core areas of many cities will continue to be congested, accident-prone environments.

Business Performance

1. When convenient alternative parking is available, it appears that parking removal for a major portion of the day has no adverse effect on retail sales.

2. Merchants, to a degree, are willing to participate in evaluations of sales trends, providing their anonymity can be assured.

3. Merchants recognize that traffic access, circulation, and parking characteristics can have a direct effect on business performance.

CITY CONCLUSIONS

Although the objective of this project was not to prepare a recommended plan for each test city, the close association of the researchers with the city staffs and business leaders dictates that at least general conclusions be presented regarding the most desirable plan for CBD traffic regulation and control.

Redwood City

The downtown core of Redwood City would benefit considerably from a plan incorporating the best elements of the last two test stages, R56.0 and R70.0. Broadway and Marshall should be converted to a one-way couplet with more efficient terminal transitions than were possible during the project. Jefferson should be established as the major north-south traffic artery and through traffic should be prevented from using Middlefield. Additional parking could then be installed on Middlefield and the entire core area could be studied for spot improvements that would assure maximum efficiency. Among the improvements are STOP-sign removal, signal timing, and intersection channelization.

The city has adopted an ambitious Downtown Development Plan. The plan will evolve only through staged development, and the traffic circulation elements should be among the first to be re-evaluated, with the conclusions from this project as a guide.

Sunnyvale

In Sunnyvale there is also an ambitious development plan for a CBD core area. The traffic circulation and parking elements have been established and major reconstruction of the boundary arterials began after completion of test stage S30.0. The decisions regarding the circulation pattern within the core area undoubtedly will be influenced by the results of this project.

The unbalanced flow pattern has been retained by the city, and Taaffe Street will someday be closed to vehicular traffic. Murphy should be closed to through traffic and made attractive for local circulation, parking, and shopping. Also, maximum use of the signal system flexibility should be made. As conditions stabilize, the core area should be closely studied and areawide spot improvements should be considered. The separate turning lanes at McKinley and Murphy, evaluated during stages S20.0 and S30 0, are examples of the further refinement in flow efficiency that can result from relatively inexpensive regulation and control measures.

CHAPTER FOUR

APPLICATIONS AND SUGGESTED RESEARCH

APPLICATIONS

This project has shown the need for immediate solutions to the increasing traffic problems in urban areas. The penalty for failure to solve these problems in a timely manner is increased accidents, congestion, and delays. It has also been shown in this study that changes in traffic regulations and control supported by the public can significantly reduce the traffic problems while maintaining or improving the economic viability of the CBD. Conversely, lack of public acceptance combined with restrictive self-interests tend to apply a negative force against implementing improvements.

A community cannot afford to wait for 10 or 15 years while blighted areas or the entire urban core area are rebuilt to modern geometric standards. Nor can it afford to wait for 10 years for an experimental program of traffic regulations and controls to determine the best method of handling access, circulation, and parking in the CBD. Application of sound traffic engineering techniques in areas demanding improvement must be made soon, on a broad level that hits at the core of the problem, and with strong public support.

The communities experiencing the inexorable increases in accidents, congestion, and delay must be made aware of the ways in which maximum use can be made of existing street space. Further, the communities must be made aware of the relationships between operational and business performance and of the characteristics of public opinion as related to traffic operations.

The findings and conclusions of this project do not lend themselves directly to incorporation in design handbooks, manuals, policy guides, etc These research results must be applied within the framework of the complex interrelationships that contribute to the operational efficiency and economic well-being of an urban core area. The human element is a strong factor in this environment. A successful improvement program requires broad-based community awareness and participation.

The question of how to apply the research results most effectively is of concern to sponsors and professionals in traffic engineering at all levels of government who are seeking *additional* operational improvements in their respective jurisdictions where existing roadways can yield more efficient operation.

The key will be in developing a feeling of public trust in the engineers, administrators, and business leaders who are seeking solutions to the urban problems. All too often the public works administrators, particularly traffic engineers, pursue their goals in a paternalistic manner. They do not receive, nor do they seek, the necessary public support. This support requires a basic awareness of the community's needs on the part of the public. This can best be accomplished through workshops or seminars attended by:

1. City Managers (or their first-line assistants).
2. Council Members (transportation committee).
3. Chamber of Commerce Retail Managers.
4. Downtown merchant group leaders.

The sessions should be oriented toward problem-solving and should use illustrated case studies from this project and experiences of other cities to show what can be done. Supporting these illustrations should be the direct testimony of administrators and civic leaders from the cities involved. After the seminars, the interest momentum should be guided toward formulation of hard-core planning committees in the communities needing assistance. From that point on, the sponsors could monitor the progress of program planning for traffic regulation and control, and play an advisory role while the counties and cities share the direct involvement.

The transferability of research results from this project to other cities obtains credibility from comparisons made within the project. It is doubtful whether actual predictions of travel speed can ever be accurately made for situations where traffic pressures and characteristics differ.

In this study, measures of effectiveness were related to weighted average link volumes to determine the relative magnitudes of change in operational performance. Control techniques, and combinations thereof, were compared and were ranked according to their effectiveness. Although numerical values were calculated for performance measures, the actual numbers of some depend on the description of the street system in terms of links. The precise values of operational characteristics, therefore, cannot be generalized to be applicable in all cities in the same population range.

However, one of the more remarkable study findings was a consistency of performance measures for both cities when related to weighted average link volume. For example, Figure 19 shows that in Redwood City, where volumes were higher than in Sunnyvale, density was proportionately higher. A similar consistency was found for weighted average speed and kinetic energy.

Although Redwood City and Sunnyvale differ in many respects, they have certain similarities, such as two-way street systems, street spacing between 250 and 700 ft, adequate parking, medium pedestrian densities, and the circulating nature of off-peak street use. When these similarities are considered, the consistency of the results supports the conclusions as to relative operational performance and degree of transferability.

This project has demonstrated several techniques that have produced various levels of operational efficiency. The effects of these techniques, both local and areawide, are not always beneficial (as with angle parking, or in cases where enforcement problems occurred). Nevertheless, all of the findings have application in the process of formulating the most efficient traffic improvement program. For example, the research findings and conclusions can make a significant contribution to the Traffic Operations Program for Increasing Capacity and Safety (TOPICS). With the advent of an expanded TOPICS program, large sums of money will be available for the implementation of areawide traffic improvement programs and will, in effect, provide a laboratory for carrying this study further.

SUGGESTED RESEARCH

During the course of this study certain areas were identified that should be studied in greater detail. These areas are critical elements in adopting, implementing, and evaluating an areawide traffic program.

Regulation and Control Techniques

Areawide performance measures need to be developed for the following techniques that were not available for study in this project:

1. Pedestrian control.
2. Right-turn prohibitions during peak pedestrian hours.
3. Peak-hour left-turn prohibitions with a concurrent change in signal phasing.
4. Two-way continuous left-turn lanes.
5. Reversible lanes to achieve one-way or unbalanced flow.

Some techniques applied in this study were inconclusive because of limited time and difficulty in achieving stabilization. To ascertain their true impact and effectiveness throughout an area of streets, further study should be made of the following:

1. Preferential route signal timing.
2. Establishment of through routes.
3. Street de-emphasis.
4. Altering habitual travel patterns.

Because of the necessity of consolidating certain techniques into a single test stage, it was impossible to develop individual areawide measures of performance specifically for all techniques evaluated. Further research will be necessary to demonstrate the effect of the individual techniques that had to be implemented simultaneously.

Areawide Measures

To evaluate extensive traffic programs, future research should continue to concentrate on areawide analysis of operational changes. Techniques of areawide analysis are described in this report, and other methods probably can

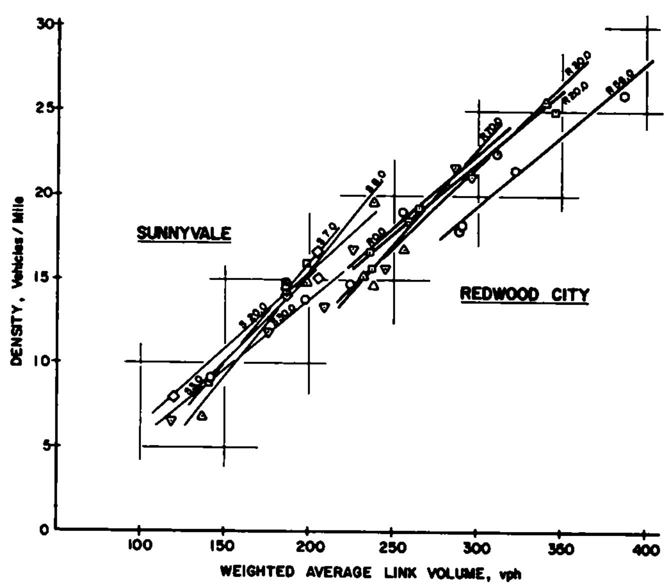

Figure 19. Consistency of areawide measures. Density as a function of volume for base condition and four test stages in Redwood City and Sunnyvale.

be found. However, more information will be required about the statistical distribution of the measures if they are to become reliable tools for analyzing operational performance. Specifically, it would be desirable to know how the variance of the measures changes with travel time, sample size, volume, and speed. Although traffic engineers will be able to calculate the measures for their street systems once they have the data, it is less likely that they will be able to generate the distributions of the measures by repeated sampling.

This additional research into the characteristics of the areawide measures should first consider the definitions of the measures. In this project, directional travel paths were called links and were evaluated as such, regardless of the number of lanes. Travel times were obtained accordingly, with the floating-car driver having free choice of travel lanes and changing lanes, when possible, to avoid unnecessary delays. Volumes were also developed, regardless of the number of lanes in the link. The resulting areawide measures provided good relative comparisons. This study indicated that perhaps refined link volume-speed measurements should be obtained by a lane-by-lane evaluation. A study should be undertaken to assess the value of increased accuracy compared to the cost of collecting these more precise data.

Another method of obtaining areawide data that became apparent during the study and that should merit consideration is the use of aerial photography. Areawide density could be measured from an aerial photograph by counting the vehicles in the area and dividing by total link length. Space mean speed could be determined from two successive photos by dividing the average displacement of all vehicles in the area by the time interval between photos. From these two measures and the total link or lane length, the four other areawide measures used in this project could be calculated. A study should be undertaken to determine if trees and building shadows would cause insurmountable sight obstructions and if the photographic measurements would be sufficiently accurate.

Business Performance

Economic studies of retail sales, similar to those made by highway departments when a freeway has bypassed a local community, should be made in depth for urban areas where extensive changes in access, circulation, and parking are contemplated. It is imperative that objective correlations be established between various levels of networks speed and volume and the business performance of the surrounding area. The business community, to a degree, generally claims a potential adverse effect on sales whenever a restrictive traffic regulation is proposed that will expedite traffic. The opposite effect must be demonstrated if areawide traffic programs are to be welcomed by the business community.

Public Opinion

Further research is needed to clarify the degree of awareness and soundness of judgment of various sectors of the public. A way must be found to effectively incorporate representative public opinion into the decision-making processes associated with traffic regulations and control.

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APPENDIX A

SUPPLEMENTAL DATA—CHAPTER ONE

VOLUME

To obtain a measure of apparent travel demand, relative street importance, and data for test stage design and evaluation, it was necessary to collect several types of volume data. Details of the techniques and objectives of the various volume studies are described as follows.

Hourly Volume Patterns

The hourly changes in rate of flow throughout the day were studied to determine the time of the peak hours, an approximate peak-hour factor, and the magnitude of volumes throughout the day.

The method selected to obtain the necessary volume counts was by automatic recording counters actuated by rubber road tubes in the traveled traffic lanes. The tubes were located to minimize the chance that a vehicle would park on them. Nevertheless, there were many gaps in the volume data due to cars parking on the tubes, counter malfunction, and vandalism.

During the base-data collection period, counts of a week's duration were made on most streets in the CBD of both test cities. The counts indicated that, in Redwood City, peak home-to-work flow occurs from 7:30 to 8:30 AM. The evening peak period is from 4:30 to 5:30 PM. In Sunnyvale, the morning peak was from 7:15 to 8:15 AM and the evening peak was from 4:30 to 5:30 PM. There was also a peak in Sunnyvale from 12:00 noon to 1:00 PM when workers came from outside the CBD to eat and shop during their lunch period. In both cities, the arrival and departure of shoppers during the afternoon created relatively heavy volumes.

Data for test stage evaluation were collected for periods of the day representative of the various flow conditions. It was originally planned to look at the morning peak period, a midmorning period, a midafternoon period, and the evening peak period. After the base data and data from early test stages were examined, it was found that the midmorning traffic did not cause serious traffic problems. Data from the noontime period were, therefore, substituted for the midmorning period. Four standard time periods were finally selected for the collection of data (Table A-1).

The differences in times for the morning and noon periods are caused by the impact of starting time and lunch hour at Lockheed Aircraft Corporation in Sunnyvale, with a total employment of about 20,000 persons. The morning shift start times are spread, but high volumes still exist on a street adjacent to the CBD. There is a similar effect for the lunch hour when the CBD restaurants are heavily patronized and considerable shopping activity takes place.

An examination of the volume data also allowed an estimate of peak-hour factors to be made. In Sunnyvale this appeared to be 0.85, and in Redwood City this appeared to be about 0.80.

Special manual counts were also made to determine peak-hour factors and load factors on a sample basis.

Daily and Monthly Volume Patterns

At a particular location the volume can be expected to be different for different days of the week and for different months of the year. To determine this variation, continuous count stations were set up for both directions of one street in the core areas of Redwood City and Sunnyvale. Streeter-Amet counters were used to record volume data by 15-min periods and were serviced weekly. In addition, continuous hourly courts for several years were obtained from the California Division of Highways for a count station on a major route midway between Redwood City and Sunnyvale. With the data from the three locations, daily and monthly volume factors were calculated for the selected time periods. The records were not available for an entire year previous to test stage implementation at the continuous count stations in Redwood City and Sunnyvale; therefore, monthly factors were first calculated by dividing monthly average volumes by the average volume of a particular month—specifically, May. Because the existing Redwood City factors appeared to agree with the State factors, these factors were used in Redwood City. The Sunnyvale factors did not agree with the State factors, and it was necessary to fill in the missing Sunnyvale factors with factors derived from counts made frequently, but not continuously, at an intersection adjacent to the core.

Figure A-1 shows the factors finally selected for Redwood City and Sunnyvale. The variation that would be caused by analyzing the data separately for day of week and direction of flow is shown as shaded. The daily factors were found to vary with time of day. Table A-2 gives the factors selected, using Thursday as 100 percent.

TABLE A-1

STANDARD TIME PERIODS

STANDARD TIME PERIOD[a]	TIME PERIOD IN: REDWOOD CITY	SUNNYVALE
1 Morning peak	7:30-8:30 AM	7:15-8:15 AM
5 Noon	12:30-1:30 PM	12:00-1:00 PM
3 Midafternoon	2:00-3:00 PM	2:00-3:00 PM
4 Evening peak	4:30-5:30 PM	4:30-5:30 PM

[a] Period 2 (10.00 AM to 11:00 AM) was deleted.

Intersection Turning Movements

Manual counts of turning movements were made at selected intersections in both test cities during the base condition and during test stage evaluation. From these counts, it was possible to evaluate the observance of regulations such as left-turn prohibitions, to select peak hours at particular intersections to compliment the recording counter data, and to obtain input and output volumes for intersections in the core areas.

In the morning and evening peaks, counts were made for 2-hr periods to assure that the peak hour was covered. In the noon and midafternoon periods, counts were taken for the hourly periods given in Table A-1.

The input and output volumes derived from the turning movement counts were the prime source of data for link volumes used in the calculation of areawide measure of effectiveness. If turning movement counts were made at adjacent intersections, the output volume from an upstream intersection and the input volume to the adjacent downstream intersection were averaged to obtain a link value. If counts were not made at adjacent intersections, the input volume or the output volume, whichever was available, was chosen as the link volume.

TABLE A-2

DAILY VOLUME FACTORS

	DAILY VOLUME FACTORS					
	REDWOOD CITY			SUNNYVALE		
TIME PERIOD	TUES.	WED	THURS.	TUES	WED.	THURS.
Morning peak	1.01	1.03	1.00	0.97	0 95	1.00
Noon	1.04	1.01	1 00	1.05	0.99	1.00
Midafternoon	1 04	1.01	1.00	0.93	0 89	1.00
Evening peak	0.99	0.94	1.00	0.98	0.95	1.00

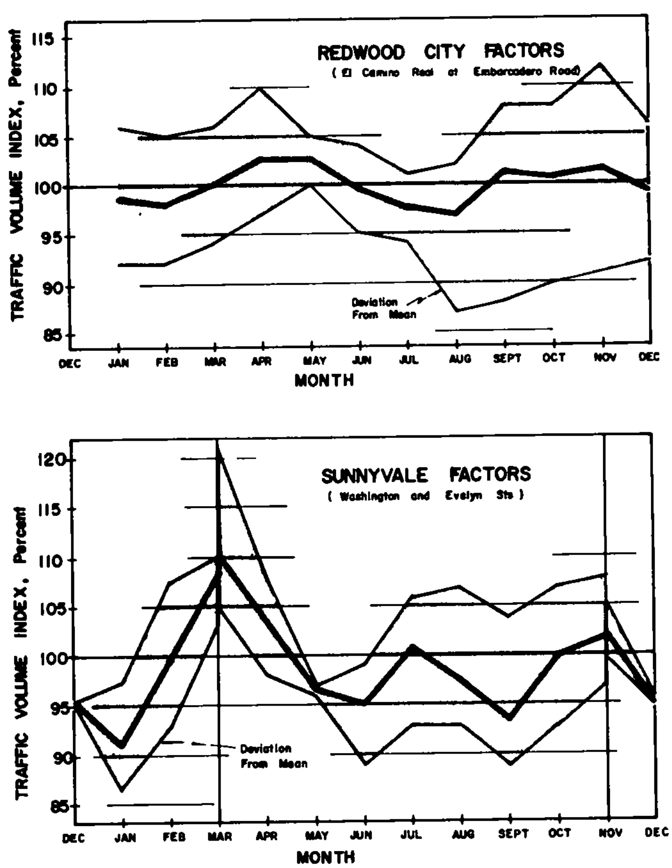


Figure A-1. Monthly volume variation factors.

Lane Distribution

Manual counts of vehicular volume by lane were made on Broadway to evaluate the effect of lane width on flow.

Pedestrians

Manual pedestrian counts were made to quantify base conditions and to establish if there were any significant pedestrian problems that could be studied in the test stage program. There was none, however, the counts were used to help explain some of the right-turning delay that occurred in certain test stages.

With Stopped Delay Studies

To calculate the mean stopped delay per vehicle and the percentage of vehicles stopping at an intersection it was necessary to count the number of stopping and nonstopping vehicles in conjunction with stopped delay studies. This also allowed plotting of stopped delay as a function of volume to compare the results of various regulation and control techniques.

With Travel Time and Delay

It has generally been established that there is a relationship between travel time and volume on a route To determine this relationship for the two test cities, manual volume counts, summarized in 6-min intervals, were made in conjunction with floating-car travel-time runs during the base data collection period and early test phases. A linear correlation and regression analysis was made for selected streets in both cities to determine the magnitude and significance of the relationship. It was found that on streets with low volumes a significant relationship could not be found. On streets with high volumes such a relationship was indicated. Rather than consider each travel time run and its associated volume as a separate entity or adjust each travel time according to the indicated relationship, it was decided to aggregate the data by the four standard time periods, each with its own prevailing volume.

TRAVEL TIME, SPEEDS, AND DELAYS

Travel time and the concomitant stops and delays are generally considered as meaningful measures of street system performance. To gather travel-time data in the two cities a series of routes was laid out and the floating-car technique was used (5). Most major streets in the CBD of each city were included in the study. Each direction of a street was considered as a separate route in the study design concept. Checkpoints, or points along a route at which stopwatch times were recorded, were taken at each cross street. The far-side property line was taken as the exact checkpoint. Travel time, therefore, could be determined for each length of route between two successive intersections in the test areas.

For the stop data, an observer recorded the duration of each stop made by the test-car driver with a code indicating the cause of the stop (e.g., signal, STOP sign, left turn, pedestrian). The observations for each floating-car run were then averaged. Averaged stops between the checkpoints were cumulated first by street and then for the several streets in the CBD core areas.

Early in the project the required number of travel-time runs for various statistical confidence levels was determined by standard statistical techniques. It was found that a sample size of about 30 runs would be necessary if the 95-percent confidence limits for travel time on typical signalized links would fall within 7 sec of the observed value. Because it was believed that performing this many runs was not feasible for the project, 12 runs was set as the target.

In determining whether an observed change was statistically significant, the difference between observations must be somewhat greater than the confidence limit. This requirement makes it difficult to determine if there is a significant change on a link-by-link basis. It was found, however, that, for most streets, the ratio of standard deviation to mean travel time decreases as the travel time is measured over more links, and it becomes easier to show that a given percentage change in travel time is significant when the length over which the travel time is measured is increased. This finding made the use of 12 runs acceptable for most analyses.

The speed measurements in Appendix B were calculated as space mean speed by dividing street length by mean travel time. The speed changes indicating significant difference were calculated from the required travel-time changes, link length, and approximate speed using the relationship

$$V \approx \frac{l}{t^2} \Delta t$$

in which

V = necessary speed change for a significant change;
l = street length;
t = approximate street travel time; and
Δt = necessary travel-time change for a significant change.

A further method of considering travel times was used in this project to provide an areawide representation. Isochronal, or travel-time contour, maps were investigated for each test stage. As shown in Appendix B, a good representation of change can be portrayed.

Confidence limits for representative isochronal maps were calculated from the expression

$$C(l) \approx \frac{l}{t} C(t)$$

in which

$C(l)$ = confidence limit for a particular time contour;
l = street length from centroid to contour;
t = approximate travel time from centroid to contour; and
$C(t)$ = approximate confidence limit for the travel time.

STOPPED DELAY

Stopped delay is a measure of intersection performance. Stop delay represents stopped time only and does not include time loss due to acceleration and deceleration.

A sampling procedure developed by Berry and Van Til (*6*) was used to collect stop-time data at each location. This procedure involved the counting of the number of vehicles stopped in an intersection approach at periodic intervals. A 15-sec counting interval was found suitable for this study. In addition to recording stop-time data, each observer counted approach volume either by tally counters or by tally marks. If an approaching vehicle came to a complete stop it was registered on one tally counter. Other vehicles were registered on a second tally counter. The total stopped and through volumes were recorded at the end of each 15-min interval. It was possible for one observer to do both 15-sec counts and volume counts when the largest queue (cars waiting on red) was 20 vehicles or less. When queues exceeded 20 vehicles, one or more additional observers were assigned to share the volume counts. Greater accuracy was obtained when cumulative volumes were registered at the end of each period, as opposed to resetting counters to zero.

All major approaches to the four signalized intersections on Broadway in the core area of Redwood City were counted 50 percent of the time. Each observer counted two different approaches, by alternating his approach every 15 min. Data at all other locations were collected continuously, 100 percent of the time.

Stop-time data at each approach to an intersection were summarized during each 15-min time period. The summaries included total delay, average delay per approach vehicle, average delay per stopped vehicle, and percentage of vehicles stopped. The summarized data were used to evaluate the performance of both single intersections and a system of intersections.

Volume-delay curves were plotted by approach for the intersections studied Total delay as a function of approach volume was used for comparison of intersection operation during various test stages.

In addition, the four Broadway signalized intersections in the core area of Redwood City were considered as a system of intersections. Graphs of average delay per vehicle as a function of system lane volume were prepared for all test stages except the one-way stage. Average delay per vehicle in the system was calculated by weighting the average delay per vehicle from each approach in the system using the traffic volume of that approach. The system lane volume was taken as the sum of average lane volumes of each approach in the system.

COMPARISON OF STOPPED-TIME- AND TRAVEL-DELAY DATA

In Redwood City the opportunity was presented to compare measures of average signal delay per vehicle as measured by two types of studies: (1) sampling stopped-time intersection delay, and (2) travel delays as measured by the floating-car technique. The comparison was made to determine if both types of measures were producing similar results and to shed some light on which measure it would be better to use in the future.

Stop-time delays at four signalized intersections on Broadway were measured by both the floating-car technique and the stopped-time-delay sampling procedure.

Figure A-2 shows the comparison of the data from the two techniques for both one- and two-lane approaches on Broadway. The figure uses all the available data from the approaches to Broadway signalized intersections in the Redwood City core area. Each point on the figure represents signal delay on one intersection approach during one time period and was obtained from a sample of 6 to 14 travel-time runs and a 50-percent sample of stop-time data.

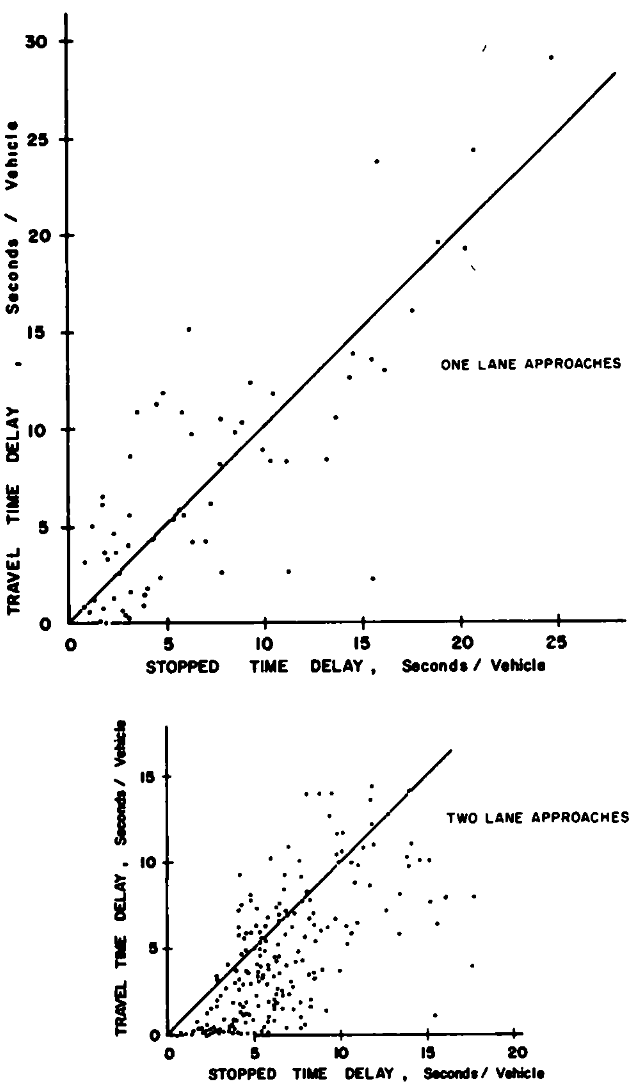


Figure A-2. Comparison of stopped-time delay and travel-time delay. Broadway, Redwood City.

The results show that the width of the approach to an intersection controls the delay relationship to a great extent. Signal delays that were measured by the floating-car technique are considerably lower than delays from the stopped-time method in all test stages during which Broadway carried two through lanes of traffic in each direction The difference in results for one- and two-lane approach is because a through vehicle may be able to avoid turn delays by selecting an appropriate lane on a multilane approach to an intersection. However, through traffic experiences larger delays when the vehicles cannot go around the turning vehicles.

Figure A-2 also shows that on a one-lane approach travel-time data can provide a good measure of stop delays when signal delays are large (15 sec or more per vehicle). There is a large variation between the signal delays obtained by the two methods at lower magnitudes of delay.

AREAWIDE MEASURES OF EFFECTIVENESS

To use areawide measures of effectiveness it is first necessary to define measures that quantify the operations. There are many ways of deriving the measures, some of which are discussed in the previous sections of this appendix. Besides these measures it is also possible to define a set of dimensionally consistent measures that give a further picture of areawide performance.

A set of four such measures has been chosen for this project. The definition and applicability of each are described as follows.

Average Speed

Average speed is the measure with the most intuitive appeal. Drivers, merchants, and traffic engineers have a feeling for what speed they would like to see on a street. They can perhaps conceptualize such a thing as average speed for a system of streets, although they may be somewhat subjective in their determination.

An objective measure of average speed has been chosen as the total vehicle-miles in the area divided by the total vehicle-hours. This procedure in effect weighs what would be the space mean speed by volume to give a measure of areawide performance. This definition, which has been used by Texas Transportation Institute for a freeway corridor (7), should be equally applicable to a street network.

Average Volume

Vehicle-miles of travel have often been used as measure of travel demand. The magnitude of the number, however, depends on the size of the area being considered and has little intuitive appeal as an absolute measure of performance. By dividing vehicle-miles by the total length of streets in the area, an average volume (the volume on each link weighted in proportion to link length) can be calculated.

Density

A fundamental law of traffic flow in a steady-state stream is that volume equals the product of space mean speed and density. Density, or the number of vehicles per mile of street links, can be considered a measure of effectiveness because, for a constant volume, a decrease in density must imply an increase in speed. By taking the definition of areawide volume and dividing it by the definition of areawide average speed, an areawide density measurement can be calculated. The resulting definition is mathematically equivalent to the number of vehicles per mile of street link throughout the area.

Kinetic Energy

Kinetic energy of a traffic stream seems to be a good measure of the stream's performance. Average speed and volume as described previously can be multiplied to get an average areawide measure of kinetic energy. As it is desirable to increase speeds without decreasing volumes, this parameter is meaningful as an areawide measure.

When applying the areawide measures of effectiveness it is necessary to define the area in which the measures are to be applied. It is important that the chosen area include those streets that are likely to have changes in performance due to the application of a traffic-engineering technique. If a series of techniques is to be applied and compared, as in this project, it is desirable to have a consistent area that can be used for several comparisons. The area, however, should not be so large that a change in performance is dwarfed by the performance on nonaffected streets.

The analysis work did not involve an extensive sensitivity analysis to determine the physical limits within which a change in regulation or control would have an effect on driver performance. Considerable judgment was involved in selecting the area and, for practical reasons, it had to be limited in street mileage. Some knowledge of sensitivity was obtained, however, during the critical analysis stages when apparently poor performance was found to be due to circumstances outside the immediately affected area.

Two areas in each test city were chosen for comparing areawide measure of effectiveness. In Redwood City these areas have been called the "core" and "Broadway" areas; in Sunnyvale these are the "core" and "Mathilda" areas. Figures 2 and 10 show the street segments included in these areas. In Redwood City the core area includes the Broadway area. Each street was considered as two one-way streets running in opposite directions. The shadings in the figures indicating which streets are included are drawn along the right side of the streets as would be seen by a driver. For those test stages where streets were closed or made one way, those directional segments on which traffic was prohibited were removed from the area.

To calculate the areawide measures, three types of data were necessary: street lengths, travel times, and link volumes. Street lengths were obtained from maps of the test cities; travel times were obtained from floating-car travel-time and delay runs; and volumes were obtained from intersection turning movement counts. The travel-time data and volume data were not collected simultaneously, but were collected for the same time periods within a few days of each other. Although the areawide measures would be somewhat more meaningful if all data were gathered simultaneously—the resulting measures would then be a "snapshot" of system performance at a given instant—the actual method of calculating the measures probably did not introduce serious inaccuracies.

PUBLIC-OPINION SURVEY

Five times during the study a large number of questionnaires along with postpaid self-addressed envelopes were placed on the windshields of motor vehicles parked in the core areas of the test cities. In addition, except for the first survey in Redwood City, questionnaires were also given to selected merchants at their places of business in the downtown core area of each city.

In each city the questionnaires were distributed after the stabilization period of the test stage for which the questionnaire was designed. The dates, test stages, and the number of questionnaires distributed in both cities are listed as follows.

Redwood City

1. November 17, 1967 (Friday)—test stage R40.0.
   1,100 questionnaires placed on parked vehicles.
   No questionnaires distributed directly to downtown merchants.
2. March 13, 1968 (Wednesday)—test stage R56.0.
   918 questionnaires placed on parked vehicles.
   58 questionnaires distributed directly to downtown merchants.
3. April 24, 1968 (Wednesday)—test stage R70.0.
   1,100 questionnaires placed on parked vehicles.
   62 questionnaires distributed directly to downtown merchants.

Sunnyvale

1. January 19, 1968 (Friday)—test stage S20.0.
   1,042 questionnaires placed on parked vehicles.
   28 questionnaires distributed directly to downtown merchants.
2. March 8, 1968 (Friday)—test stage S30.0.
   800 questionnaires placed on parked vehicles.
   50 questionnaires distributed directly to downtown merchants.

Sample questionnaires used in each of the surveys are shown in Figures A-3 to A-7.

RETAIL SALES STUDY

The retail sales study was carried out with the generous cooperation of merchants in Redwood City and Sunnyvale. In both cities the city traffic engineer and project engineer made personal calls on the merchants, explained the purpose of the study, and distributed questionnaires. In Redwood City the Chamber of Commerce introduced the study to the merchants by means of a letter. The questionnaire forms used and the letter from the Redwood City Chamber of Commerce are shown in Figures A-8 to A-10.

MOTORIST SURVEY

Express Your Opinion and Help Improve Traffic Conditions in Downtown Redwood City

City officials and Peat, Marwick, Livingston & Co are conducting a survey and study to determine the best traffic pattern for the downtown area of Redwood City Your cooperation in completing and mailing the postage paid questionnaire as quickly as possible will contribute significantly to this study. If you receive more than one questionnaire, please fill in and return the first one Check the box which most closely answers the questions

1 How often do you drive on Broadway?

☐ Seldom ☐ Once a week ☐ Once a day ☐ More than once a day

2 What time do you usually drive on Broadway?

☐ Morning Rush Hour (7 30 to 8 30AM) ☐ Evening Rush Hou (4 30 to 5 30PM) ☐ Other Periods

] No Definite Time

3. To your knowledge, which of the following regulations are in force on Broadway?

No-Turn Prohibitions

☐ No Left Turn ☐ No Right Turn

☐ No Right or Left Turns

Parking Restrictions

No-Stopping/Towaway on -

☐ South Side ☐ North Side ☐ Both Sides

4 How do No-Turn Prohibitions on Broadway affect you in arriving at your destination?

I find the same route (or best alternate route) takes

☐ More Time ☐ Less Time ☐ About the Same Time

5 How do parking restrictions on Broadway affect you in arriving at your destination?

☐ I can find a parking space on Broadway or on another street or lot within easy walking distance.

☐ I cannot find a parking space within easy walking distance

6 Have you noticed any difference in traffic movement or congestion on Broadway since August, 1967?

	Morning Rush	Afternoon	Evening Rush
Traffic conditions seem better	☐	☐	☐
Traffic conditions seem worse	☐	☐	☐
Traffic conditions seem the same	☐	☐	☐

7. Based on my driving experience in Redwood City, I would like to make the following comments

____

____

____

8. For statistical purposes -

Your Sex ☐ Male ☐ Female Occupation __________

Your Age ☐ 16-20 ☐ 21-25 ☐ 25-65 ☐ Over 65

Type of Vehicle Driven ☐ Passenger Car ☐ Light Commercial ☐ Heavy Commercial

Thank you for your help in making Redwood City a better place to live

Figure A-3. Public opinion questionnaire, test stage R40.0.

YOUR OPINION

To improve traffic conditions in downtown Redwood City, City officials and Peat, Marwick, Livingston & Co are conducting a study to determine the best traffic patterns Please return this questionnaire with your answers as soon as possible in the postage-paid envelope

1 How often do you drive on Broadway?

☐ Seldom ☐ Once a week ☐ Once a day ☐ More than once a day

During what periods?

☐ Morning rush hour 7 30 to 8 30AM ☐ Evening rush hour 4 30 to 5 30PM ☐ Other periods

☐ No definite time

2 How often do you drive on Marshall?

☐ Seldom ☐ Once a week ☐ Once a day ☐ More than once a day

During what periods?

☐ Morning rush hour 7 30 to 8 30AM ☐ Evening rush hour 4 30 to 5 30PM ☐ Other periods

☐ No definite time

3 With the one-way operation on Broadway and Marshall, have you noticed any difference in traffic movement or congestion in different periods of the day?

		Morning Rush	Evening Rush	Other periods
Traffic conditions on BROADWAY	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
Traffic conditions on MARSHALL	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
Marshall/Jefferson INTERSECTION	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
Marshall/Middlefield INTERSECTION	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐

(Questionnaire continues on reverse side)

4. What is your opinion of traffic conditions at -

		Morning rush hour 7 15 to 8 15AM	Evening rush 4 30 to 5 30PM	Other periods
Jefferson/Middlefield Intersection	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐

5 Based on my driving experience in Redwood City, I offer the following comments

____

____

____

____

6 Information needed for statistical purposes

Sex ☐ Male ☐ Female

Age Group ☐ 16 to 20 ☐ 21 to 25 ☐ 25 to 65 ☐ Over 65

Occupation

Vehicle Driven ☐ Passenger car ☐ Light commercial ☐ Heavy commercial

☐ I live in Redwood City ☐ I DO NOT live in Redwood City

7 Any additional comments especially as to shopping ease under present traffic patterns

____

____

____

____

____

THANK YOU FOR YOUR COOPERATION

Figure A-4. Public opinion questionnaire, test stage R56.0.

YOUR OPINION

To improve traffic and shopping conditions in downtown Redwood City, City officials and Peat, Marwick, Livingston & Co are conducting a study to determine the best traffic patterns Please return this questionnaire with your answers as soon as possible in the postage-paid envelope provided

1 How often do you drive on Broadway?

☐ Seldom ☐ Once a week ☐ Once a day ☐ More than once a day

During what periods?

☐ Morning rush hour 7 30 to 8 30AM ☐ Evening rush hour 4 30 to 5 30PM ☐ Other periods No definite time

2. How often do you drive on Marshall?

☐ Seldom ☐ Once a week ☐ Once a day ☐ More than once a day

During what periods?

☐ Morning rush hour 7 30 to 8 30AM ☐ Evening rush hour 4 30 to 5 30PM ☐ Other periods No definite time

3. To your knowledge, which of the following streets (or any part thereof) are ONE WAY?

	Direction Going North	Direction Going South
☐ Arguello	☐	☐
☐ Winslow	☐	☐
☐ Hamilton	☐	☐
☐ Middlefield	☐	☐
☐ Jefferson	☐	☐
☐ Main	☐	☐

	Direction Going East	Direction Going West
Marshall	☐	☐
Broadway	☐	☐

4 Under the existing traffic pattern, have you noticed any difference in traffic movement or congestion during different periods of the day on the following streets?

		Morning rush hour 7 30 to 8 30AM	Evening rush hour 4 30 to 5 30PM
Broadway	better	☐	☐
	worse	☐	☐
	same	☐	☐
Marshall	better	☐	☐
	worse	☐	☐
	same	☐	☐
Jefferson	better	☐	☐
	worse	☐	☐
	same	☐	☐

(Questionnaire continues on reverse)

5 How often do you shop downtown?

☐ Seldom ☐ Once a week ☐ More than once a week

6. If you feel that the downtown shopping facilities are not satisfactory, which of the following factors needs improvement most? Check one.

☐ Parking supply ☐ Traffic flow ☐ Service to customers

☐ Quality and variety of merchandise ☐ Appearance of shopping area

7. With the existing traffic pattern, do you notice any change in shopping convenience in the Central Business District on the following streets?

	Better	Worse	Same
Broadway	☐	☐	☐
Main	☐	☐	☐
Jefferson	☐	☐	☐
Middlefield	☐	☐	☐
Hamilton	☐	☐	☐
Winslow	☐	☐	☐

8. From your driving experience in Redwood City, what is your opinion of the existing traffic pattern?

____

9. Information needed for statistical purposes.

Sex: ☐ Male ☐ Female

Age ☐ 16 to 20 ☐ 21 to 25 ☐ 25 to 65 ☐ Over 65

Occupation ____________________

Vehicle Driven: ☐ Passenger car ☐ Light commercial ☐ Heavy commercial

☐ I DO live in Redwood City ☐ I DO NOT live in Redwood City

Figure A-5. Public opinion questionnaire, test stage R70.0.

YOUR OPINION

To improve traffic conditions in downtown Sunnyvale, City officials and Peat, Marwick, Livingston & Co. are conducting a study to determine the best traffic patterns for downtown Sunnyvale. Please return this questionnaire with your answers as soon as possible in the postage-paid envelope.

1. How often do you drive in downtown Sunnyvale?

   ☐ Seldom ☐ About once a week ☐ Daily

2. What time do you usually drive in downtown Sunnyvale?

   ☐ 7 15 to 8 15 AM ☐ 4 30 to 5 30 PM ☐ Other Periods ☐ No Set Time

3. At which intersections have you noticed left-turn restrictions?

   ____

   ____

4. On which streets have you noticed additional parking prohibitions?

   ____

   ____

5. How do the current restrictions affect you in your driving time? Does it take

   ☐ Less Time ☐ More Time ☐ Same Time

6. Have the current parking restrictions affected you in finding a parking space?

   ☐ No ☐ Yes

7. With the current parking restrictions, can you find a parking space within acceptable walking distance?

   ☐ No ☐ Yes

8. What is your view regarding the closure of Taaffe Street?

Traffic conditions appear	☐ Better	☐ Worse	☐ No Different
Parking facilities appear	☐ Better	☐ Worse	☐ No Different
Shopping attractiveness is	☐ Better	☐ Worse	☐ No Different

   Any other comments on the closure of Taaffe Street?

   ____

   ____

   ____

(Continued on reverse side)

9. Have you noticed any difference in traffic movement or congestion on the following streets since early November, 1967?

		7 15 to 8 15 AM	4 30 to 5 30 PM	Other Periods
Washington Ave.	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
McKinley Ave.	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
Murphy Ave.	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
Frances St.	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐

10. For statistical purposes

Sex	☐ Male	☐ Female	
Age Group	☐ Under 25	☐ 25 to 65	☐ Over 65
Occupation	______________		
Vehicle Driven	☐ Passenger Car	☐ Light Commercial ☐ Heavy Commercial	

11. Any additional comments?

   ____

   ____

   ____

   ____

   ____

THANK YOU FOR YOUR COOPERATION

Figure A-6. Public opinion questionnaire, test stage S20.0.

YOUR OPINION

To improve traffic conditions in downtown Sunnyvale, City officials and Peat, Marwick, Livingston & Co are conducting a study to determine the best traffic patterns Please return this questionnaire with your answers as soon as possible in the postage-paid envelope

1 How often do you drive in downtown Sunnyvale?

☐ Seldom ☐ Once a week ☐ Once a day ☐ More than once a day

2 What time do you usually drive in downtown Sunnyvale?

☐ Morning rush hour 7 15 to 8 15AM ☐ Evening rush hour 4 30 to 5 30PM ☐ Other periods

☐ No set time

3 How do the current restrictions affect your driving time? Does it take -

☐ Less time ☐ More time ☐ About the same time

4 In your opinion, what is the result of the one-way traffic on Murphy Avenue?

Traffic conditions seem	☐ Better	☐ Worse	☐ No different
Parking facilities seem	☐ Better	☐ Worse	☐ No different
Shopping attractiveness seems	☐ Better	☐ Worse	☐ No different

Other comments on one-way operation of Murphy Avenue -

____

____

____

5 Since one-way traffic operation on Murphy Avenue began, have you noticed any difference in traffic flow at the following intersections?

		7 15 to 8 15AM	4 30 to 5 30PM	Other Periods
Murphy/McKinley	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
Murphy/Washington	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
Murphy/Evelyn	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
Frances/McKinley	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
Frances/Washington	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐

(Questionnaire continues on the reverse side)

5 (Continued)

		7 15 to 8 15AM	4 30 to 5 30PM	Other Periods
Frances/Evelyn	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
Sunnyvale/McKinley	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
Sunnyvale/Washington	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
Sunnyvale/Evelyn	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐

6 What is your opinion about the parking prohibition along the north side of Washington?

		Morning rush hour 7 15 to 8 15AM	Evening rush hour 4 30 to 5 30PM	Other periods
WESTBOUND traffic flow is	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐
EASTBOUND traffic flow is	- better	☐	☐	☐
	- worse	☐	☐	☐
	- same	☐	☐	☐

7 Information needed for statistical purposes,

Sex ☐ Male ☐ Female

Age Group ☐ 16-20 ☐ 21-25 ☐ 25-65 ☐ Over 65

Occupation

Vehicle Driven ☐ Passenger car ☐ Light commercial ☐ Heavy commercial

☐ I live in Sunnyvale ☐ I DO NOT live in Sunnyvale

8 Other comments -

____

____

____

____

THANK YOU FOR YOUR COOPERATION

Figure A-7. Public opinion questionnaire, test stage S30.0.

CHAMBER OF COMMERCE
REDWOOD CITY, CALIFORNIA 94064

WORLD PORT
FOR THE SAN FRANCISCO PENINSULA AND SOUTH BAY
SAN MATEO COUNTY SEAT

Middlefield Road at Jefferson Avenue • EMerson 9-3705

Dear Downtown Merchant:

In conjunction with the present traffic survey, we request your assistance in helping the city develop information about the effect of the survey on retail sales.

They will need sales figures for the period one year prior to the survey and during the survey. They will need the amount of weekly sales for 1966 and 1967 from August 1st thru November 30th. We are eliminating December as the traffic survey was suspended, but they will need the weekly sales from January 1st thru April 30th for 1967 and 1968.

Arthur Eskelin, City Traffic Engineer and T.S. Khanna, Survey Engineer, will call on you either February 20 or 21 to give you a detailed explanation of their needs.

Please give them your complete co-operation so that both the city and our downtown businesses can benefit from this survey in better traffic flow and parking availability for our residents and your customers.

Sincerely,

Jerry Chandler
Retail Dept. Manager

Figure A-8. Letter from Chamber of Commerce to Redwood City merchants.

REDWOOD CITY

CENTRAL BUSINESS DISTRICT RETAIL SALES EVALUATION

As a supplement to the traffic research study now being conducted in the City, city officials and Peat, Marwick, Livingston & Co. (San Francisco) respectfully request comparative weekly retail sales information for your store for the weeks indicated below. Please note that the information requested is not in actual dollar value but only in terms of percentage measured against the base period which is the week ending August 27, 1966.

Check applicable box for information provided: ☐ Gross Sales ☐ Net Sales

NOTE: ALL INFORMATION FURNISHED WILL BE KEPT CONFIDENTIAL

YEAR	WEEK ENDING ON						
1966	Aug. 27 100%	Sept. 3	Sept. 10	Sept. 17	Sept. 24	Oct. 1	Oct. 8
	Oct. 15	Oct. 22	Oct. 29	Nov. 5	Nov. 12	Nov. 19	Dec. 17
	Dec. 24	Jan. 21	Jan. 28	Feb. 4	Feb. 11	Feb. 18	Feb. 25
1967	Mar. 4	Mar. 11	Mar. 18	Mar. 25	Apr. 1	Apr. 8	Apr. 15
	Apr. 22	Apr. 29	May 6	May 13	May 20	Aug. 26	Sept. 2
	Sept. 9	Sept. 16	Sept. 23	Sept. 30	Oct. 7	Oct. 14	Oct. 21
	Oct. 28	Nov. 4	Nov. 11	Nov. 18	Dec. 16	Dec. 23	
1968	Jan. 20	Jan. 27	Feb. 3	Feb. 10	Feb. 17	Feb. 24	Mar. 2
	Mar. 9	Mar. 16	Mar. 23	Mar. 30	Apr. 6	Apr. 13	Apr. 20
	Apr. 27	May 4	May 11	May 18			

Name of Store: ____________________ Type of Store: __________

Address: ____________________

Figure A-9. Retail sales questionnaire, Redwood City.

CITY OF SUNNYVALE

CENTRAL BUSINESS DISTRICT RETAIL SALES EVALUATION

As a supplement to the traffic research study now being conducted in the City, city officials and Peat, Marwick, Livingston & Co. (San Francisco) respectfully request comparative weekly retail sales information for your store for the weeks indicated below. Please note that the information requested is not in actual dollar value but only in terms of percentage measured against the base period which is the week ending November 5, 1966.

Check applicable box for information provided: ☐ Gross Sales ☐ Net Sales

YEAR	WEEK ENDING ON					
1966	Nov. 5 100%	Nov. 12	Nov. 19	Nov. 26	Dec. 3	Dec. 10	Dec. 17
	Dec. 24	Dec. 31					
1967	Jan. 7	Jan. 14	Jan. 21	Jan. 28	Feb. 4	Feb. 11	Feb. 18
	Feb. 25	Mar. 4	Mar. 11	Mar. 18	Nov. 4	Nov. 11	Nov. 18
	Nov. 25	Dec. 2	Dec. 9	Dec. 16	Dec. 23	Dec. 30	
1968	Jan. 6	Jan. 13	Jan. 20	Jan. 27	Feb. 3	Feb. 10	Feb. 17
	Feb. 24	Mar. 2	Mar. 9	Mar. 16			

NOTE: ALL INFORMATION FURNISHED WILL BE KEPT CONFIDENTIAL

Name of Store: ______________________ Type of Store: ____________

Address: ______________________

Figure A-10. Retail sales questionnaire, Sunnyvale.

APPENDIX B

SUPPLEMENTAL DATA—CHAPTER TWO

This appendix contains figures and tables giving detailed information substantiating the findings in Chapter Two and partially summarized in Figures 17 and 18. The information is divided into four areas: operational performance, business performance, public opinion, and user and test stage implementation costs.

OPERATIONAL PERFORMANCE

Measures of volume, travel speeds, travel time, system delay, areawide performance, and travel cost are presented separately for each city. A separate section on accidents follows.

Many of the figures use symbols to indicate test stage number and time period for each data point. These symbols are summarized and explained in Figure B-1.

Redwood City

Volumes during each stage and time period on four major streets in Redwood City are given in Tables B-1 and B-2. Travel speeds for these same streets through the core are shown in Figures B-2 through B-5. Measures of effectiveness derived from floating-car data treating adjacent streets as couplets are given in Tables B-3 and B-4. Time contours for one time period from a selected point of access to the CBD are shown in Figure B-6. Average stopped delay for the Broadway signal system is shown in Figure B-7 for peak periods and in Figure B-8 for off-peak periods. Figures B-9, B-10, and B-11 show special areawide measures of effectiveness for the Broadway area. Figure B-12 shows control device delay and number of stops found in the Broadway area. Figures B-13 through B-16 give the same information for the Redwood City core area as do Figures B-9 through B-12 for the Broadway area.

REDWOOD CITY		
○	R0.0	Base Conditions
+	R1.0/2.0	Signal Timing
□	R20.0	Left-Turn Prohibition
△	R30.0	Towaway and Angle Parking
◇	R40.0	Towaway and Angle Parking
○	R56.0	One-Way and Unbalanced Flow
▽	R70.0	The Downtown Plan
1	....	7 30-8 30 a.m.
5	...	12 30-1 30 p m
3	. . . .. .	2 00-3 00 p.m.
4	... .	4 30-5 30 p.m.
SUNNYVALE		
○	S3.0	Base Conditions
□	S7.0	Signalized Grid Timing
△	S8.0	Signalized Grid Timing
◇	S20.0	Street Closure and Unbalanced Flow
▽	S30.0	Street Closure and Unbalanced Flow
1	... ...	7 15-8 15 a.m.
5	.. ..	12 00-1 00 p m.
3	....	2 00-3 00 p.m.
4	......	4 30-5 30 p m.

Figure B-1. Identification symbols for test stages and standard time periods (used on graphs of operational performance).

Sunnyvale

Volumes on four major streets in Sunnyvale are given in Table B-5 for base conditions and the two test stages with street closures. Travel speed for the two major east-west streets through the core is shown in Figures B-17 and B-18. Results from treating these two streets as a couplet are given in Table B-6. Figure B-19 shows the time contours from a point of access to the CBD. Special areawide measures of effectiveness for the Sunnyvale core area are shown in Figures B-20, B-21, and B-22. Figure B-23 shows control device delay and number of stops for the Sunnyvale core area. Figure B-24 shows areawide weighted average speed for the Mathilda area. Figure B-25 shows control device delay and number of stops in the Mathilda area. Table B-7 summarizes the average stopped delay at the two Mathilda signals.

Accidents

In the 3 years prior to the opening of the Woodside Expressway, south of the CBD, in April 1965, the number of accidents in Redwood City had been rising steadily at a rate of about 9 percent per year. The opening of the new road reversed the accident trend which had been established, and the number of accidents dropped by 14 percent from the 1964 level. Table B-8 gives the citywide, study-area, and core-area accident trends for Redwood City.

The opening of the Woodside Expressway also caused a substantial drop in downtown traffic volumes. On Broadway and on Main Street this drop in volumes amounted to 16 and 27 percent, respectively. This volume change was also a major factor contributing to the reduction in the accidents for that area.

The effect of the test stages was apparently to renew the decline in CBD accidents that had begun with the opening of the Expressway. Areawide totals were down from the same period of 1966-1967. Accidents in the study area

TABLE B-1

REDWOOD CITY CBD MAJOR TRAFFIC VOLUMES (ADJUSTED FOR DAILY AND SEASONAL VARIATION)

Time Period	Direction	BROADWAY						MARSHALL					
		Base	R20.0	R30 0	R40 0	R56 0	R70 0	Base	R20.0	R30 0	R40.0	R56 0	R70.0
1	EB	383	386	411	402	590	316	160	143	157	146	---	131
	WB	228	289	241	262	---	171	164	218	249	254	441	314
	Total	611	675	652	664	590	487	324	261	406	400	441	445
5	EB	---	354	386	406	658	457	---	246	247	228	---	192
	WB	---	347	377	324	---	324	---	278	280	264	537	267
	Total	---	701	763	730	658	781	---	524	527	492	537	459
3	EB	452	370	344	351	552	435	186	212	218	244	---	183
	WB	457	283	339	349	---	309	203	249	222	253	479	232
	Total	909	653	683	700	552	744	389	461	440	497	479	416
4	EB	450	455	347	513	646	413	205	343	290	307	---	340
	WB	555	477	486	515	---	331	244	315	366	347	782	294
	Total	1005	932	833	1028	646	744	449	658	656	654	782	634
24-Hour Total	EB	6335						2635					
	WB	6170						3432					
	Total	12505						6067					

TABLE B-2

REDWOOD CITY CBD MAJOR TRAFFIC VOLUMES (ADJUSTED FOR DAILY AND SEASONAL VARIATION)

Time Period	Direction	MIDDLEFIELD						JEFFERSON					
		Base	R20 0	R30 0	R40 0	R56 0	R70 0	Base	R20 0	R30 0	R40 0	R56 0	R70 0
1	NB	154	185	193	200	241	---	271	281	307	329	313	503
	SB	88	97	100	101	64	73	92	110	119	107	114	127
	Total	242	282	293	301	305	73	363	391	426	436	427	630
5	NB	---	200	197	204	260	---	---	245	259	254	284	404
	SB	---	181	173	162	147	71	---	187	231	193	207	198
	Total	---	381	370	366	407	71	---	432	490	447	491	602
3	NB	150	158	164	196	107	---	299	267	223	282	242	335
	SB	142	170	175	166	129	84	247	192	206	214	213	231
	Total	292	328	339	362	236	84	546	459	429	496	455	566
4	NB	98	144	122	153	201	---	183	207	196	189	211	242
	SB	263	365	340	342	285	86	243	406	366	381	330	477
	Total	361	509	462	495	486	86	526	613	562	570	541	719
24-Hour Total	NB	2174						2912					
	SB	2808						2394					
	Total	4982						5306					

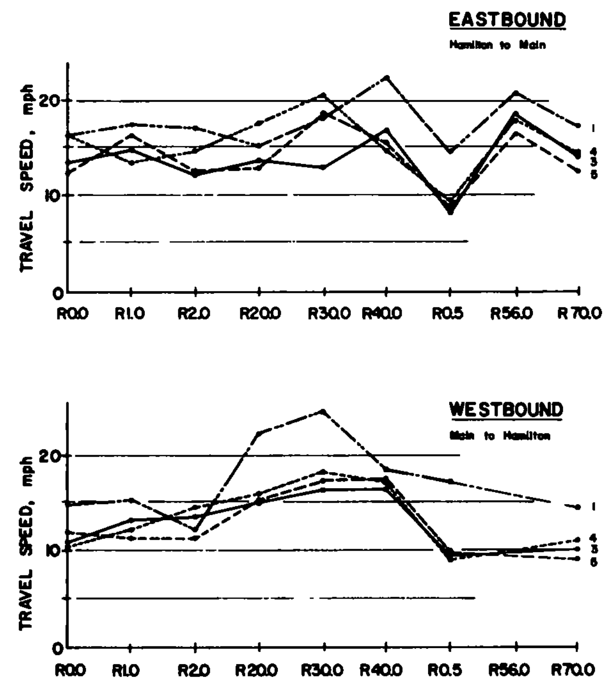


Figure B-2. Travel speeds on Broadway by test stage and time period. Required change to be significant at 5-percent level: eastbound, 5.5 mph; westbound, 4.0 mph.

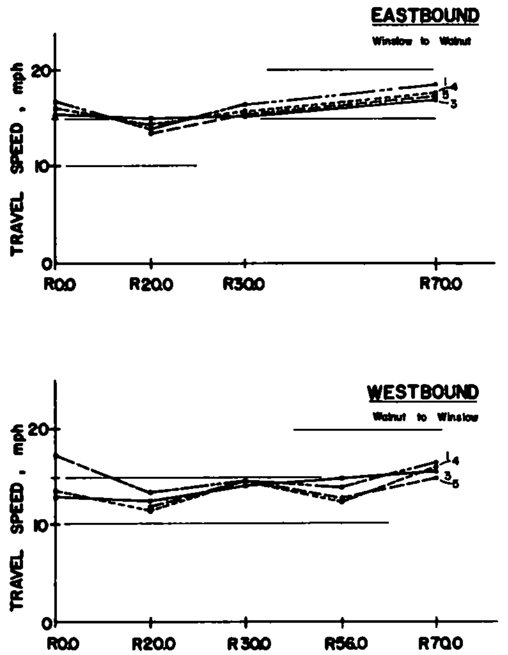


Figure B-3. Travel speeds on Marshall Street by test stage and time period. Required change to be significant at 5-percent level: eastbound, 3.5 mph; westbound, 2.0 mph.

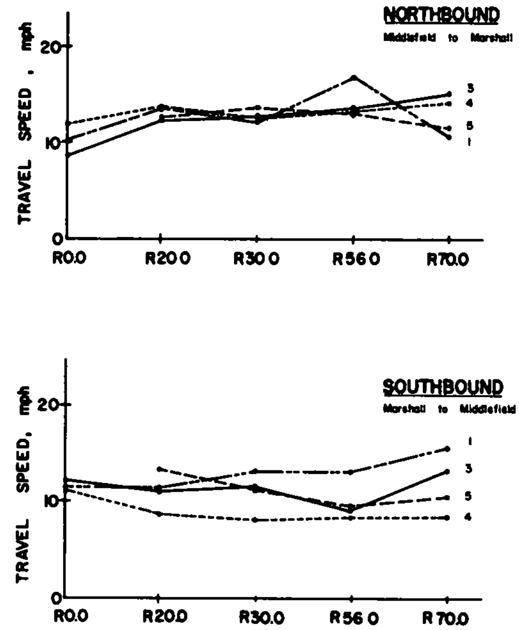


Figure B-5. Travel speeds on Jefferson Street by test stage and time period. Required change to be significant at 5-percent level: northbound, 4.0 mph; southbound, 5.0 mph.

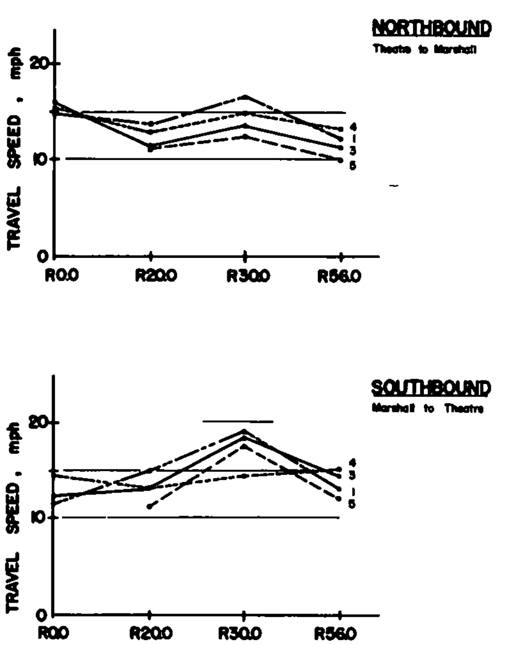


Figure B-4. Travel speeds on Middlefield Road by test stage and time period. Required change to be significant at 5-percent level: northbound, 3.5 mph; southbound, 6.0 mph.

TABLE B-3

COUPLET ANALYSES: BROADWAY—MARSHALL (FROM BROADWAY AT ARGUELLO TO BROADWAY AT SPRING)

		STANDARD TIME PERIODS			
EFFECTIVENESS MEASURE	TEST STAGE NUMBER	7 30-8 30 a m (1)	12 30-1 30 p m (5)	2 00-3 00 p.m (3)	4 30-5 30 p.m (4)
Number of Stops	0 0	10 67	11 70	12 93	10 82
	30 0	10 19	11 34	11.40	10 13
	56 0	2 82	3 41	3 09	3.53
	70 0	8 65	10 24	10 07	10 00
Signal Delay	0 0	40 97	78 55	84.34	70 89
	30 0	73 12	66 65	71 79	71.91
	56 0	21 22	24 92	17.84	30 83
	70 0	46.55	79 11	77 44	76.95
Other Delay	0 0	4 52	6 69	9 79	4.57
	30 0	0 64	4.77	4.90	1 51
	56 0	-	2 33	0 84	1 83
	70 0	2 73	8 05	3 37	2.43
Travel Time	0 0	6 87	7.62	8 11	7 86
	30 0	6 51	7 03	7.31	6 97
	56 0	3.16	3 72	3 28	3 50
	70 0	7.39	8 66	8 50	8.26
Average Speed	0 0	16.3	14.7	13.8	14.2
	30.0	17 2	15 9	15 3	16.1
	56 0	18 7	15 9	18 0	16.9
	70 0	16 8	14 3	14 6	15 0

Results obtained from summing floating car data for both directions of both streets except where streets were one-way

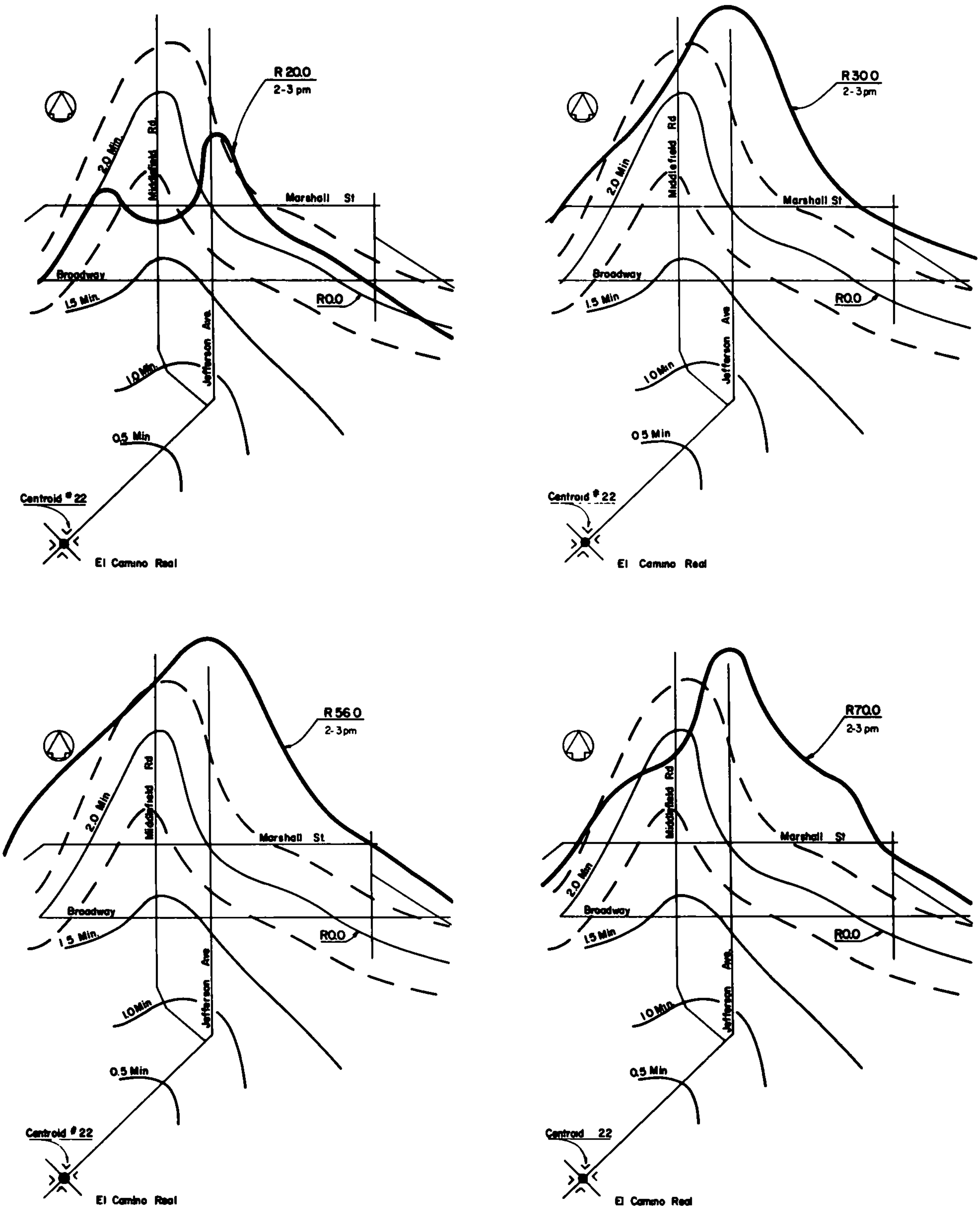


Figure B-6. Time contours—Redwood City. Times from Jefferson Street and El Camino Real. Major test stages compared with base condition for 2.0-min contour during time period 2-3 PM. *Dashed lines: 95 percent confidence limits for base condition—2.0-min contour.*

TABLE B-4

COUPLET ANALYSES: MIDDLEFIELD—JEFFERSON (FROM COMMON POINT OF INTERSECTION TO BRADFORD)

EFFECTIVENESS MEASURE	TEST STAGE NUMBER	STANDARD TIME PERIODS 7 30-8 30 a m (1)	12 30-1 30 p m (5)	2 00-3 00 p m (3)	4 30-5 30 p m (4)
Number of Stops	R20 0 R30 0 R56 0	8 00 7 63 7 19	8 94 8 10 8 89	8 74 8 59 9 58	9 83 9 70 8 77
Signal Delay	R20 0 R30 0 R56 0	72 58 69 88 64 36	77 88 69 80 80 56	91 54 61 73 86 65	87 80 95 93 118 26
Other Delays	R20 0 R30 0 R56 0	83 91 3 77	6 07 4 30 5 49	6 27 6 92 6 41	7 28 6 54 3 75
Travel Time	R20 0 R30 0 R56 0	4 98 4 64 4 60	5 20 4 89 5 36	5 42 4 80 5 16	5 86 5 52 5 29
Average Speed	R20 0 R30 0 R56 0	13 4 14 4 14 5	12 9 13 7 12 5	12 3 13 9 13 0	11 4 12 1 12 6

Results obtained from summing floating car data for both directions of both streets

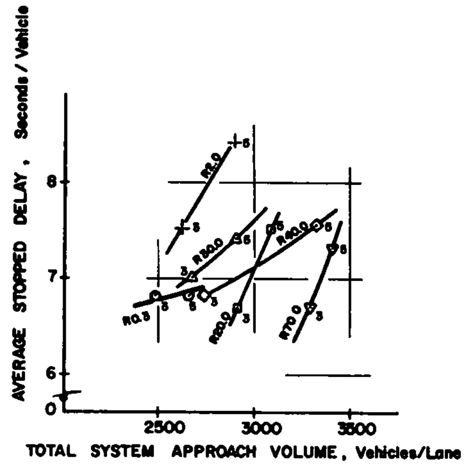


Figure B-8. Average stopped delay for 14 approaches to signalized Broadway intersections —off-peak periods. Stopped delay in each approach weighted in proportion to approach volume. Total system approach volume is sum of approach lane volumes.

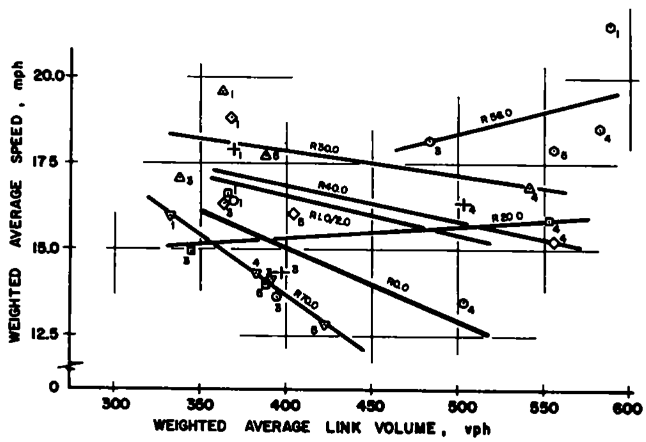


Figure B-9. Areawide weighted average speed for Broadway area.

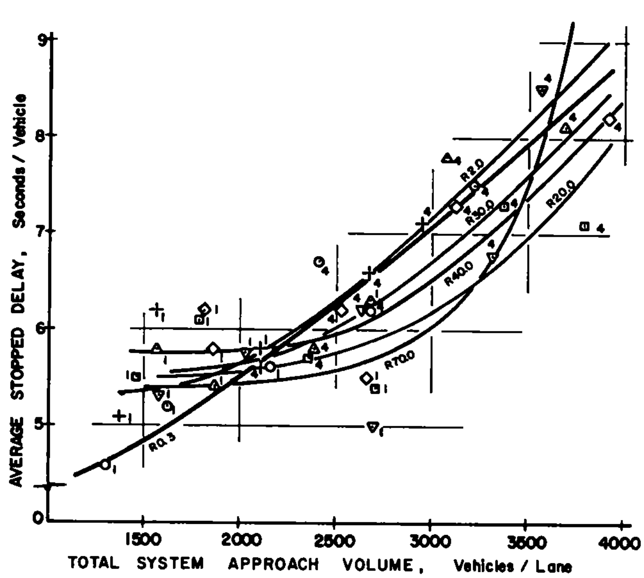


Figure B-7. Average stopped delay for 14 approaches to signalized Broadway intersections—peak periods only. Stopped delay for each approach weighted in proportion to approach volume. Total system approach volume is sum of approach lane volumes.

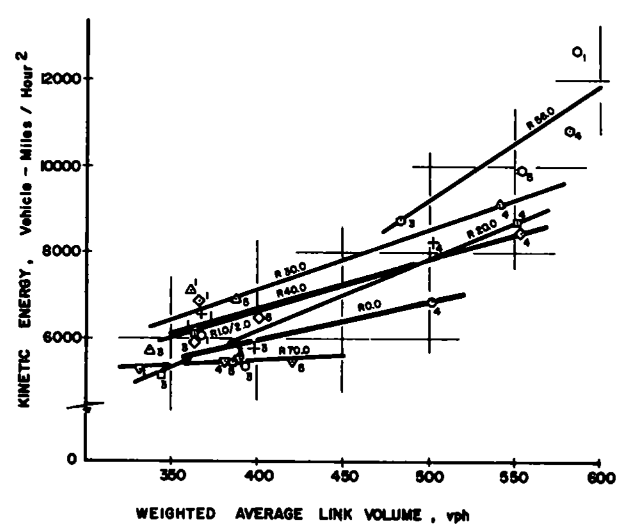


Figure B-10. Areawide kinetic energy for Broadway area.

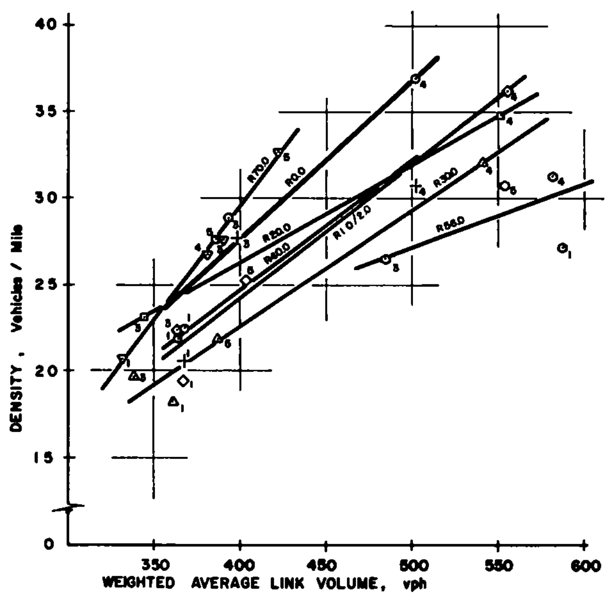


Figure B-11. Areawide density for Broadway area.

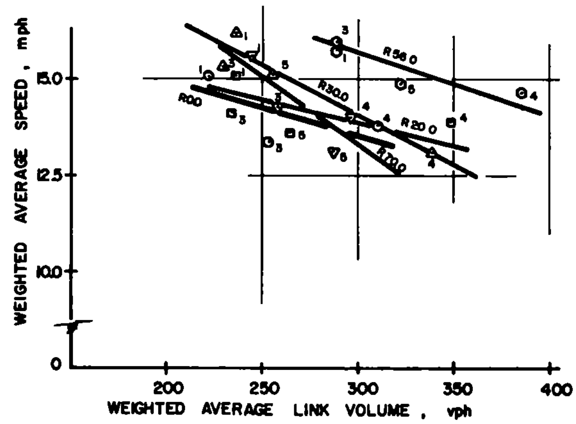


Figure B-13. Areawide weighted average speed for Redwood City core area.

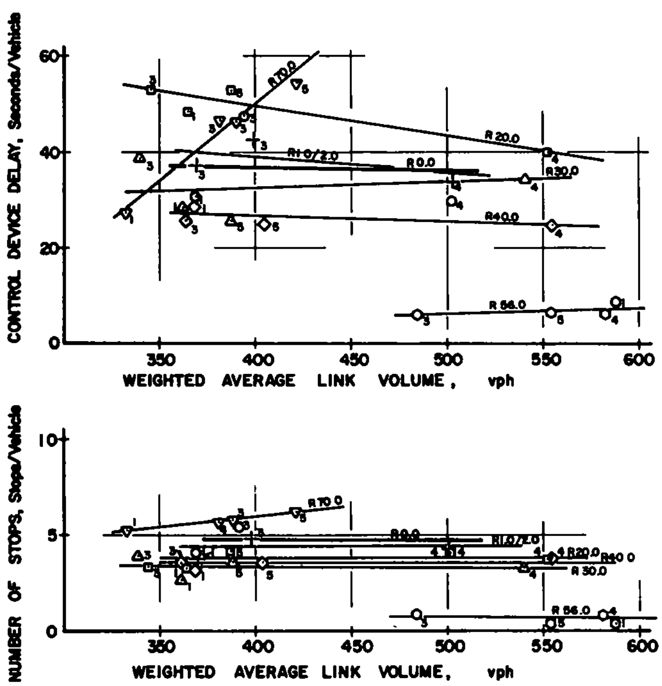


Figure B-12. Control device delay and number of stops for Broadway area. Data from floating-car studies.

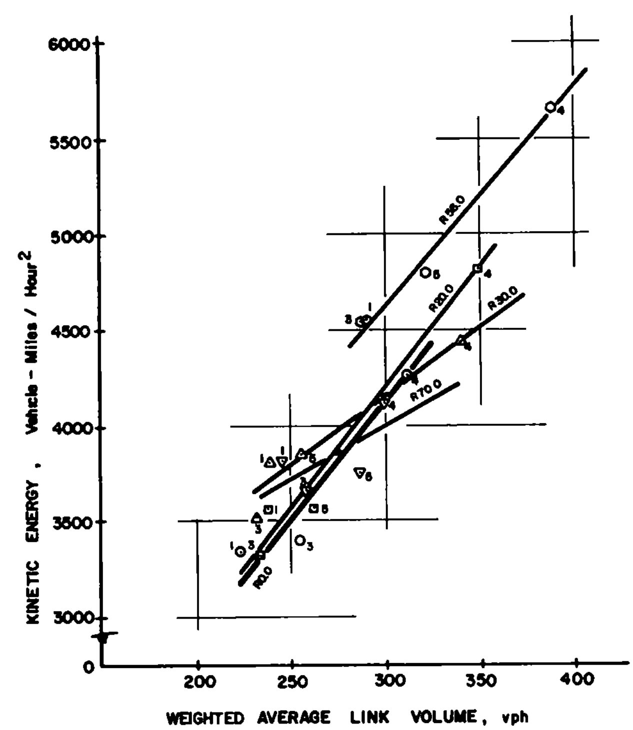


Figure B-14. Areawide kinetic energy for Redwood City core area.

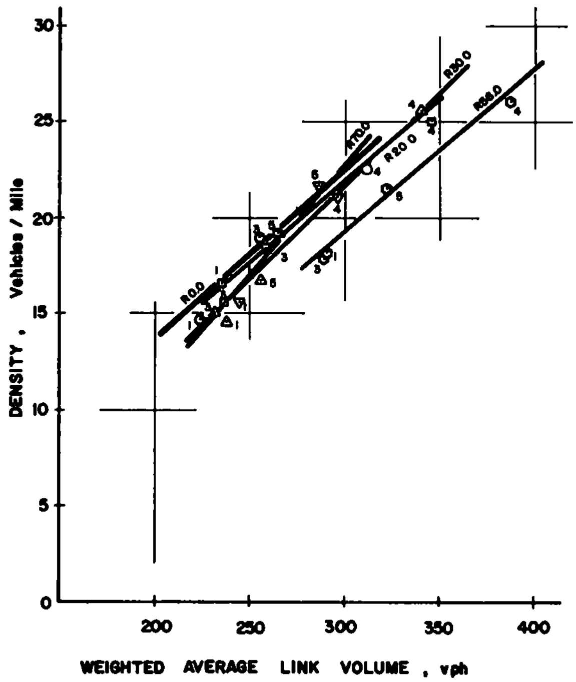


Figure B-15. Areawide density for Redwood City core area.

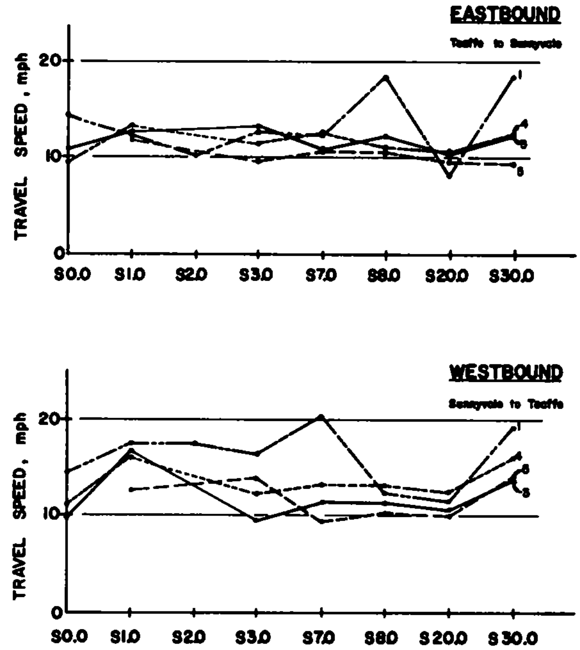


Figure B-17. Travel speeds on Washington Avenue by test stage and time period. Required change to be significant at 5-percent level: eastbound, 3.0 mph; westbound, 3.0 mph.

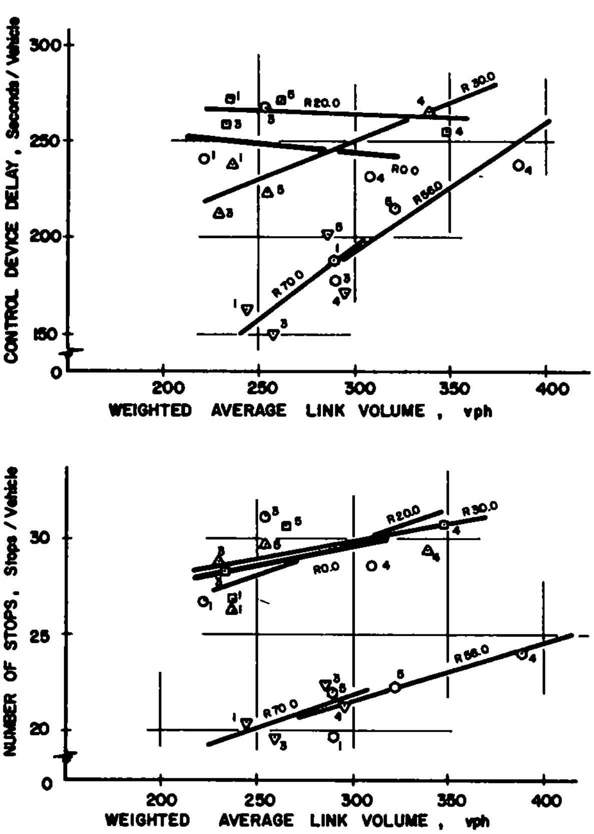


Figure B-16. Control device delay and number of stops in Redwood City core area. Data from floating-car studies.

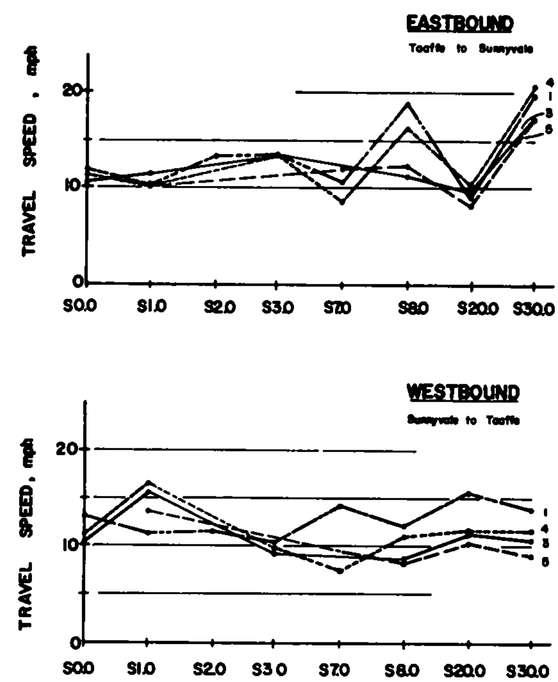


Figure B-18. Travel speeds on McKinley Avenue by test stage and time period. Required change to be significant at 5 percent level: eastbound, 2.5 mph; westbound, 2.5 mph.

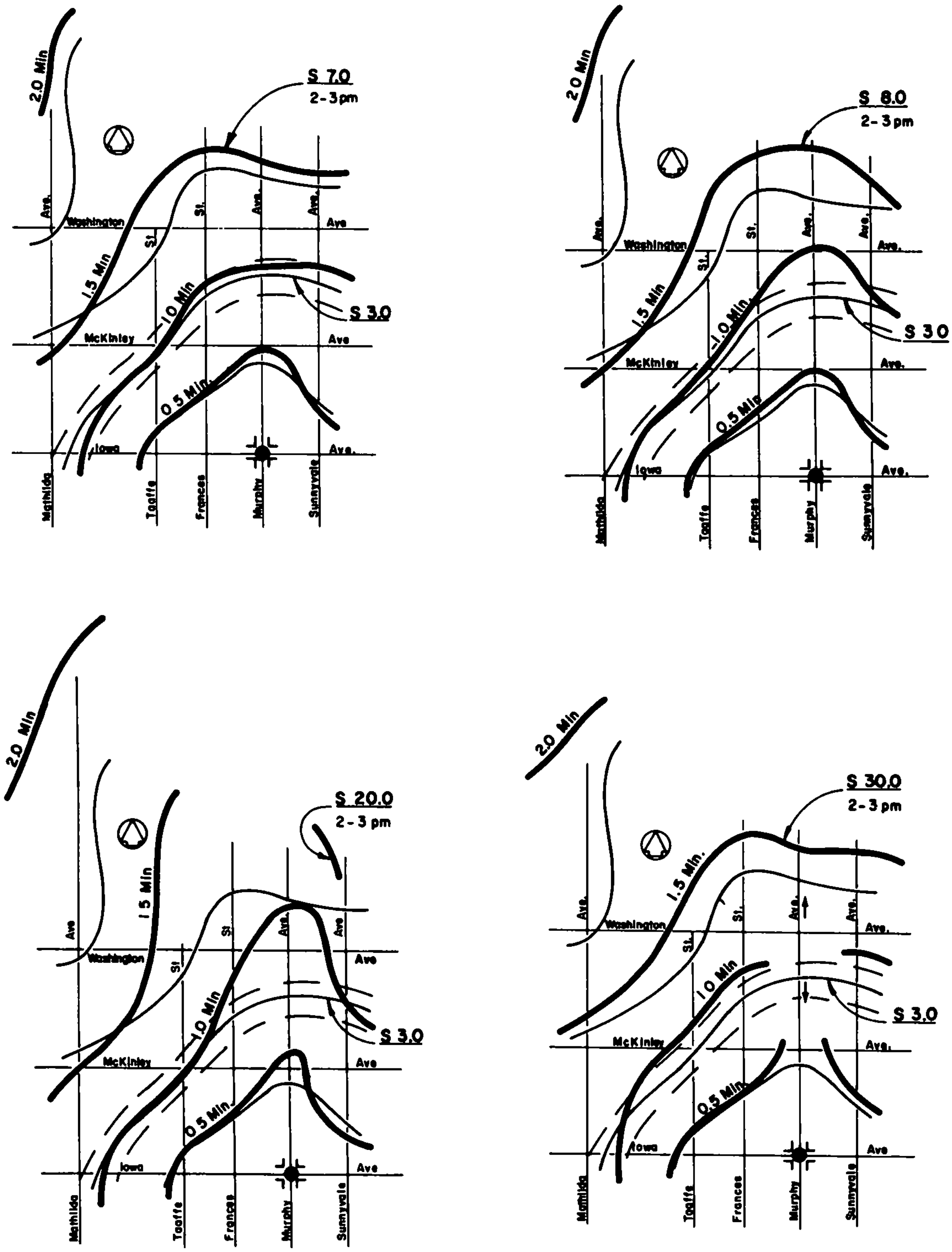


Figure B-19. Time contours—Sunnyvale. Times from Murphy Avenue and Iowa Avenue. Test stage compared with base conditions for 0.5-, 1.0-, 1.5-, and 2.0-min contours during time period 2-3 PM. Dashed lines: 95-percent confidence limits for base condition—1.0-min contour.

TABLE B-5

SUNNYVALE CBD MAJOR TRAFFIC VOLUMES

(VEHICLES PER HOUR)
(Adjusted for Daily and Seasonal Variation)

Time Period	Direction	FRANCES Base	FRANCES S20.0	FRANCES S30.0	SUNNYVALE Base	SUNNYVALE S20.0	SUNNYVALE S30.0	Direction	McKINLEY Base	McKINLEY S20.0	McKINLEY S30.0	WASHINGTON Base	WASHINGTON S20.0	WASHINGTON S30.0
1	NB	29	45	138	562	467	529	EB	89	59	58	117	220	103
	SB	20	26	29	135	99	111	WB	98	102	200	86	104	102
	Total	49	71	167	697	566	640	Total	187	161	258	203	324	205
5	NB	---	196	195	---	219	324	EB	---	261	221	---	204	123
	SB	---	216	220	---	250	216	WB	---	357	417	---	166	161
	Total	---	412	415	---	469	540	Total	---	618	638	---	370	284
3	NB	196	132	201	194	185	244	EB	374	301	205	185	190	161
	SB	316	187	183	245	191	188	WB	433	285	370	138	142	120
	Total	512	319	384	439	376	432	Total	806	586	575	323	332	281
4	NB	87	77	119	206	227	242	EB	304	278	266	208	290	178
	SB	222	186	241	361	380	360	WB	275	234	259	191	198	190
	Total	309	263	360	587	607	602	Total	579	512	525	399	488	368
24	NB	2036			2527			EB	3585			4450		
Hour	SB	1876			2444			WB	3237			2233		
Total	Total	3912			4971			Total	6822			6683		

TABLE B-6

COUPLET ANALYSES: WASHINGTON—McKINLEY (EASTBOUND FROM MATHILDA TO SUNNYVALE AND WESTBOUND FROM CARROLL TO TAAFFE)

EFFECTIVENESS MEASURE	TEST STAGE NUMBER	STANDARD TIME PERIODS 7 15-8 15 a m (1)	12 00-1 00 p m (5)	2 00-3 00 p m (3)	4 30-5 30 p m (4)
Number of Stops	S3 0	5 57	7 60	6 84	7 31
	S7 0	7 11	9 23	9 80	7 92
	S8 0	4 73	8 76	8 30	7 05
	S20 0	7 77	9 77	7 93	7 36
	S30 0	3 97	6 91	6 28	5 17
Signal Delay	S3 0	60 60	82 10	80 11	86 25
	S7 0	70 18	84 47	85 30	105 64
	S8 0	38 65	111 57	96 70	65 61
	S20 0	105 91	112 34	80 26	86.06
	S30 0	40 61	69 83	52 26	42.64
Other Delay	S3 0	0 00	4 80	7 63	9 58
	S7 0	0 00	12 58	5 77	7.63
	S8 0	1 13	5 00	3 10	2 82
	S20 0	0.00	7 32	1 94	2 94
	S30 0	0 16	0 33	2 00	0 45
Travel Time	S3 0	4 61	--	5.50	5 48
	S7 0	4 67	5 72	--	5 93
	S8 0	3 93	6 01	5 44	5.34
	S20 0	5 47	6 01	5 54	5 39
	S30 0	3 56	4 72	4 35	4 27
Average Speed	S3 0	13 66	--	11 45	11 49
	S7 0	13 49	11 01	--	10 62
	S8 0	16 03	10 48	11 58	11 79
	S20 0	11 51	10 48	11 56	11 69
	S30 0	17 69	13 34	14 48	14 75

Results obtained from summing floating car data for both directions of both streets

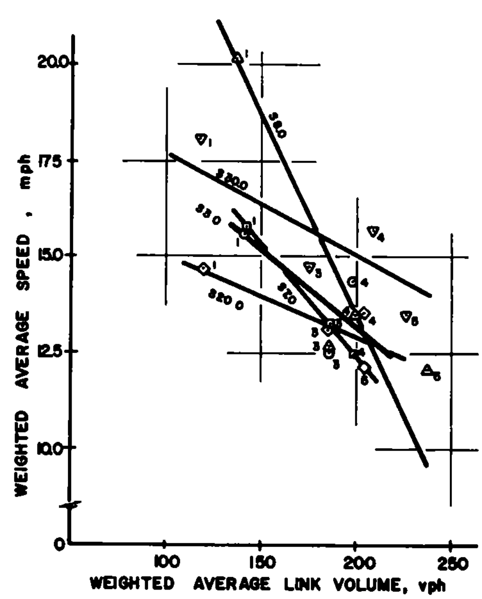


Figure B-20. Areawide weighted average speed for Sunnyvale core area.

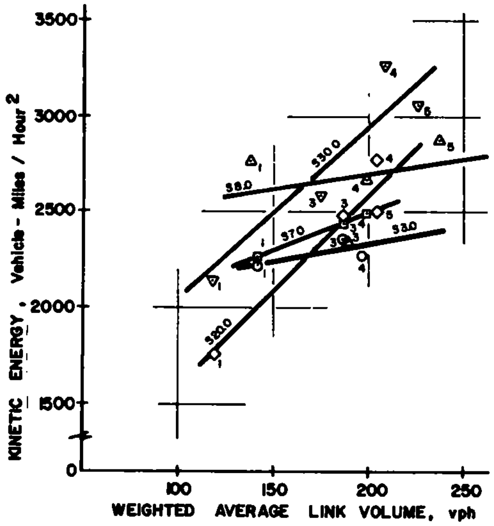


Figure B-21. Areawide kinetic energy for Sunnyvale core area.

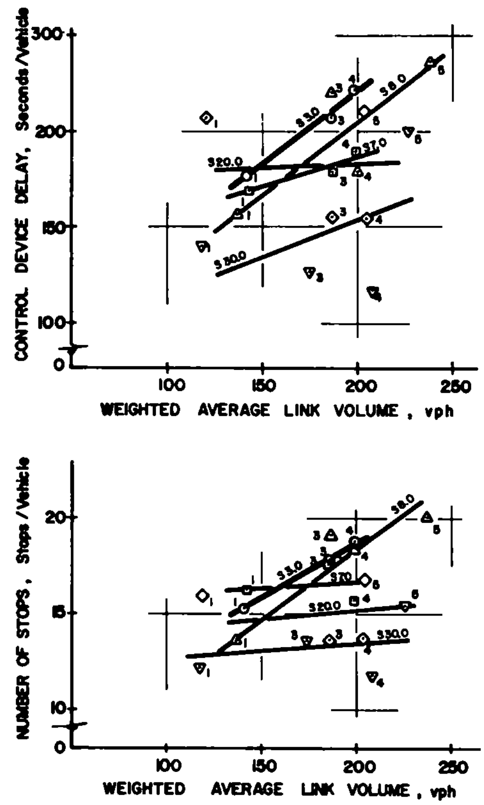


Figure B-23. Control device delay and number of stops for Sunnyvale core area. Data from floating-car studies.

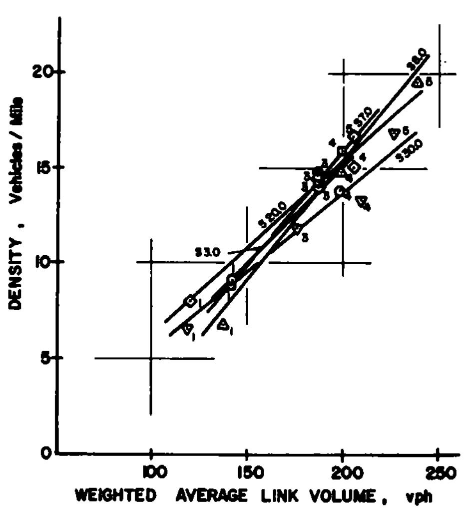


Figure B-22. Areawide density for Sunnyvale core area.

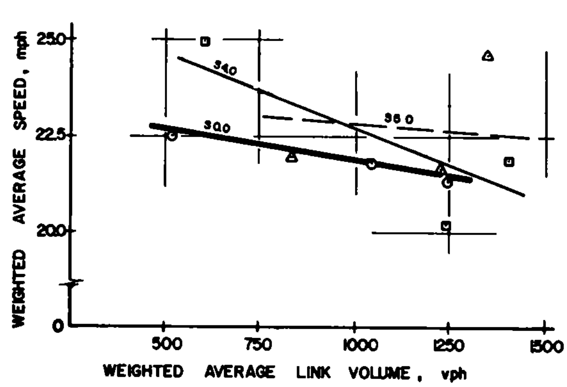


Figure B-24. Areawide weighted average speed for Mathilda area.

TABLE B-7

AVERAGE STOPPED DELAY PER VEHICLE, MATHILDA AVENUE SIGNALS

STANDARD TIME PERIOD	INTERSECTION DELAY, MATHILDA AND WASHINGTON (SEC)			COMBINED DELAY AT MCKINLEY AND WASHINGTON (SEC)					
				NORTHBOUND			SOUTHBOUND		
	S0.0	S4.0	S5.0	S0.0	S4.0	S5.0	S0.0	S4.0	S5.0
1	22.0	14.5	25.0	35.0	30.5	32.2	9.0	15.0	10.0
5	12.0	11.0	15.0	20.0	25.0	23.5	15.5	20.8	21.0
3	14.0	10.0	12.5	16.0	19.5	19.0	13.3	11.0	14.8
4	25.0	20.0	15.5	23.0	13.0	16.2	33.0	13.0	9.0

TABLE B-8

REDWOOD CITY ACCIDENT TRENDS

TIME PERIODS	NUMBER OF ACCIDENTS PER YEAR		
	CITYWIDE	APPROX. STUDY AREA	APPROX. CORE AREA
1962	1,487	—	—
1963	1,604	—	—
1964	1,786	380	—
Before test stages 4/1/65 to 4/1/66	1,539	275	78
Before test stages 4/26/66 to 4/26/67	—	357[a]	82[a]
Test stage period 4/26/67 to 7/26/68	—	317[a]	62[a]

[a] Annual accidents projected from a 9-mo. period from Apr. 26 to July 24

TABLE B-9

SUNNYVALE ACCIDENT TRENDS

CALENDAR YEAR	STUDY-AREA ACCIDENTS		
	INTERSECTION	MIDBLOCK	TOTAL
1962	65	53	118
1963	29	71	100
1964	33	119	152
1965	40	79	119
1966	45	78	123
Average	42	80	122

TABLE B-10

SUNNYVALE ACCIDENT SUMMARY

TIME PERIOD	CORE-AREA ACCIDENTS		
	INTER-SECTION	MIDBLOCK	TOTAL
Signal timing stages 2/8/67 to 11/10/67	53	24	77
Previous year 2/8/66 to 11/10/66	49	35	84
Street closure stages 11/11/67 to 1/19/68	12	9	21
Previous year 11/11/66 to 1/19/67	11	9	20

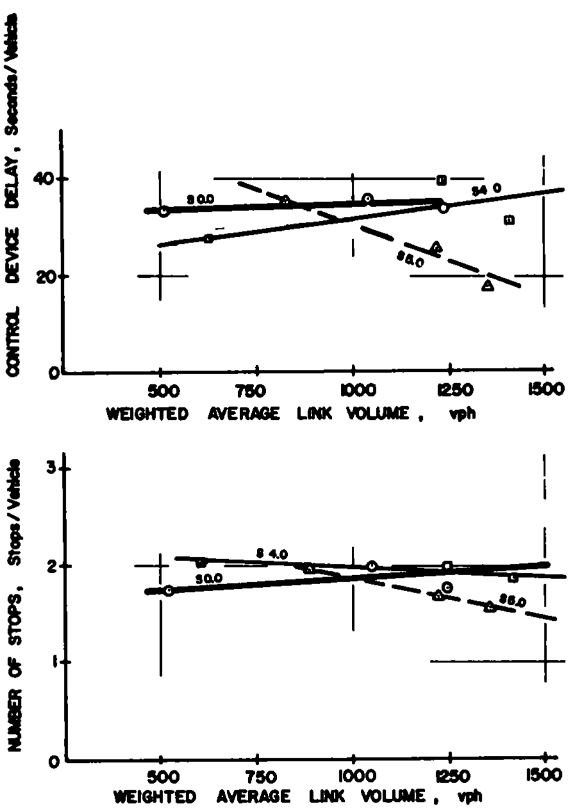


Figure B-25. Control device delay and number of stops for Mathilda area. Data from floating-car studies.

rose in the 1966-1967 period but did not reach the level existing before the Expressway was opened.

Accidents in the Sunnyvale study area have been averaging 122 per year, as given in Table B-9.

Comparisons of core-area accidents for test stage periods with periods 1 year previous indicate no significant change. Table B-10 gives the record.

More detailed summaries of test city accidents, by type and location during the test stages and the same periods of previous years are given in Tables B-11 and B-12 for Redwood City and Tables B-13 and B-14 for Sunnyvale.

BUSINESS PERFORMANCE

The main emphasis on retail sales analysis was in Redwood City where the greatest response was received. Table B-15 gives the participating store categories. These stores represent 8 percent of the total number of business establishments in the CBD.

Table B-16 gives the performance of general merchandise and apparel stores for the city as a whole and for San Mateo County.

Figures B-26, B-27, and B-28 show weekly retail sales factor differences in Redwood City for participating stores. Figure B-29 compares the retail sales factors from the last two weeks of the test stages. Figures B-30, B-31, and B-32 show the weekly retail sales factors from three Sunnyvale businesses.

PUBLIC OPINION

The substantiating data for the findings regarding public opinion are presented as follows for each city.

Table B-17 gives the response level to the three Redwood City questionnaires.

Table B-18 gives the reaction of the public in Redwood City to the test stages as inferred from their comments. The acceptability of the operations on six downtown streets is given in Table B-19. Tables B-20 and B-21 indicate awareness of frequent drivers to regulations existing during test stages R40.0 and R70.0, respectively. Tables B-22 and B-23 give the judgment of frequent drivers regarding operational performance on streets and intersections, respectively.

The response level for the two Sunnyvale questionnaires is given in Table B-24. Tables B-25 and B-26 give the public acceptance index for the closing of Taaffe Street and the closing of Murphy Avenue, respectively. Table B-27 indicates the awareness of frequent drivers to regulations existing during test stage S20.0, and Table B-28 gives the judgment measures for Washington in stage S30.0.

Figure B-33 summarizes the acceptability of test stages in both cities. Opinions from drivers who were both frequent and infrequent travelers in the CBD's of the test cities were used for this figure. The results show that stage R56.0 with one-way and unbalanced flow, was least

TABLE B-11

REDWOOD CITY CORE AREA ACCIDENTS—INTERSECTIONS

		Test Stage and Comparable Period for Two Previous Years																							
		R1.0			R2.0			R20.0			R30.0			R40 0			R0.5			R56.0			R70 0		
STREET(S)	ACCIDENT TYPE	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67	'66	'66-7	'67-8	'66	'67	'68	'66	'67	'68
BROADWAY																									
Signalized Hamilton, Middlefield Jefferson, and Main	Right Angle		2					1	1	1			1		1	1	2	1	3	3	2	4	1	3	
	Rear End							1																	
	Left Turn		1			1								1				2			1	2	1	1	
	Right Turn															1								1	
	Side Swipe																					2			
	Pedestrian												1						2						
Non-Signalized Arguello, Winslow, Walnut, and Spring	Right Angle	1	1	1		1			1						1				1		1			1	
	Rear End										1			1	1				1	1					
	Right Turn			1																					
	Side Swipe																					3			
	Pedestrian	1																							
MARSHALL																									
Signalized Main	Right Angle														1			1						2	
	Left Turn																1					1			
Non-Signalized Arguello, Warren, Winslow, Hamilton, Middlefield, Jefferson, and Walnut	Right Angle							1			1						3		1						2
	Left Turn																1						1		
	Side Swipe																1					1			
OTHER																									
Walnut at Spring	Right Angle																						1		
	Subtotal Intersections	2	4	2	0	2	0	3	2	1	2	0	2	2	4	2	8	4	8	4	4	13	4	8	2

TABLE B-12

REDWOOD CITY CORE AREA ACCIDENTS—MIDBLOCK

Test Stage and Comparable Period for Two Previous Years

STREET(S)	ACCIDENT TYPE	R1.0 '65	R1.0 '66	R1.0 '67	R2.0 '65	R2.0 '66	R2.0 '67	R20.0 '65	R20.0 '66	R20.0 '67	R30.0 '65	R30.0 '66	R30.0 '67	R40.0 '65	R40.0 '66	R40.0 '67	R0.5 '66	R0.5 '66-7	R0.5 '67-8	R56.0 '66	R56.0 '67	R56.0 '68	R70.0 '66	R70.0 '67	R70.0 '68
Winslow and Hamilton	Parking				1						1	1					1	2		1				2	1
	Other (Fixed Object)																1								
Middlefield and Jefferson	Parking		2	1				1			2						1	1							
	Rear End		1																1						
	Side Swipe																	1							
	Other (Right Angle)																					1			
Broadway	Parking	1	2	2	1	1	1	1	1	2	2	2		1	1		6	6	2	5	2		4	2	
	Rear End																	3	1			1			
	Side Swipe			1						1													1	1	
	Other (Right Turn)																				1				
	(Pedestrian)																							1	
Marshall	Parking										1						1		1						
	Rear End																1								
Arguello, Walnut, and Spring	Parking											1													
	Side Swipe																		1						
	Subtotal Midblock	1	5	4	2	1	1	2	1	3	6	4	0	1	1	0	11	13	6	6	3	2	5	6	1
	Subtotal Intersections	2	4	2	0	2	0	3	2	1	2	0	2	2	4	2	8	4	8	4	4	13	4	8	2
	Total	3	9	6	2	3	1	5	3	4	8	4	2	3	5	2	19	17	14	10	7	15	9	14	3

TABLE B-13

SUNNYVALE ACCIDENT SUMMARY (TEST STAGE PERIODS COMPARED WITH SAME PERIOD OF PREVIOUS OR NEAREST COMPARABLE YEAR)

LOCATION	ACCIDENT TYPE	INTERSECTION					
		Signal Stages S1 0 thru S8 0		S20 0		S30 0	
		'67	'66	'67/'68	'66/'67	'68	'65
Problem Area 1 EVELYN	Right Angle	4	3			2	1
	Rear End	4	2	1	1		1
	Left Turn	5	5		1		1
	Right Turn		1				
	Sideswipe	3	1	1			
	Pedestrian		3				
Problem Area 2 CORE AREA	Right Angle	9	13		2	1	1
	Rear End	4	2	1	2		
	Left Turn		1	1			
	Right Turn						
	Sideswipe	2					1
	Pedestrian	1		1		1	
Problem Area 3 MATHILDA	Right Angle	10	3	5			
	Rear End	6	3			1	3
	Left Turn	1	1		2	1	
	Right Turn						
	Sideswipe	1	2				1
	Pedestrian		1				
TOTAL		50	41	10	8	6	9

TABLE B-14

SUNNYVALE ACCIDENT SUMMARY (TEST STAGE PERIODS COMPARED WITH SAME PERIOD OF PREVIOUS OR NEAREST COMPARABLE YEAR)

LOCATION	ACCIDENT TYPE	MIDBLOCK					
		Signal Stages S1 0 thru S8 0		S20 0		S30 0	
		'67	'66	'67/'68	'66/'67	'68	'65
Problem Area 1 EVELYN	Parking			1	1		
	Rear End						
	Sideswipe						
	Fixed Object	1					
	Pedestrian						
	Right Angle (driveways)						
Problem Area 2 CORE AREA	Parking	11	10	2	2		1
	Rear End	2	2		1		
	Sideswipe	1				1	
	Fixed Object	1	3				
	Pedestrian				1	1	
	Right Angle (driveways)		2	1	1	1	2
Problem Area 3 MATHILDA	Parking						
	Rear End						
	Sideswipe						
	Fixed Object	1*	2*	1*	1*		
	Pedestrian						
	Right Angle (driveways)					1	
TOTAL		17	19	5	7	4	3

*Occurred at intersections

TABLE B-15

PARTICIPATING STORE CATEGORIES

STORE TYPE	NUMBER OF REPLIES: NORTH SIDE	SOUTH SIDE	TOTAL
General merchandise	—	3	3
Apparel	2	2	4
Drugs	—	1	1
Appliances	1	—	1
Other	—	1	1
Total	3	7	10

TABLE B-16

QUARTERLY SALES PERFORMANCE—REDWOOD CITY AND SAN MATEO COUNTY

	PERCENT CHANGE OF CITY AND COUNTY SALES (THIRD QUARTER 1966 AS BASE)					
	THIRD QUARTER 1967		FOURTH QUARTER 1967		FIRST QUARTER 1968	
STORE TYPE	CITY	COUNTY	CITY	COUNTY	CITY	COUNTY
General merchandise	−1.5	+6.7	+5.0	+7 4	+0.6	+3.6
Apparel	+15.9	+11.2	+15.6	+14 3	−2.3	+6.2
Combined	+4 0	+7.9	+8.5	+9.2	−0.3	+4 3

opposed in Redwood City, and stage S20.0, with Taaffe Street closed, was least opposed in Sunnyvale.

USER AND TEST STAGE IMPLEMENTATION COST

The user costs for the test stages in both test cities were based on vehicle operating cost and user time cost. Values of $0.07779 per vehicle-mile and $1.55 per vehicle-hour were used in the determination.

Values of user cost for the test stages in Redwood City and Sunnyvale are shown in Figures B-34 and B-35, respectively

Costs for implementing each major test stage were calculated from data supplied by the traffic engineer of Red-

TABLE B-17

RESPONSE LEVEL—REDWOOD CITY

	PERCENTAGE OF RETURNS		
PUBLIC	R40 0	R56 0	R70.0
Merchants	Not surveyed	53.4	40.3
Nonmerchants	26 4	22.8	23.0

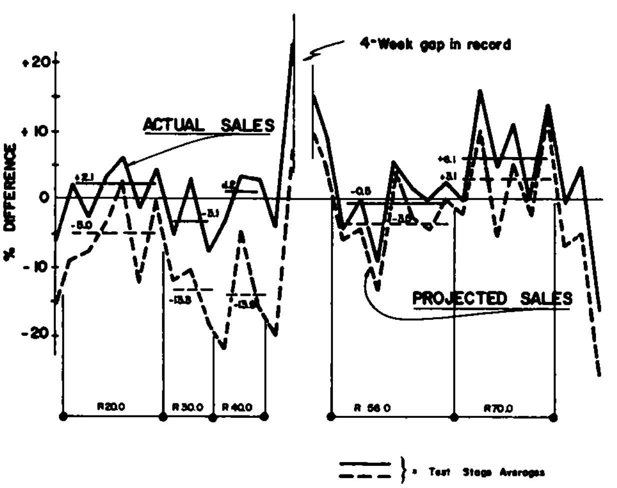


Figure B-26. Weekly retail sales factors—Redwood City, all participating stores. Differences between actual sales during test stage periods and (1) actual sales for corresponding weeks of previous year, (2) projected sales for same weeks of test stage period.

TABLE B-18

PUBLIC REACTION—REDWOOD CITY

		PERCENTAGE EXPRESSING[a]			
STAGE	PUBLIC	SUPPORT	OPPOSITION	APATHY	OTHERS[a]
R40 0	Merchants	7 5	45.5	38.5	8.5
	Nonmerchants	8 7	31 9	30 5	28.9
R56.0	Merchants	23.0	32.0	45.0	0 0
	Nonmerchants	27.0	45.0	28.0	0.0
R70 0	Merchants	0.0	65.5	11.5	23.0
	Nonmerchants	3 5	67.5	7.0	22.0

[a] Others include those who were neither favorable nor unfavorable, both favorable and unfavorable, or who offered other suggestions

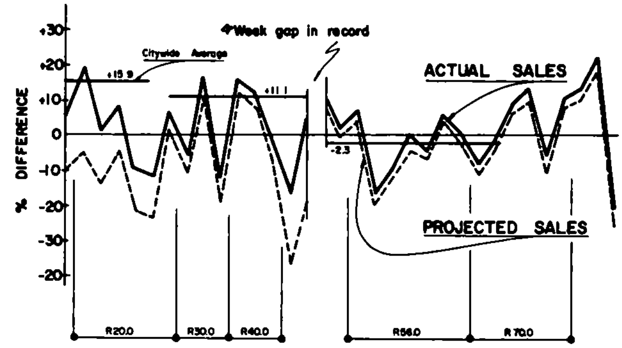


Figure B-27. Weekly retail sales factors—Redwood City, one store outside CBD core area. Differences between actual sales during test stage periods and (1) actual sales for corresponding weeks of previous year, (2) projected sales for same weeks of test stage period.

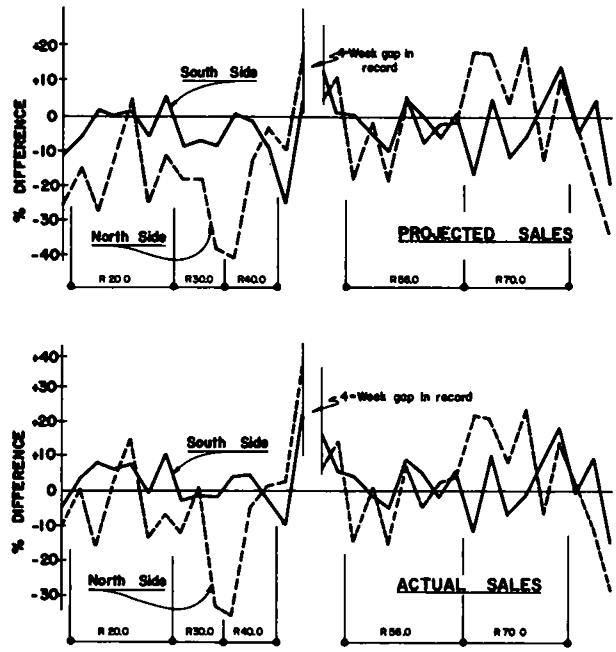


Figure B-28. Weekly retail sales factors—Redwood City, north and south side participating stores. Differences between actual sales during test stage periods and (1) actual sales for corresponding weeks of previous year, (2) projected sales for same weeks of test stage period.

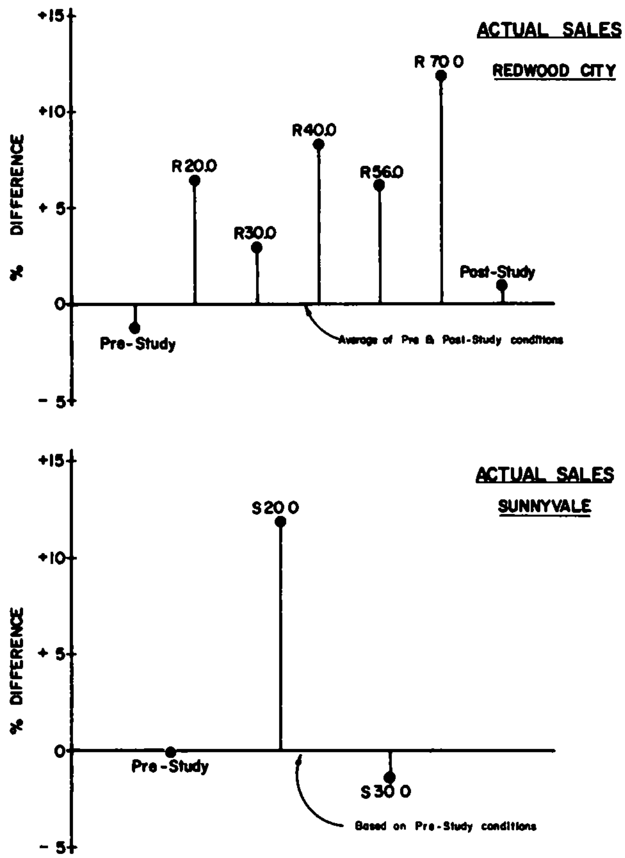


Figure B-29. Retail sales factors—relative test stage comparisons. Average of last two weeks of each test stage.

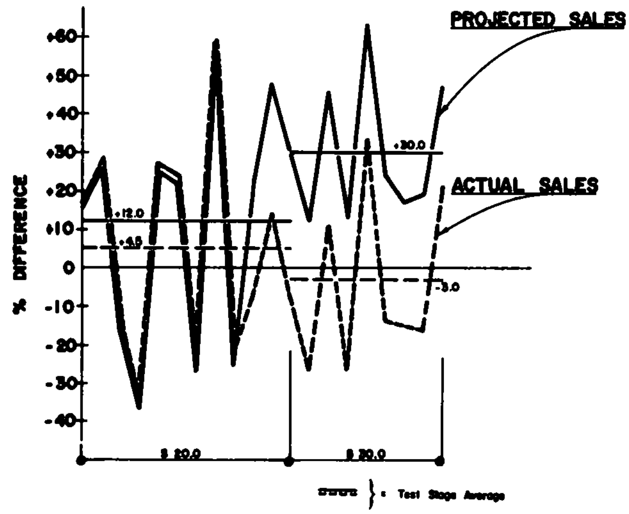


Figure B-30. Weekly retail sales factor—Sunnyvale, one apparel store. Differences between actual sales during test stage periods and (1) actual sales for corresponding weeks of previous year, (2) projected sales for same weeks of test stage period.

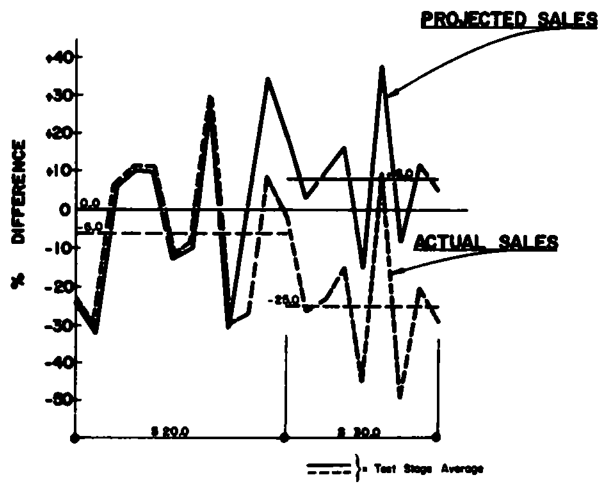


Figure B-31. Weekly retail sales factors—Sunnyvale, another apparel store. Differences between actual sales during test stage periods and (1) actual sales for corresponding weeks of previous year, (2) projected sales for same weeks of test stage period.

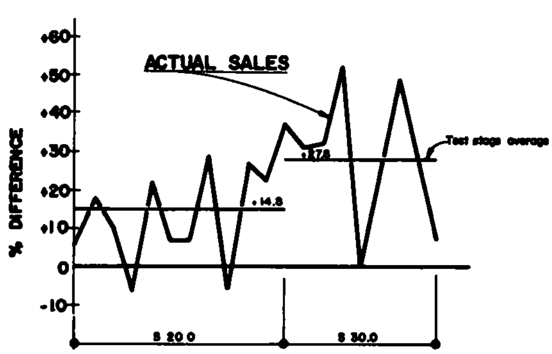


Figure B-32. Weekly retail sales factors—Sunnyvale, a tavern. Differences between actual sales during test stage periods and actual sales for corresponding weeks of previous year.

TABLE B-19

PUBLIC ACCEPTANCE INDEX FOR FREQUENT SHOPPERS, STAGE R70.0

	PUBLIC ACCEPTANCE INDEX					
PUBLIC	BROADWAY	MAIN	JEFFERSON	MIDDLE-FIELD	HAMILTON	WINSLOW
Merchants	−0.62	−0.13	−0.23	−0.40	−0.29	−0.29
Nonmerchants	−0.63	−0.31	−0.40	−0 41	−0.28	−0.33

TABLE B-20

PUBLIC AWARENESS, STAGE R40.0

	PERCENTAGE GIVING ANSWERS REGARDING REGULATIONS					
	LEFT-TURN REGULATIONS			PARKING REGULATIONS		
PUBLIC	CORRECT	IN-CORRECT	NO ANSWER	CORRECT	IN-CORRECT	NO ANSWER
Merchants	100.0	0.0	0.0	69.2	15 4	15 4
Nonmerchants	96.8	2.7	0.5	60 0	16 8	23.2

TABLE B-21

PUBLIC AWARENESS, STAGE R70.0

	PERCENTAGE GIVING CORRECT ANSWERS REGARDING REGULATIONS ON:							
PUBLIC	BROAD-WAY	MAR-SHALL	MIDDLE-FIELD	JEF-FERSON	HAMIL-TON	MAIN	WINS-LOW	ARGUELLO
Merchants	97.0	11.0	22.5	83.8	97.0	30.5	27 5	19.5
Nonmerchants	89.5	22.0	33.0	90.0	91.0	21.0	27.0	7 5

TABLE B-22

SOUND JUDGMENT MEASURES FOR TRAFFIC CONDITIONS ON STREETS

	SOUND JUDGMENT MEASURES (%)					
	R40 0	R56 0		R70.0		
PUBLIC	BROADWAY	BROADWAY	MARSHALL	BROADWAY	MARSHALL	JEFFERSON
Merchants	60.6	65 4	66.1	80.9	59.0	63.5
Nonmerchants	63.3	70.7	59.2	85.8	54.3	63.2

TABLE B-23

SOUND JUDGMENT MEASURES FOR TRAFFIC CONDITIONS AT INTERSECTIONS, STAGE R56.0

	SOUND JUDGMENT MEASURES (%)	
PUBLIC	MARSHALL/ JEFFERSON	MIDDLEFIELD/ JEFFERSON
Merchants	72.8	71.4
Nonmerchants	74.0	70.9

TABLE B-24

RESPONSE LEVEL—SUNNYVALE

	PERCENTAGE OF RETURNS	
PUBLIC	S20.0	S30.0
Merchants	50.0	28.0
Nonmerchants	13.8	9.3

TABLE B-25

PUBLIC ACCEPTANCE INDEX TO CLOSURE OF TAAFFE STREET, STAGE S20.0

PUBLIC	PUBLIC ACCEPTANCE INDEX FOR ACCEPTABILITY OF: TRAFFIC CONDITIONS	PARKING FACILITIES	SHOPPING ATTRACTIVENESS
Merchants	−0.22	−0.43	−0.08
Nonmerchants	+0.20	−0.36	+0.48

TABLE B-26

PUBLIC ACCEPTANCE INDEX FOR DE-EMPHASIS OF MURPHY AVENUE, STAGE S30.0

PUBLIC	PUBLIC ACCEPTANCE INDEX FOR ACCEPTABILITY OF: TRAFFIC CONDITIONS	PARKING FACILITIES	SHOPPING ATTRACTIVENESS
Merchants	−0 22	−0.22	−0 22
Nonmerchants	−0.14	+0.06	−0.34

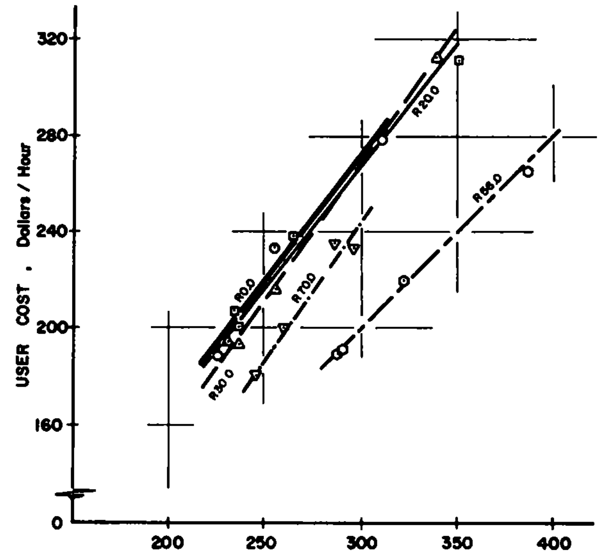


Figure B-34. User cost for Redwood City test stages. Includes vehicle operating cost and user time cost.

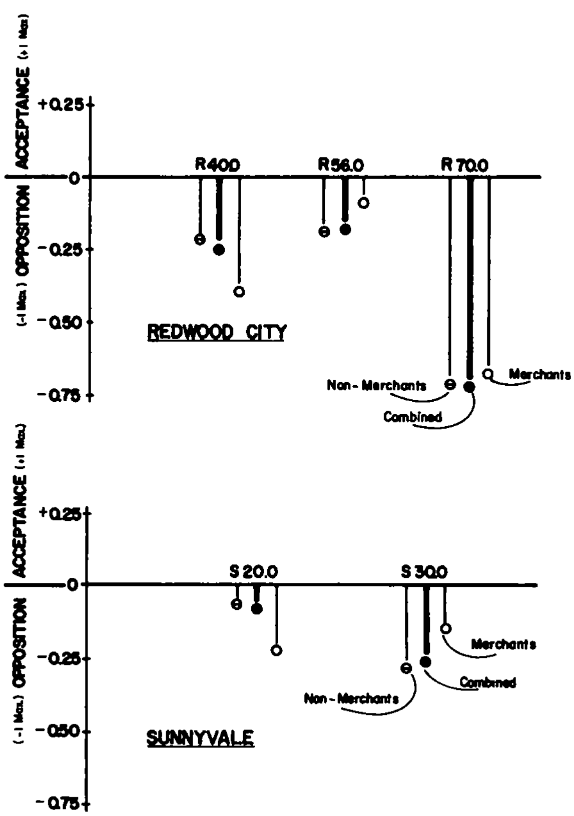


Figure B-33. Public acceptance index (PAI) for test stages as a whole. Frequent and infrequent drivers range: −1.00 <PAI <+1.00.

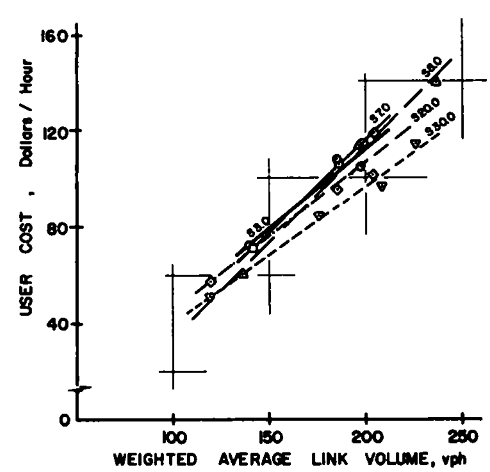


Figure B-35. User cost for Sunnyvale test stages. Includes vehicle operating cost and user time cost.

TABLE B-27

PUBLIC AWARENESS, STAGE S20 0

PUBLIC	PERCENTAGE GIVING ANSWERS REGARDING REGULATIONS: LEFT-TURN REGULATIONS: CORRECT	LEFT-TURN: INCORRECT	LEFT-TURN: NO ANSWER	PARKING REGULATIONS: CORRECT	PARKING: INCORRECT	PARKING: PARTLY CORRECT	PARKING: NO ANSWER
Merchants	42.0	29.0	29.0	37.0	21.0	21.0	21.0
Nonmerchants	28.0	22.0	50.0	10 0	30.0	33.0	27.0

wood City and the Director of Public Works of Sunnyvale. Four elements of cost were used in the calculations: materials, labor, equipment rental, and engineering.

Material costs were used directly as supplied by the cities. Labor costs, as received, were calculated on two different bases. In Redwood City direct wage rates were used. In Sunnyvale a rate that included an amount for overhead was used. The rate used in Sunnyvale, $7.20/hr, was believed to be more representative of the total labor cost and was used in both cities.

Equipment rental costs were received from Sunnyvale but not from Redwood City. To get a value for Redwood City, the average percentage that equipment cost was of direct labor cost in Sunnyvale was used for Redwood City. This value was 12.4 percent.

Because the test stages were designed by the researchers rather than by personnel of the test cities, engineering costs from the cities were not available. It was believed that 50 percent of the implementation labor cost would be representative of the engineering cost. For the signal timing stages, however, there were no implementation labor costs An engineering cost for these stages was based on a man-hour estimate and a salary rate, including overhead, of $100 per day.

TABLE B-28

SOUND JUDGMENT MEASURES FOR WASHINGTON STREET, STAGE S30.0

PUBLIC	SOUND JUDGMENT MEASURES (%): EASTBOUND	WESTBOUND
Merchants	41.0	38.2
Nonmerchants	35.0	37.0

The costs for the major test stages are given in Table B-29. In each city some stages were implemented incrementally; that is, the techniques of one stage were carried over to a subsequent stage. The costs, however, were calculated as if each stage were implemented from the base condition.

The hourly costs were calculated assuming a 1-year life, no interest, and the implementation cost equal for all hours of the day.

TABLE B-29

IMPLEMENTATION COSTS

STAGE	COST ($): MATERIAL	LABOR	EQUIPMENT	ENGINEERING	TOTAL	COST/HR
			(*a*) Redwood City			
R20 0	475	335	41	167	1,019	0.1163
R30.0	771	655	81	328	1,835	0.2095
R40 0	695	1,019	126	509	2,349	0.2681
R56 0	1,271	3,199	396	1,599	6,464	0 7379
R70 0	614	2,644	327	1,322	4,907	0 5602
Total	3,826	7,852	971	3,925	16,574	N A.
			(*b*) Sunnyvale			
S7 0	nil	nil	nil	200	200	0 0228
S8.0	nil	nil	nil	700	700	0.0799
S20.0	374	1,067	108	533	2,082	0.2376
S30.0	1,426	4,435	526	2,218	8,605	0.9823
Total	1,800	5,502	634	3,651	11,587	N.A.

APPENDIX C
OTHER MEASURES

CURB PARKING AND TRAFFIC FLOW

A study was conducted to evaluate the effect of parallel parking on traffic flow with unmarked stalls, 24-ft stalls, tandem stalls (20 ft-20 ft-8 ft), and no parking. Washington Street and Murphy Avenue in Sunnyvale were selected as test sites for conducting the study.

The time a passenger car took in backing into a parking space in between two parked vehicles was recorded, as well as the time it took to complete the parking maneuver. In addition, the distance of the front and rear wheels of the parking vehicle from the curb was recorded. The time a vehicle took in backing into a parking space was considered the "flow obstruction time." The total time a vehicle took from the point it started backing up till it came to a stop was considered the "parking maneuver time."

Averages of flow obstruction time, parking maneuver time, and cumulative distance of wheels from the curb are given in Table C-1.

The data indicate that parking in unmarked stalls took considerably less time. For marked stalls, the tandem design appeared preferable.

It might be concluded that unmarked stalls are better than marked stalls in terms of time. It appears, however, that this improvement was made at the expense of curb parking capacity. The results are applicable only in an area where there is an abundance of off-street parking and the demand for curb space is considerably lower than the supply.

ENFORCEMENT AND STABILIZATION

Observance studies conducted during various test stages showed that driver obedience to traffic regulations was directly related to the level of enforcement.

Parking Regulations

Curb parking characteristics on McKinley and Washington Streets in Sunnyvale were observed at regular intervals during test stage S20.0, when no-parking regulations were in effect. One to four vehicles were illegally parked on each street during each observation interval, even though citations were issued to parking violators. The enforcement level was increased from 16 to 28 man-hr per week for on-street parking due to the new parking regulations in Sunnyvale. (At the same time, the enforcement level in the parking lots decreased from 24 to 12 man-hr per week.)

Similar observations were made on Broadway in Redwood City during the periods when towaway zones were in effect. These observations showed a high frequency of curb parking violations as long as only citations were issued to illegally parked vehicles. The frequency of illegal parking reached a minimum, however, when the towaway regulations were being strictly enforced. Lane distribution of traffic was studied during the operation of towaway lanes, and it was found that drivers tend to avoid towaway lanes, probably due to occasional illegally parking vehicles in this lane.

Left-Turn Prohibitions

The impact of enforcement on driver observance of the newly installed NO LEFT TURN signs on Broadway in Redwood City was found to be significant during the stabilization period of test stage R20.0. The heaviest Broadway left-turn volumes within the core area during the base condition existed at the following locations:

1. Eastbound at Arguello during the morning and evening rush hours.
2. Westbound at Jefferson Avenue during the morning and evening rush hours.

Figure C-1 shows left-turn volumes at the foregoing two locations during the four standard time periods in test stage R20.0. Table C-2 gives the number of citations issued to the left-turn violations during each day. The enforcement level had a significant impact on the eastbound left-turn violations when courtesy citations (warnings) started. It

TABLE C-1
PARALLEL PARKING STALL COMPARISONS—SUNNYVALE

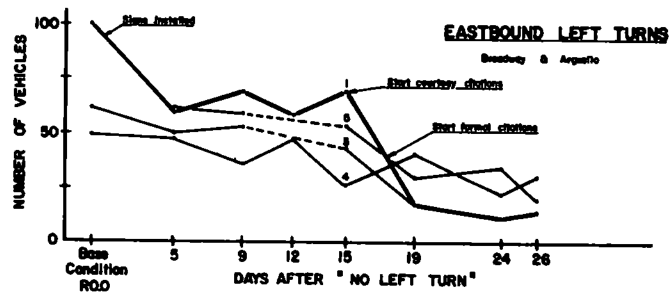
PARKING STALL PATTERN	EFFECTIVENESS MEASURE: FLOW OBSTRUCTION TIME (SEC)	PARKING MANEUVER TIME (SEC)	CUMULATIVE DISTANCE, CURB TO WHEELS (IN.)
Unmarked	4.9	12.9	14.8
Uniform (24 ft)	9.9	32.5	20.0
Tandem (20 ft-20 ft-8 ft)	11.0	20.7	21.6

TABLE C-2

CITATIONS ISSUED FOR LEFT-TURN VIOLATIONS—REDWOOD CITY

DATE AND DAYS FOLLOWING LEFT-TURN PROHIBITION	NUMBER OF CITATIONS ISSUED, BY TIME PERIODS		
	7-9 AM	9 AM-4 PM	4-6 PM
9/11/67 to 9/13/67	a	a	a
9/14/67 (18 days)	11	29	17
9/15/67 (19 days)	10	14	15
9/18/67 (22 days)	8	5	10
9/19/67 (23 days)	9	11	9
9/20/67 (24 days)	3	7	1
9/21/67 (25 days)	5	9	1

a Courtesy citations only



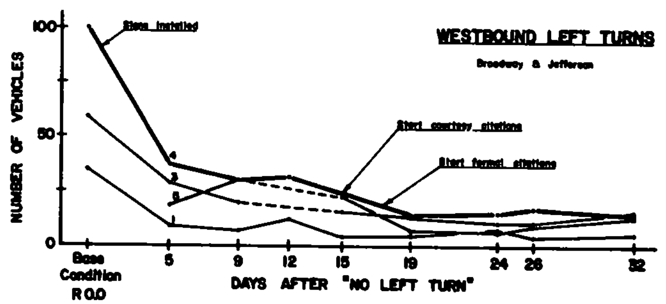


Figure C-1. Stabilization and observance of left-turn prohibitions.

can be seen, however, that the impact of enforcement on westbound left-turn violations was very small during the same week.

An examination of a map of Redwood City indicates that Marshall Street is readily available as an alternate route for westbound left-turning traffic; no such route was available for eastbound traffic. It was hypothesized, therefore, that there would be diversion for westbound traffic to Marshall Street during the time left turns were prohibited. A corresponding diversion for eastbound traffic was not expected.

Directional traffic volumes on Broadway and Marshall were studied during the stabilization period. On Broadway, there was a decrease in westbound volumes, but only a slight change in the eastbound approach volume. Westbound traffic volumes on Marshall Street were found to have increased significantly during test stage R20.0, as compared with base conditions, but this diversion occurred primarily at locations east of the signed diversion point.

APPENDIX D

DOCUMENTATION OF COMMUNITY ATTITUDES

The prospect of using Redwood City and Sunnyvale, California, as test sites for this project made headlines as a "$200,000 grant" toward the "best traffic-engineered central business district in the United States." City Council officials of both cities pledged their support and cooperation, and were pleased at the thought of their two communities being turned into "national showcases." Official city reaction to Sunnyvale's choice for the traffic study was "all smiles," stated the Sunnyvale *Standard-Register Leader:*

> "This is going to provide more publicity for Sunnyvale than we've ever had on any one single project," a beaming Mayor William Fernandez said. "This will help us solve many questions we've had about downtown traffic patterns."
>
> "Besides," he added, "I've often wondered what would happen if we tried one-way streets. . . ."

As the project was launched in Redwood City and Sunnyvale, vocal citizens were quick to express their opinions. Motorists, pedestrians, and merchants were noticeably discomforted with the deviation from normalcy; and from their dismay came the pressure on city officials.

The discouragement felt by City Council members was eventually expressed in terms of delays and halts in the traffic study. Study engineers were obliged to combine various test stages to complete the study, and the result was confusion. Motorists, once confused with alternate experimental routes within the city, became angry with compounded changes. The numerous, and sometimes complicated, changes in traffic patterns were major sources of irritation and resulted in an onslaught of angry "Letters to the Editor." Construction projects requiring detours were commenced without previous notice. The paint, especially mixed to block out street markings, failed to hide the old stripes, and both old and new lane markings were clearly visible. In Sunnyvale, a book containing data for the study was stolen, causing a significant delay in the study while more data were collected. Weather conditions often compounded the difficulties. Originally hailed as an outstanding opportunity, the project became linked with "controversial" for dubious readers, and was dubbed "Pneumatic Traffictitus" by one irate citizen.

All methods of communication were exploited to obtain public awareness, commitment, and support of the project. Newspapers, radio, and television cooperated fully in this effort. The media were particularly helpful in educating the public as to the purpose of the project, preparing them for its implementation, and advising them as to changes in traffic regulations. News releases were readily accepted; editorials supporting the study were run in primary space; and maps alerting motorists to the intricacies of the various test stages occupied, in some cases, the complete center folds of the newspapers.

To face the difficulties inherent in any traffic improvement project, support is required not only of city officials, but of the public most directly involved in the test stages. The success of the study, in terms of completeness and resulting from reliable and sophisticated techniques, depended entirely on the cooperation of those people involved. The support of some of the public did not waver. Others expressed, through individual voices or in groups, their change of attitude and adamant disapproval.

Documentation of the attitudes of city officials and local motorists, merchants, and pedestrians in Redwood City and Sunnyvale throughout the course of the study is included in this appendix.

APRIL-SEPTEMBER, 1966: During the proposal phase Redwood City and Sunnyvale expressed their interest and pledged cooperation through City Council resolutions, Chamber of Commerce endorsement, and letters of support. Grant to proceed with the study project was greeted with equal enthusiasm.

REDWOOD CITY

R E S O L U T I O N N O. 4990 4/11/66

RESOLUTION APPROVING AND ENDORSING THE PROPOSED NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM IN THE CITY OF REDWOOD CITY

WHEREAS, the Highway Research Board of the National Academy of Sciences, National Research Council, has proposed to conduct a study of traffic conditions in urban areas throughout the country and an evaluation of the solutions of their traffic problems; and

WHEREAS, the Traffic Research Corporation wishes to participate in the Highway Research Board's program and conduct a study in Redwood City as part of such program; and

WHEREAS, it is the desire of this Council that such a study be conducted here and to cooperate to our fullest in the program; and

WHEREAS, it is for the benefit of all of our citizens that such a study be made;

NOW, THEREFORE;

BE IT RESOLVED BY THE COUNCIL OF THE CITY OF REDWOOD CITY, AS FOLLOWS:

1. That this Council hereby expresses to both the Traffic Research Corporation and the Highway Research Board its full and complete approval of its conducting a segment of the National Cooperative Highway Research Program in the City of Redwood City.

2. That this Council hereby pledges the support and full assistance of the City staff and employees in cooperation with the Traffic Research Corporation in conducting field experiments

in traffic regulation and control proposed by the project consultants on a temporary basis.

3. That this Council hereby indicates its willingness to provide services through the City Public Works, Police, and other departments. These services will include:

(a) Erection and dismantling of temporary and permanent traffic signs and devices.

(b) Painting and paint removal of traffic stripes and curb markings.

(c) Placement of sand bags for temporary channelization.

(d) Setting out available automatic traffic counters.

(e) Special police enforcement and control.

In addition this Council indicates its willingness to provide materials, including:

(a) Paint for temporary and permanent traffic markings;

(b) Miscellaneous, on-hand signal and other equipment for temporary installation;

(c) New hardware for permanent installations;

and, indicates its assurance for specific legislation authorizing temporary alteration of stop signs, signals, one-way streets, speed limits, turning controls, and parking modifications.

* * *

I, Helen C. Moore, City Clerk of the City of Redwood City, do hereby certify that the above and foregoing resolution/ ~~ordinance~~ was duly and regularly passed and adopted by the City Council of the City of Redwood City at a regular meeting held by said Council on the 11th day of April, 1966, by the following vote:

AYES: Councilmen: Bury, Granger, Herkner, Petersen, Royer, Weymouth, and Mayor Rosselli

NOES: Councilmen: None

ABSENT: Councilmen: None

IN WITNESS WHEREOF, I have hereunto set my hand and affixed the Official Seal of said City this 13th day of April, 1966.

Helen C. Moore
CITY CLERK OF THE CITY OF
REDWOOD CITY

Seal

CITY OF REDWOOD CITY

SAN MATEO COUNTY
CALIFORNIA

Office of the City Manager April 19, 1966

Mr. Donald K. Goodrich
Senior Transportation Engineer
Traffic Research Corporation
228 Mc Allister Street
San Francisco, California

Dear Mr. Goodrich:

Attached are two certified copies of Resolution No. 4990 adopted by the City Council of Redwood City. This resolution expresses the complete cooperation and interest of the community as a participant in the proposed traffic study to be conducted under the auspices of the Highway Research Board.

The many projects now in their formative state in Redwood City will result in a doubling of our existing population during the next fifteen years. This rapid increase in area and population will produce a myriad of traffic problems, particularly in the area of our present downtown business district. In our opinion a traffic study such as is proposed will lay the groundwork for an orderly integration of our existing business community with the "new city" created by the Redwood Shores Project.

The City Council has directed me to assure you of their complete cooperation if Redwood City is selected as the subject of the traffic study. We have met with the Downtown Merchants' Retail Committee of the Chamber of Commerce and have their enthusiastic support of the project. As further evidence of community interest we inclose clippings from the Redwood City Tribune of April 11, and 12.

If we can furnish you with any additional information pleast permit us to do so.

Sincerely yours,

Howard C. Ullrich

HOWARD C. ULLRICH
City Manager

HCU:W
Inc.

CHAMBER OF COMMERCE
REDWOOD CITY, CALIFORNIA 94064

WORLD PORT
FOR THE SAN FRANCISCO PENINSULA AND SOUTH BAY
SAN MATEO COUNTY SEAT

Middlefield Road at Jefferson Avenue • EMerson 9-3705

April 20, 1966

Mr. Donald K. Goodrich
Senior Transportation Engineer
Traffic Research Corp.
228 McAllister St.
San Francisco, Calif.

Dear Mr. Goodrich:

Your proposed traffic study of Redwood City's central business district was enthusiastically endorsed by the Chamber of Commerce Retail Committee on April 19.

Present at the meeting were leading merchants, representing varied businesses in Redwood City, including the president of the Downtown Merchants Association who is manager of one of our key department stores.

The committee is hearty in its endorsement of your proposed study because it believes your new concept of traffic study - actual testing of proposed operational improvements right "in the field"- will be highly superior to the ordinary traffic engineering study and accomplish in two years that which would ordinarily take ten.

Our committee feels that this is a wonderful opportunity to solve many of our traffic problems, improve our downtown business district and accelerate its economy. We are confident that this is the feeling of the majority of the business people in the downtown area as traffic operation has long been one of our major problems.

In the event that Redwood City is chosen as the city in the Bay Area for your study, let us assure you that you will receive the fullest cooperation from our business community in addition to that of our City Administration and Chamber of Commerce.

Sincerely,

Paul A. Brunkow

Paul A. Brunkow
General Manager

PB/bm

CITY OF REDWOOD CITY
SAN MATEO COUNTY
CALIFORNIA

April 21, 1966

Mr. Donald K. Goodrich
Senior Traffic Engineer
Traffic Research Corporation
228 McAllister Street
San Francisco, California

Dear Mr. Goodrich:

At your request, at our Meeting in my office on April 20, 1966, I have outlined Redwood City's need for the Central Business District Traffic Study.

NEED FOR CENTRAL BUSINESS DISTRICT TRAFFIC STUDY

Redwood City's geometric layout of street, in the Central Business District was centered about the railroad station before the advent of the automobile; the extension of this geometric layout continues to funnel traffic through the central core to reach adjacent highways and industrial areas nearby.

Redwood City now has a distinct need for minimization of this through traffic and a maximization of pedestrian access to the various business establishments and governmental buildings within the C. B. D. This could be accomplished by an arterial system around the C. B. D. to serve through traffic as well as traffic destined for locations around the perimeter of the arterial system.

This system of streets, as determined by this study, may require the use of one-way streets where vehicular capacities of existing streets are insufficient. It may require removal of curb parking where one-way streets are not feasible.

Adjustment in the timing of signals or the addition of turn restrictions would be needed to improve the desirability of the route on the basis of travel time.

The attractiveness of the Central Business District can be strengthened by similar controls within the C. B. D. At present there are more accidents between intersections than at intersections on the major street in the C. B. D.

Time lost by the pedestrian and the driver in traversing the C. B. D. is an index to the congestion in the area which, in turn, has a detrimental monetary effect.

The geometric layout of streets in the C. B. D. and the immediate area about it can, with proper traffic controls, be adapted to the plan as outlined with a minimum of discomfort to both pedestrian and driver.

Yours very truly,

Arthur U. Eskelin
Traffic Engineer

AUE:kn

SUNNYVALE

RESOLUTION NO. 7471

RESOLUTION APPROVING CITY COOPERATION FOR A TRAFFIC RESEARCH PROJECT FOR THE SUNNYVALE CENTRAL BUSINESS DISTRICT BY HIGHWAY RESEARCH BOARD, NATIONAL ACADEMY OF SCIENCES - NATIONAL RESEARCH COUNCIL

WHEREAS, the Highway Research Board, National Academy of Sciences - National Research Council is about to engage in an experimental traffic engineering program to develop the best traffic engineering procedures for a central business district, preferably a city of over 50,000 population; and

WHEREAS, the City of Sunnyvale has a present population of over 85,000, with a projected population of over 100,000 by 1975; and

WHEREAS, the City of Sunnyvale has a unique location in that it is located approximately 45 miles south of the City of San Francisco, and has six main highways or freeways passing through its city limits throughout various points; and

WHEREAS, the City of Sunnyvale is presently engaged in the revitalization of its central business district, and has obtained the services of Victor Gruen Associates to prepare a planning and traffic study of the downtown area; and

WHEREAS, a timely complete traffic engineering study as proposed by the Highway Research Board in conjunction with the present planning study now under way will increase to maximum the operational efficiency of the city streets which serve the downtown area; and

WHEREAS, the City Council of the City of Sunnyvale is highly desirous that the Highway Research Board, National Academy of Sciences - National Research Council, select the City of Sunnyvale for its traffic research project for the central business district;

NOW, THEREFORE, BE IT RESOLVED that should the Highway Research Board, National Academy of Sciences - National Research Council, select the City of Sunnyvale as the city in which to conduct a study for its traffic research project, the City of Sunnyvale will give to the Board and its consultants its full and wholehearted support and cooperation.

That the City of Sunnyvale is willing to frequently experiment with the newest and best traffic ideas and operations proposed by the project consultants on a temporary basis including but not limited to the following:

(1) Erection and dismantling of temporary and permanent traffic signs and devices;

(2) Painting and paint removal of traffic stripes and curb markings;

(3) Placement of sand bags for temporary channelization;

(4) Setting out available automatic traffic counters;

(5) Paint for temporary and permanent traffic markings;

(6) Miscellaneous, on-hand signal and other equipment for temporary installation; and

(7) New hardware for permanent installations.

That the various departments of the administration of the City of Sunnyvale, including the Department of Public Safety, which department has control over the level of traffic law enforcement, will give their full cooperation to the Board and its consultants in the furtherance of the traffic study.

That in addition to the support of its various departments and officers, the City will give whatever financial support is necessary to the Board for the physical changes and modifications proposed in furtherance of its study.

PASSED AND ADOPTED by the City Council of the City of Sunnyvale at a regular meeting held on the 12th day of April, 1966, by the following called vote:

AYES: Councilmen: Fernandez, Hayden, Koreski, Logan, McDaniel and Conrardy

NOES: Councilmen: None

ABSENT: Councilmen: Jones

APPROVED:

Eugene M Conrardy
Mayor

ATTEST:

THOMAS H. SWEENEY, City Clerk

By Florine M. Leonard
Deputy City Clerk

(SEAL)

Certified as a True Copy
THOMAS H SWEENEY, City Clerk
by: Florine M Leonard
Deputy Clerk of ...

City of Sunnyvale

CITY HALL — SUNNYVALE, CALIFORNIA — REgent 9-0531

April 15, 1966

Mr. Donald K. Goodrich
Traffic Research Corporation
228 McAllister Street
San Francisco, California

Dear Mr. Goodrich:

Enclosed are six copies of Resolution No. 7471 approving City cooperation for a Traffic Research Project for the Sunnyvale Central Business District by Highway Research Board, National Academy of Sciences, National Research Council.

We want you to know that not only the City Council, but also the Chamber of Commerce and the industries are most interested in cooperating with this Project. We would welcome this Traffic Research Project with a great deal of enthusiasm. With the type of community expansion, the nature of the City will offer an excellent opportunity for a Project of this type.

Yours very truly,

Thomas H. Sweeney
City Manager

THS:cmr
Encl.

SUNNYVALE CHAMBER OF COMMERCE 499 SOUTH MURPHY AVENUE, SUNNYVALE, CALIFORNIA 94086, TELEPHONE 736 4971

April 14, 1966

Mr. Donald K. Goodrich
Senior Traffic Engineer
Traffic Research Council
228 McAllister Street
San Francisco, California

Dear Mr. Goodrich:

Attached is a resolution adopted by the Board of Directors of the Sunnyvale Chamber of Commerce at their regular meeting on April 6th.

It is the desire of the directors that the Sunnyvale Chamber of Commerce, supported by and representing the business community of the city, approve cooperation for a traffic research project for the Sunnyvale Central Business District to be sponsored by the Highway Research Board, National Academy of Sciences, National Research Council.

Inasmuch as the City of Sunnyvale is presently engaged in the revitalization of its central business district and is well supported by the community in its efforts, a study of this magnitude and stature would be most desireable.

The Chamber of Commerce realizes and accepts the possibility that certain regulations may be imposed upon the City in order to best observe and evaluate the results of any experiments.

Attached is a list of the members of the Board of Directors and their business affiliations, said members having indicated strong support for cooperation in this project. Additional resolutions from those firms desiring to indicate individual support will be forwarded.

Sincerely yours,

E. L. Beaty
General Manager

ELB/ec
encl

BOARD OF DIRECTORS OF THE SUNNYVALE CHAMBER OF COMMERCE

Approving Attached Resolution

Oscar H. Liebert	Liebert Construction Company
Gilbert R. Gunn	Pacific Gas & Electric Company
Stuart L. Rosendale	Waldron & Associates
Kenneth D. Hill	Ken Hill Realty
Robert T. Sapp	Allstate Insurance Company
Elmer Sutherland	Personal Products Corporation
Harry Brooks	Irving Lundborg & Company
Edward C. DeVoe	Perdue Plymouth Agency
Urban L. Gebo	Boise Cascade Container Corporation
Larry Hopkins	Hopkins Pontiac
James C. Keegan	Bank of America
Elizabeth R. McCraigh	Travel Advisors, Inc.
Sidney R. Mitchell	Consulting Civil Engineer
Allan D. McGrath	Youngsters of California
J. H. Moore	Western Electric Company
Robert C. Pelz	United California Bank
Donald L. Putt, Lt. Gen. USAF (Ret.)	United Aircraft Corporation
Peter L. Pavlina	Pavlina Realty
Marion L. Sellers	Lockheed Missiles and Space Company
Bert L. Smith	Developer
John W. Thompson, Jr.	Thompson, Curtis & Lawson - Attorneys at Law

RESOLUTION

RESOLUTION EXPRESSING SUPPORT FOR A TRAFFIC RESEARCH PROJECT FOR THE SUNNYVALE CENTRAL BUSINESS DISTRICT BY HIGHWAY RESEARCH BOARD, NATIONAL ACADEMY OF SCIENCES, NATIONAL RESEARCH COUNCIL

WHEREAS, the Highway Research Board, National Academy of Sciences, National Research Council has indicated it will engage in an experimental traffic engineering program to develop the best traffic engineering procedures for a central business district for a city of over 50,000 population, and

WHEREAS, the City of Sunnyvale with a present population of over 85,000 and being presently engaged in the revitalization of its central business district using the services of Victor Gruen Associates to execute a planning and traffic study of the downtown area, and

WHEREAS, the traffic engineering study proposed by the Highway Research Board will greatly enhance the business community, and

WHEREAS, the Board of Directors of the Sunnyvale Chamber of Commerce has unanimously agreed that such a study would be most desireable and beneficial to the community,

NOW, THEREFORE, BE IT RESOLVED that the Sunnyvale Chamber of Commerce urges that the City of Sunnyvale cooperate fully in the fulfillment of such a study and further respectfully requests that the Highway Research Board sponsor this research study in Sunnyvale.

APPROVED: Oscar H. Liebert

Oscar H. Liebert, President
Sunnyvale Chamber of Commerce

Dated: 4-14-66

$200,000 Grant Share Likely For Sunnyvale

By BILL LEONARD

Word was all but officially confirmed today that Sunnyvale will receive a traffic engineer, at least part of a $200,000 grant, and what has been called "the best traffic - engineered central business district in the United States."

City Manager Thomas H. Sweeney has scheduled a Tuesday morning press conference in city council chambers where it is expected the full scope of Sunnyvale's involvement will be explained at that time.

The Highway Research Board of the National Academy of Sciences, National Research Council told councilmen in April that Sunnyvale was a candidate for the $200,000 study.

City spokesmen indicated today that Sunnyvale will probably not receive the whole $200,000 from the national foundation. One other city will also be involved in the plan.

The organization had originally selected four cities in the Bay Area as candidates for the project, and the field was later narrowed to Sunnyvale and Redwood City.

In April, the city council went on record as favoring the project. At that time councilmen were told by a representative for the organization that likelihood of the city being selected would "depend a great deal on the strength of the resolutions and documents involved."

At that time it was said Sunnyvale's chances of being selected were about one in three.

Councilman Richard D. Hayden said today Sunnyvale was an "excellent choice" for the study.

"I am most happy that Sunnyvale has been selected as an experimental city," Hayden said. "Other cities will be able to benefit from the data gathered here," he added.

Hayden also said Sunnyvale's selection indicated the city was "moving ahead with the best studies available."

Vice - mayor Donald Koreski, caught by surprise by the news this morning, said simply, "I thing it's great."

The mammoth project is expected to take an estimated two to three years to complete. Spokesmen for the national organization have said the cost to the city would be a "modest" amount.

.Redwood City, Sunnyvale Get Traffic Funds

By LARRY STAMMER
Mercury Staff Writer

Sunnyvale and Redwood City have landed a coveted $200,000 grant for comprehensive traffic studies designed to turn the two communities into "international showcases."

Word the two cities had won the study in competition with cities across the United States was discussed Friday by city officals, as well as Bernard Johnson of Traffic Research Corp. of San Francsco.

Johnson's firm nominated Sunnyvale and Redwood City last April to be "test sites" for exhaustive downtown traffic analyses which will take between two and two and a half years.

The studies will be conducted by Traffic Research Corp. and financed 100 per cent by the National Academy of Sciences, the National Research Council and the Highway Research Board. Only "very minor" costs will be borne by the two cities.

Johnson said the three national organizations have signed contracts for conducting the studies. And he disclosed planning has already begun and "data collection" will begin next week.

He said motorists won't notioe any changes in streets until after the Christmas holidays.

The studies will augment, not duplicate, another downtown traffic and planning study which cost the city $47,500. Victor Gruen Associates of Los Angeles have completed that study.

Johnson said there is no way to compute how much of the $200,000 will go to Sunnyvale and how much to Redwood City. In effect, he said the study was being made by his firm under contract for the Highway Research Board. Sunnyvale and Redwood City are the "guinea pigs."

But benefits from the test are expected to be enormous by city officials.

Sunnyvale Public Works Director Donald M. Somers said the studies would be of "great development and financial advantage to the cities, plus being an international example of a city with outstanding traffic engneering."

Sunnyvale and Redwood City stand to gain the best designed downtown traffic pattern in the United States, officials have said.

Word of the grant was not supposed to have been given until press conferences in Sunnyvale and Redwood City next Tuesday mornng.

In announcing the press conference Friday—but not the purpose—Sunnyvale City Mgr. Thomas H. Sweeney said it would deal with a subject of "the greatest importance" to Sunnyvale.

Originally, only one city was to have been nominated by each consulting firm. But Traffic Research Corp. in San Francisco decided to recommend both Sunnyvale and Redwood City.

In this way, they explained, different traffic engineerng systems could be tested simultaneously. Similar concepts could also be tested in two cities to see if the reaction was the same.

$200,000 Study Set

It's official· Sunnyvale is one of two Bay Area cities selected for a two-year, $200,000 traffic engineering and control study.

Redwood City is the other city involved.

Representatives of Traffic Research Corporation, (TRC) made the official announcement in a press conference this morning.

The Standard Register Leader Friday exclusively reported Sunnyvale's participation as being all but officially confirmed.

James Kell, TRC western region director and principal traffic engineer, cited the "enthusiastic cooperation" of Sunnyvale and Redwood City as a major factor in the selection.

Kell and Barnard C. Johnson, TRC project director and senior traffic engineer, said a number of different traffic projects would be tried in the city's central area.

Official city reaction to Sunnyvale's choice as one of two cities for a two-year, $200,000 traffic study was all smiles today.

"This is going to provide more publicity for Sunnyvale than we've ever had on any one single project," a beaming Mayor William Fernandez said. "This will help us solve many questions we've had about downtown traffic patterns."

"Besides," he added, "I've often wondered what would happen if we tried one-way streets . . ."

Each test project will take about three months, although timing on the projects is flexible.

As Johnson and Kell outlined the program, tests will range from things as subtle as chang ing traffic light times to test as complicated as one - wa streets

Although the project officiall started as of September 1, th first phase or test of a traff device will not be attempte until January 1967.

Johnson said it would take a certain amount of time to col lect basic data about the city

The three-month cycles wi be broken into installation, tra fic adjustment, and study per ods.

"The first day after an" ne device is installed," Johnso said, "we will start watchin enforcement, accident rate any long delays in signaliz tion, and opinion feedback fro merchants, and the public general."

Motorists and pedestrians wi be polled on the effectiveness the controls and the changes r sulting from them, according Johnson.

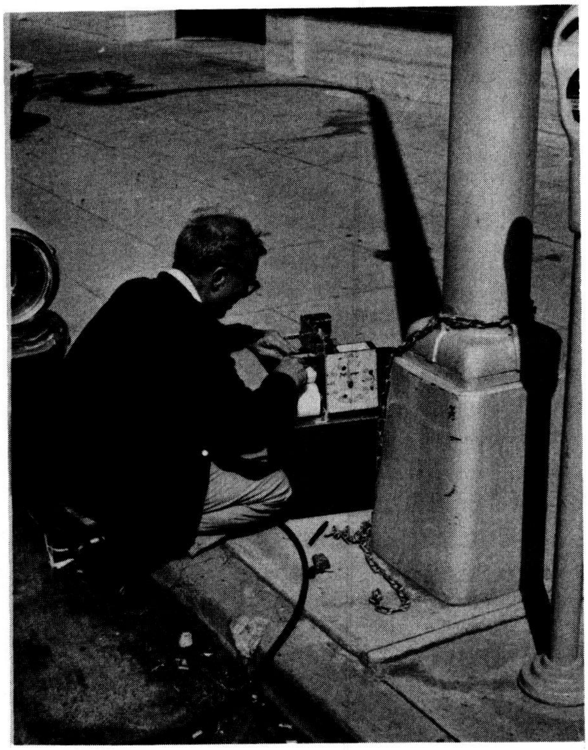
Kell said it would be "impo sible to determine in doll amounts" the chunk of t $200,000 which Sunnyvale w garner, but, Kell said, "effo in the two cities will be abo equal."

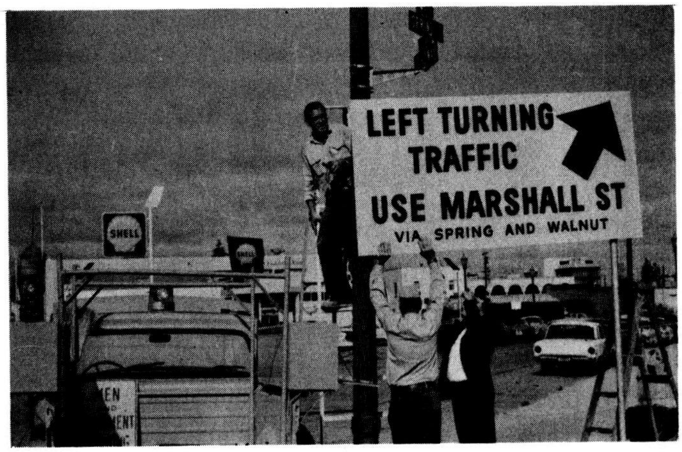
Funds for the program a provided by the American A sociation of State Highway O ficials, and the project is kno by the somewhat lengthy na of "Optimizing Street Ope tions Through Traffic Regu tions and Control."

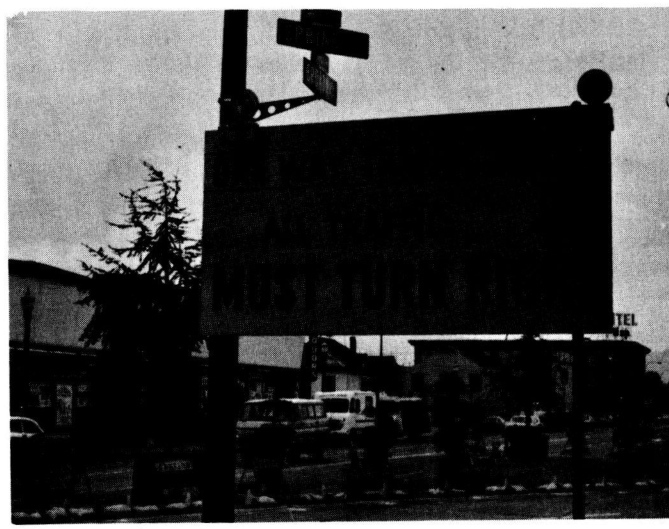
Some 15 firms, agencies a universities submitted pro sals for the model study

"By 1968," Kell said, "we ex pect Sunnyvale and Redwo City will have two of the b traffic - engineered downto areas in the country." One p pose of the study, he said, v to apply the techniques to ot cities in the nation

AUGUST, 1967: After base conditions were determined, test stages were formulated and approved by cognizant city officials. The first test stages were implemented and measurements of relative improvement were begun after a short period of stabilization.







They're Paid to Watch the Cars Go By in Sunnyvale...

By LYNDA HARP

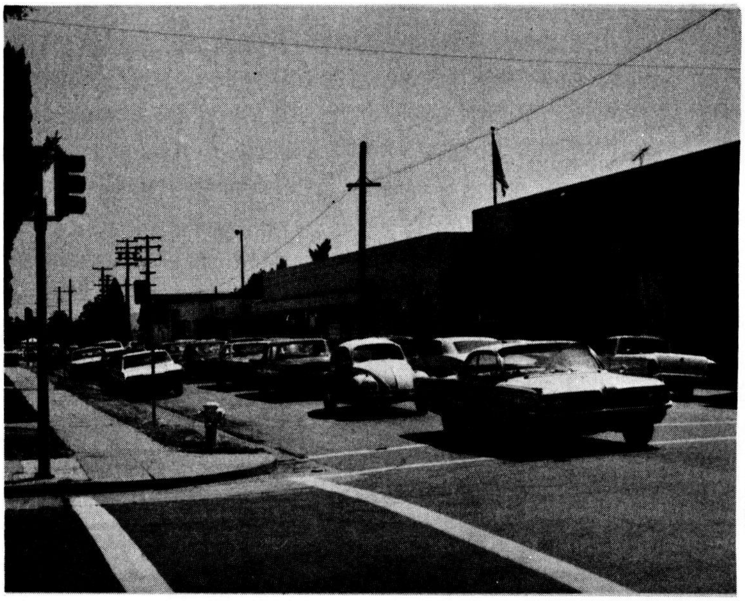
Life is "pressing" for Jim Young, Pi Silverstein and Massoud Shahapi. Every morning at about 7 o'clock, they start out on a very unusual assignment. They press buttons for a living.

Actually, what these college boys are doing is part of an extensive research project being conducted by Peat, Marwick, Livingston, and Company for the City of Sunnyvale. Last September, the federal government granted a two-year contract to this company for the investigation of suburban traffic control. Pi said, "The reason that cities like Sunnyvale are chosen is because of the rapid increase in population. The smaller cities are not used to a large amount of traffic and if the problem of congested traffic can be solved before it gets any bigger, it will save the city a large amount of time and money."

The equipment for the job is not very complicated. It consists of an oblong box which is divided into six different sections. Each section holds a device whose sole purpose is to account for the different directions a car turns at an intersection. One records the number of right turns, another left turns, and so forth. After the needed information is furnished, it is then relayed to the San Francisco office which in turn relays it to the main office in Boston, Mass.

As of this time, the field office is located in Old City Hall on Murphy Avenue in downtown Sunnyvale. But unlike the surroundings, the idea of traffic research is a relatively new one. According to Pi, who's been on the job only two months, "surveying traffic is an unusual, but interesting job. It's an easy way to earn money, and besides that, I get an excellent chance to get a tan."

Jim feels the same way. He says that although it gets boring at times, "A girl usually comes by and breaks the monotony."



Ever since the project has started, the company has employed people from such places as London to better their knowledge of traffic conditions. Not only are these people learning how to better traffic conditions, but they can educate citizens on how to cope with traffic conditions upon their return.

Jim, Pi and Massoud are three of the six men working this summer as Sunnyvale traffic surveyors. Almost all of the surveyors are engineers or engineering students. Both Pi and Jim are attending San Jose State College and although the project will continue into August of next year, they will return to their studies next month. But until then they're sitting on the corner watching all the cars go by.

NOVEMBER, 1967: As the Thanksgiving and Christmas holiday season approached, the merchants began to react. They anticipated adverse sales conditions in the downtown shopping area during the lucrative buying season if the test stages were continued. Pressure was exerted on the city administrators to halt the tests. A two-month moratorium was declared by the City Council.

Merchants Say Traffic Survey Is Ruining Their Business

Charging that the traffic survey currently under way in Redwood City is ruining their business, more than 80 downtown merchants met this morning with city officials to urge some type of relief, particularly with the Christmas season coming on.

One business leader, Art Blumenthal, owner of the Art Blumenthal Company, 2120 Broadway, charged that "too many people tell us they are not coming downtown to shop again."

One of the major concerns of the merchants is the ban on left turns off Broadway at seven intersections along the business district.

City officials were urged to lift the left turn ban for the Christmas seasons, or at least to lift the ban at the entrances to off-street parking lots.

Confused

Blumenthal contended that not only are shoppers confused and angered by parking and turning restrictions, but that police officers enforcing the regulations have been displaying "surliness and disrespect" towards the people they are citing.

However, other merchants challenged this, some reporting that officers have even gone to as many as four stores seeking owners of illegally parked cars to warn them that they face having their vehicles towed away.

Police Chief William Faulstich expressed surprise at Blu-
stich expressed surprise at Blu-
menthal's allegation. He urged that any specific instances of surliness or disrespect be reported to him

"I can assure you it will be corrected," the chief stated.

Faulstich added that "it is not a pleasant duty having to cite and to tow cars away." He noted that officers have even in some instances driven owners of towed cars to where the vehicles are stored and that the city is picking up the towing tab of $15 to $20 per vehicle.

Survey

Cause of the consternation is a two-year $200,000 traffic survey, financed by the Traffic Research Corporation, designed to improve not only traffic conditions in Redwood City, but also in similar commuities throughout the nation.

Goals and objectives of the survey were explained to the group gathered this morning at the city's community activities building by Bernard Johnson of Peat, Marwick, Livingston and Company, which is making the survey

One businessman, Henry Beeger, asked if the object of the survey was to make a "freeway" of Broadway or to "do something for the merchants."

Johnson noted that the object is not to make a freeway, but to "improve mobility and circulation" of traffic He said that the average speed of vehicles along the street prior to start of the survey was six to eight miles an hour, and that it is hoped to increase this to 16 miles an hour.

Payrolls

Attorney Robert Frank, representing a group of merchants, reiterated Blumenthal's contentions, stating that customers have told merchants they are not going to shop downtown because of the confusion concerning traffic and parking.

The loss of business is such, the attorney stated, that "many merchants may not be able to meet payrolls at the end of this month."

This statement was challenged by several persons present.

Frank urged that the city "do what it can" to terminate the study (which is scheduled to extend until the end of next August) or to at least suspend it during the Christmas shopping season, eliminate parking meters and lift the left-turn ban.

Beeger drew applause when he stated that what is needed for the area is elimination of parking meters, trimming of five feet of sidewalk off each side of Broadway and the institution of diagonal parking.

Improvement

Defending the city's decision to participate in the survey, City Manager Howard Ullrich said information will be obtained which would have taken the city ten years to garner using its own staff

"We are hopeful that this will ultimately result in marked improvement in the business condition of the downtown area," the city manager stated.

Holiday Halt for Survey

By MICHAEL PALMER
Tribune Staff Writer

At the prodding of downtown merchants, the Redwood City Council last night voted to suspend the current $200,000 traffic survey from Nov. 19 through Jan. 14.

The decision came despite a plea by the man directing the study, Barnard Johnson of San Francisco, that a less drastic action be taken.

Numerous changes in downtown traffic and parking patterns have been put into effect since the study began last August.

At a special meeting last week, merchants on Broadway and adjoining streets complained that the confusion caused by the alterations was hurting their business.

And Robert Frank, attorney for about 30 store-owners, asked that the research be halted before the Christmas shopping season and not be allowed to resume.

Only Councilwoman Mary W. Henderson dissented in last night's 6-1 vote, which put into effect the recommendations of city staff members.

The new plan, as described by Police Chief William L. Faulstich, will bring removal of all the experimental "no left turn" signs except the one erected on Broadway at Arguello Street.

Broadway, Jefferson Avenue and Middlefield Road will all have parallel parking on both sides and two lanes of traffic in each direction, as they did before the survey began.

When the project begins again in January, it will go into an "unbalanced flow" phase that was originally scheduled to begin next week. Broadway will have two lanes eastbound and one westbound, while parallel Marshall Street will have the opposite pattern.

The suspension will mean the loss, however, of "one entire stage," said Johnson, conducting the research for the San Francisco firm of Peat, Marwick and Livingston

The alteration also means that the planned progression of changes will be lost, he said. It could also cause the survey to run into the beginning of a major public works program downtown next year.

But City Manager Howard C. Ullrich said that the temporary halt was the best compromise that could be arranged in the circumstances. He explained that it represented a "value judgment of taking something away from what might have been gained against the very real possibility of jeopardizing the entire study."

Ignored was Johnson's request that his firm be allowed to come up with an alternate to the suspension.

Mrs. Henderson indicated she was voting against the change because it could damage the validity of the results of the tests.

The survey, originally scheduled to end next June, is being financed by the National Research Council of the National Academy of Sciences as part of a nation-wide urban traffic study program.

Redwood City was selected as one of the typical American communities to be surveyed during the project.

DECEMBER, 1967: To add to the difficulties created by the growing dissatisfaction, the data book for the Sunnyvale test stages was stolen. Despite an advertised reward, the book was not recovered and the data had to be collected again, once more delaying the project.

Valuable Sunnyvale Book Gone

A little black book containing valuable data for a downtown Sunnyvale traffic study has been stolen, and promises to jam up the study by six weeks unless the thief returns it.

The binder was taken recently from Traffic Research Corp. in Sunnyvale, according to Ronald J. Repper, field supervisor. It contained the results of manual traffic counts taken three-times daily at key down-

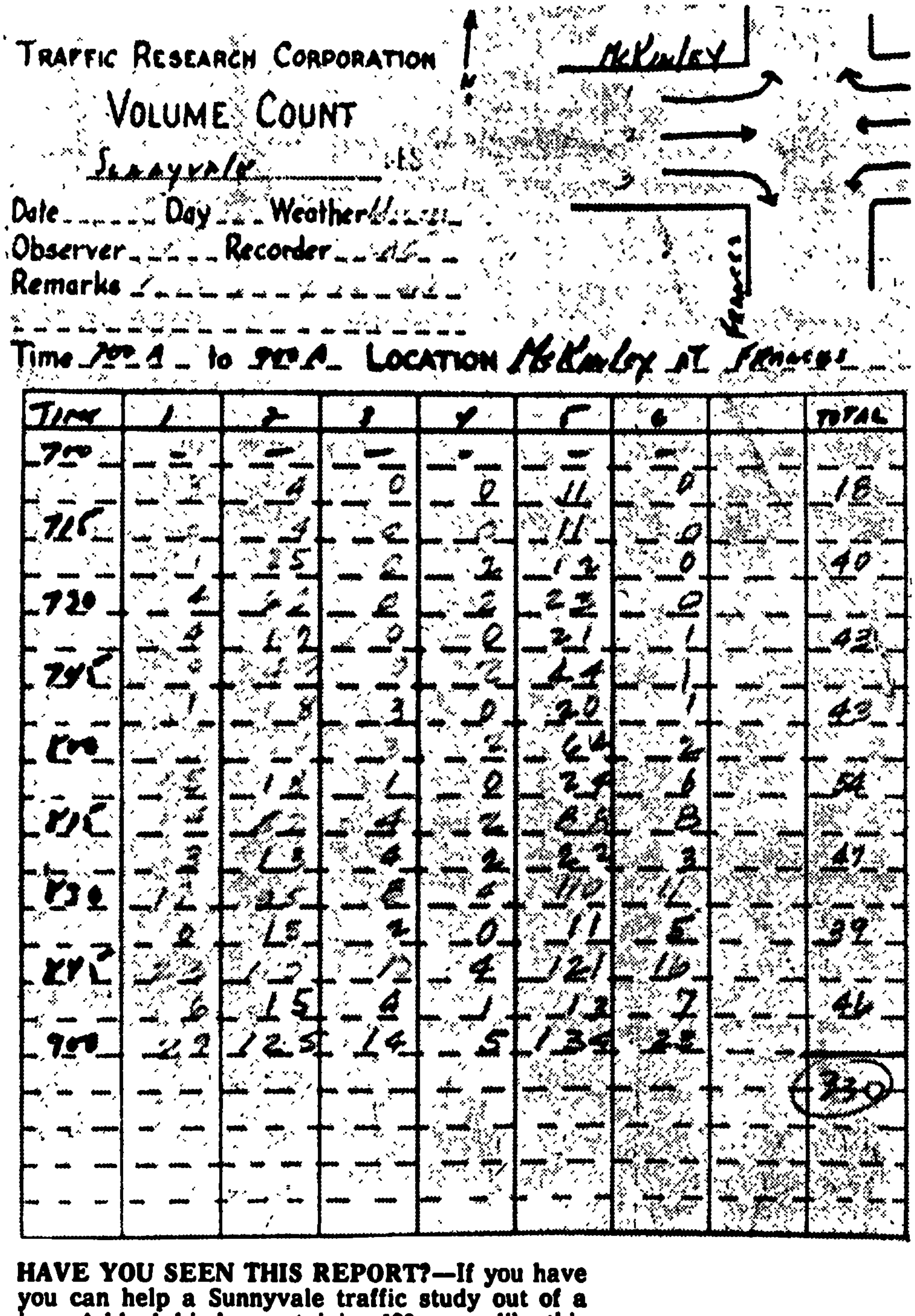
(See Photo, Page 3)

town intersections over a period of two-and-a-half months, he said.

"It's of no value to anyone but us;" Repper said. "It was the only copy we had and unless it's returned we'll have to repeat the entire survey."

This could slow down the entire traffic study by about six weeks, he estimated.

Repper said a $25 reward is being offered for the return of the binder "with no questions asked." He appealed to anyone having any information on the book to telephone the Public Safety Department at 736-3466 or him at 245-6941.



HAVE YOU SEEN THIS REPORT?—If you have you can help a Sunnyvale traffic study out of a jam. A black binder containing 130 pages like this was stolen when a thief broke into Traffic Research Corporation at Murphy and McKinley Streets. The binder contained the only copy of manual traffic counts taken downtown in the past two-and-a-half months. Unless the binder's contents are recovered, the count will have to be done over, setting back the traffic study an estimated six weeks.

JANUARY, 1968: As a result of the controversy, the City Councils and merchant groups threatened to abort the study. After the holiday moratorium, a compromise was reached in an agreement to combine test stages and, in some instances, to eliminate some of the planned regulation and control techniques.

City Revises Traffic Survey

By MICHAEL PALMER
Tribune Staff Writer

Plans for the final stages of Redwood City's storm-producing downtown traffic survey were drastically revised by the city council last night.

At the pleading of 19 downtown merchants, the next scheduled test stage of the study was dropped completely. And the remaining two phases were altered so they would be more "beneficial" to city planning.

The survey, which has brought a series of experimental changes in normal traffic and parking patterns in the central business district, has been the target of criticism almost since it began last August.

The council action was taken despite an eloquent speech in favor of retaining the original plans by T. S. Khanna, representing the firm conducting the study, Peat, Marwick & Livingston of San Francisco.

Changing the survey "gives the impression of a world champion tennis player who is losing badly in the fifth set and then gives up," Khanna stated.

But only Councilwoman Mary W Henderson voted against the alterations, which were recommended by City Manager Howard C. Ullrich.

Though the study was originally scheduled to carry straight through to May or June, it was temporarily suspended in mid-November after some businessmen said they feared it would hurt their holiday shopping receipts.

It had been scheduled to resume next Monday, but Barnard C. Johnson, manager of Peat, Marwick & Livingston, said today that the council decision would probably delay the schedule another week.

The research is being carried out by the consultant firm under a $200,000 grant from the National Academy of Sciences as part of a private, nationwide study of ways to improve urban traffic patterns.

Use of downtown Broadway and adjacent streets for the study was approved with little dissent both by the council and by the city Chamber of Commerce in 1966. But complaints began coming in from businessmen when experimental no left turn signs were put up along Broadway last September.

Test stage 5, scheduled to start next week, would have brought an unbalanced flow of traffic along Broadway, Jefferson Avenue and Middlefield Road in the central business area. Two rows of traffic would have been allowed in one direction and just one in the opposite direction, in order to widen the presently narrow lanes.

As revised, test stage 6 will mean one lane of traffic on Broadway, instead of the present two, from El Camino Real to the Southern Pacific tracks. Broadway will be made one-way eastbound from the tracks to Main Street, and Marshall Street will be one-way westbound. This may start the week after next.

It has not yet been decided whether Jefferson and Middlefield would be made one-way — as originally planned — or would have unbalanced flow.

In test stage 7, as altered, Broadway will have one lane in each direction, parallel parking, a temporary planted center strip and left-turn storage lanes.

The seventh phase will be similar to a plan proposed by Redwood City attorney Robert Frank last week as a permanent plan for Broadway. Frank last night said he represented 19 merchants who favored alterations in the survey as recommended by Ullrich.

Most vociferous of the councilmen who opposed the study as originally planned was John S. Rosselli. He is co-owner of Lock Drug Co., with a branch on Broadway, which was included on the list of firms Frank said he represented.

"I would rather support the taxpayer and the merchant rather than someone who's making a survey," Rosselli declared.

Khanna said that the study would have an "impact all around the world. You could certainly do a lot of good if you'll suffer for six more weeks, if you can call it suffering."

New Proposal for RC Broadway

A proposal to cut the number of traffic lanes on Broadway in half was unveiled at a downtown Redwood City businessmen's meeting yesterday.

In addition to giving the major thoroughfare just one lane in each direction, instead of the present two, the plan called for diagonal parking, a planted center strip, and short, left turn lanes with room for two cars.

Though yesterday's meeting was held ostensibly to discuss the controversial downtown traffic survey, the proposal for revamping Broadway — the city's main business street — received the most attention.

Arthur Balsamo, a city engineer, said he had drawn up a sketch of the suggested revisions at the request of Robert Frank, a Redwood City lawyer who has been representing merchants who oppose the traffic study.

Among other features, the plan specified an 11-foot traffic lane each way, instead of the present 8 to 9-foot lanes, and s.dewalks 10 feet in width instead of the present 15 feet.

Balsamo said it would cost about $50,000 to put the proposal into effect on Broadway between El Camino Real and Main Street, the heart of Redwood City's downtown buisness section.

'If a center divider was installed, parallel parking continued and the sidewalks left at the present size, he said, the price would be about $10,000.

Mixed reactions came from the approximately 60 merchants present. Some questioned whether both the street and sidewalks would become clogged. But a defender of the plan said that a similar project had worked well in Burlingame and that traffic had not been slowed down.

Discussion of the traffic survey was brief. Frank asked how many of those present were opposed to the study's resumption on Jan. 14, and about three-quarters raised their hands.

But others present expressed doubts whether the merchants present represented a cross-section of the downtown business community. Frank said he had invited everyone with an interest in the subject.

The survey, which began in late August, was halted in November after many merchants claimed the changes it required in downtown driving patterns were driving away customers.

Peat, Marwick and Livingston, a San Francisco research firm, is conducting the study under a grant from a private foundation. Its object is to discover if alterations in downtown street and parking patterns results in improved traffic flow.

The survey is scheduled for discussion at Monday night's city council meeting. Balsamo said the new proposal for Broadway might also be on the agenda.

Yesterday's meeting was held in the city Chamber of Commerce building.

Traffic Study Being Altered

By MICHAEL PALMER
Tribune Staff Writer

The latest experimental changes in downtown traffic patterns will probably not go into effect until Monday, Jan. 21, Redwood City officials said yesterday.

The city's $200,000 downtown traffic survey was scheduled to resume next Monday after a six-week holiday break.

But the start will be delayed a week because of the time needed to adjust to alterations in the survey voted by the city council last Monday.

At the request of some downtown merchants, worried that the traffic pattern changes brought about by the survey will hurt their business, the council decided to drop one stage of the study.

Asst. City Manager Henry Burget said yesterday that the city staff had consulted with the firm making the survey, Peat, Marwick & Livingston of San Francisco, to work out revisions in the remaining two phases.

As a result of the conference, the city staff will recommend to the council at next Monday's meeting that:

—Broadway be made one-way eastbound during the next phase, and Marshall Street be made one-way westbound, from Main Street to the Southern Pacific railroad tracks.

—Jefferson Avenue and Middlefield Road both have "unbalanced flow" during the upcoming stage — that is, each will have two lanes of traffic in one direction and one lane in the opposite diretion.

Originally, the survey plans called for Jefferson and Middlefield to be made one way also. The two would have had unbalanced flow during the test stage which was dropped by the council this week.

The next phase of the survey and the final one following it are both expected to last about six weeks.

Traffic Survey Must End Now, RC Merchants Demand

An immediate and final end to Redwood City's downtown traffic study was demanded this morning by the Downtown Merchants Association.

The association, following a 7:30 a.m. meeting, sent telegrams to all seven city council members declaring that the street patterns in the current stage of the survey were "creating an unbearable hardship."

A delegation of 12 merchants then trooped into city hall, where City Manager Howard C. Ullrich promised to do all he could to meet their complaints.

The storm was the latest in a series of tempests over the traffic experimentation, which has brought numerous temporary changes to downtown traffic patterns since last August.

The current phase is the last, and is scheduled to finish at the end of this month.

The merchants' major complaint involved the traffic jams which are occurring daily on Broadway, the city's main business thoroughfare.

The street has cut down from its normal two lanes each way to one lane in each direction, and signs have directed through traffic onto Marshall Street, one block north.

The merchants, led by association president Hugh Green, told Ullrich that the pileups on Broadway were "wrecking" downtown business.

They said they wished a quick termination of the survey because of the heavy shopping expected in the period just before Easter, which falls on April 14.

Changes in signal timing to allow freer movement of Broadway traffic were being made this morning, the merchants were told by Ullrich and Barnard C. Johnson, the private consultant in charge of the survey.

A decision to end the experiments would have to be made by the city council, which is not scheduled to meet until next Monday, Ullrich explained.

The city manager declared that he would take all the steps allowed to him under city ordinances to alleviate the poor conditions.

Ullrich and the merchants' delegation agreed to meet at 8 a.m. in city hall tomorrow to discuss whether the changes in signal timing had solved the problems.

The complainants indicated they would ask for an emergency city council meeting if the traffic jams persisted through this afternoon.

Several of the merchants suggested that a change in the experimental one-way pattern on Middlefield Road might also help remedy the situation.

They suggested that Middlefield — which now feeds cars from both north and south onto Broadway — have its flow reversed so that autos could turn off Broadway.

Deputy Police Chief T. N. (Ted) Moudakas said, however, that he would favor making Middlefield two ways again as it was in the days before the current survey phase.

Johnson and Ullrich promised to see if they could make a change.

The merchants association, with about 35 members, represents the majority of downtown businesses.

Its telegram to the councilmen read:

"The present traffic study in downtown Redwood City at this time is creating an unbearable hardship on the merchants in the downtown area during the peak Easter buying season. We urge that the study be abandoned immediately."

FEBRUARY, 1968: The combined test stages created motorist confusion, and public reaction was added to the growing merchant discontent.

Final Phase of Study:

Downtown Traffic —It's 'Real SNAFU'

Fascinated motorists were running red lights right and left yesterday in downtown Redwood City as their attention was distracted by a gaudy display of traffic warning and direction signs and a cryptic set of street markings.

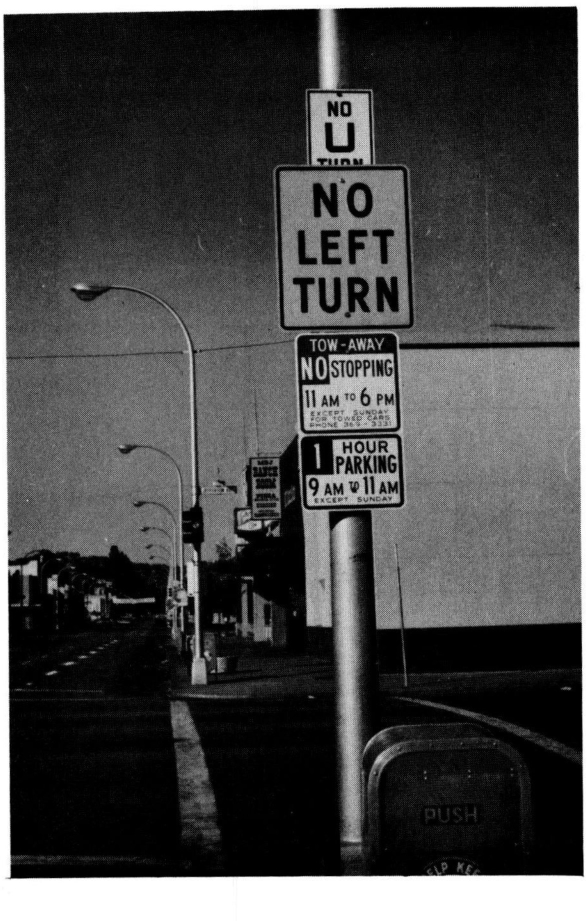
It was the first day of the seventh and final phase of Redwood City's study of various alterations in the normal downtown traffic pattern.

Policemen, who must bear the burden of the difference between the drawing board and the street, are less than unanimous in support of the experiments.

One sergeant on his written daily report wrote that the first day of the seventh stage turned out to be a "real SNAFU, as expected."

"The main cause, as before," he wrote, "was lack of preparation. Signs were inadequate, some lanes weren't painted properly, some were painted wrong, some important intersections weren't marked at all."

While the confused drivers were trying to figure it out, another officer reported, they forgot to look at the traffic lights.



Pneumatic Traffictitus

To the Editor:

Are you jittery, jumpy, generally upset? Are you shaky, in shock, insecure? Do you feel hurried, harried, hounded? Can't sleep nights? See white lines crossing yellow lines, turning into black lines, becoming yellow and white again? Do you dream of going down a street, only it isn't a street but a blind alley, with arrows zooming in on you and you can't even turn around?

Are you thinking of seeing an opthalmologist, a neurologist, a psychiatrist? Stop, cease and desist! They are probably in the same sad state.

This is an epidemic. It is known as pneumatic trafficitus. It will take two months to run its course, and, of course, there is nothing anyone now can do about it. The minute you leave your garage, you are in danger of contracting it. In fact, it seems the City Fathers were the first to contract for this $200,000 plague. Mere citizens had nothing whatever to say about it. Guinea pigs never do.

So now we know how it feels to be a guinea pig. Now we know why their teeth continually chatter and clatter; why they never eat their food, just nibble it.

But to come out of this padded cell and down to brass lines, don't you wish that Whoozit Foundation had just given us the 200,000 for — or toward — moving back the light standards, cutting our ridiculously, uselessly, antiquatedly wide sidewalks in half — except for the first block of Broadway where they are needed for an extended high school cafeteria — and so given us the space for two lanes both ways, plus parking along each curb? Any horse-sense person can find an easy solution. It takes a traffic engineer to dream up a nightmare.

FALKA G. STURGES
Redwood City

Redwood City Traffic Game Faces Rainout

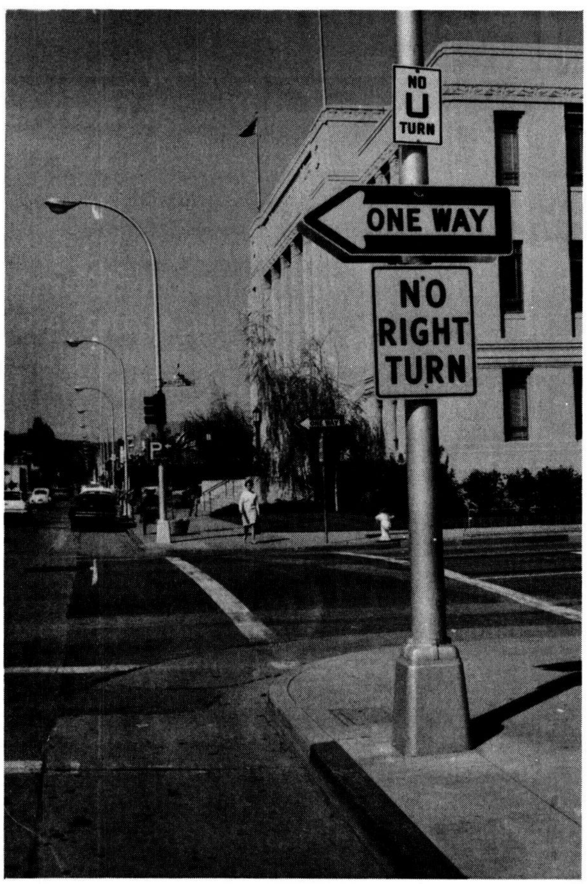
Next week's scheduled game of Redwood City traffic dodge 'em may get rained out, Asst. Police Chief T. H. (Ted) Moudakas warned yesterday.

Street crews are supposed to repaint the markings on downtown thoroughfares this weekend for the start of the next phase of the city's traffic study on Monday.

But wet weather would stop the painting and mean postponement of the traffic changes until March 25, said Moudakas.

The upcoming stage will be the seventh and last one in a study which began last August.

Traffic flow and parking patterns have been altered every few weeks so experts employed by a national research organization can gauge their effect on ease of motoring.



Broadway Disgusting

To the Editor:

It is shocking and disgusting to try to drive on Broadway in downtown Redwood City.

With all the lines that are painted on the street, you do not know where are your going. And to drive down the street, and see another car coming to meet you head on is enough to cause a heart attack. This will cause many people to stop shopping in Redwood City, and drive to a shopping center, including me.

This certainly seems unfair to the merchants who are trying to keep their places of business open.

It seems to me that our city has more than its share of vacant business places now, without the city wasting money to run out of more. Why doesn't the council wake up?

JEAN TINDALL
191 Duane St.
Redwood City

Signs, Rain And Chaos

By MICHAEL PALMER
Tribune Staff Writer

With heavy rain adding to the widespread confusion, Redwood City's downtown traffic survey resumed today after a two-month lapse.

Police patrols were heavy as scores of motorists failed to notice new street markings and made illegal turns onto Broadway, Marshall Street, Jefferson Avenue and Middlefield Road.

Normal traffic patterns have been altered on all four streets in the downtown area as part of a $200,000 research study which began last August.

The worst mix-ups this morning were occurring on Broadway and Marshall, which were both posted one-way by workmen yesterday.

To add to motorists troubles, the rain forced workmen to leave their street repainting job incomplete. As a result, there were still double yellow lines left on the two one-way streets as well as the old white dotted lines.

Jefferson and Middlefield formerly had two lanes in each direction. But each now has been cut down to two lanes in each direction and one in the other. And the wet weather meant that street crews couldn't cover up the old yellow line.

The worst trouble-spot appeared to be at the corner of Marshall Street and Winslow Street, where the San Mateo County Hall of Justice and Records is located.

"There are a lot of people who come to the courthouse once or twice a week who are conditioned to getting back to the freeway by a certain route," said Officer Robert LaBerge, one of the policemen on patrol in the downtown area.

A Tribune reporter rode with Laberge for about 30 minutes this morning, and saw cars making illegal turns onto Marshall Street on nearly every swing through the area.

Broadway, the city's major business thoroughfare, had the most wrong-way drivers. Each one usually went only a block before a patrol car would confront him and an officer would motion the driver onto a cross street.

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from.

Highway Research Board
National Academy of Sciences
2101 Constitution Avenue
Washington, D.C. 20418

Rep. No.	*Title*
—*	A Critical Review of Literature Treating Methods of Identifying Aggregates Subject to Destructive Volume Change When Frozen in Concrete and a Proposed Program of Research—Intermediate Report (Proj. 4-3(2)), 81 p., $1.80
1	Evaluation of Methods of Replacement of Deteriorated Concrete in Structures (Proj 6-8), 56 p., $2.80
2	An Introduction to Guidelines for Satellite Studies of Pavement Performance (Proj 1-1), 19 p, $1.80
2A	Guidelines for Satellite Studies of Pavement Performance, 85 p.+9 figs, 26 tables, 4 app., $3.00
3	Improved Criteria for Traffic Signals at Individual Intersections—Interim Report (Proj. 3-5), 36 p., $1.60
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5	Effects of Different Methods of Stockpiling Aggregates—Interim Report (Proj. 10-3), 48 p., $2.00
6	Means of Locating and Communicating with Disabled Vehicles—Interim Report (Proj. 3-4), 56 p. $3 20
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