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SIOUX CITY

SIGNAL SYSTEM EVALUATION STUDY

DRAFT FINAL REPORT

Prepared For

CITY OF SIOUX CITY

In cooperation with the City of Sioux City,
The Iowa Department of Transportation, and
the Federal Highway Administration

By

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I. INTRODUCTION

Sioux City has undertaken this study, in a project partially funded by the Governor's Highway Safety Program, to develop a comprehensive traffic signal system modernization plan having as its goals improved safety and efficiency of surface transportation. These are complementary goals in that increased efficiency infers that the quality and stability of traffic flow has been enhanced which in turn reduces the frequency of traffic conflicts that result in accidents, thereby increasing motorist and pedestrian safety.

The study objectives were to investigate existing and future traffic conditions and to examine non-periodic events (e.g. emergency vehicle movement, etc.) to define signal control requirements; evaluate the existing system against these requirements to identify deficiencies; develop alternative systems structured to provide the traffic control requirements; and select the system that is most cost-effective in satisfying the requirements in Sioux City. The estimated benefits to be realized from the selected system were compared to the estimated capital and recurring costs to determine whether the expenditure was justified. From this it was found that the recommended signal system is a sound investment.

BACKGROUND

Sioux City, a major meat-packing and agricultural center, has not experienced the explosive growth in the past 20 years that has been characteristic of more industrialized areas of the country. However, historical factors conflict with the prevailing progressive spirit of the City and the efficient transportation of people and goods is a major concern.

The traffic delays, high incidence of accidents, and overall transportation inefficiencies experienced today are a direct result of the no-growth philosophy that was prevalent in Sioux City during the "complacent period." During this 40 year period, ending in the late '50's, physical improvements were virtually nonexistent and the economic base of the City began to erode. To reverse the apparent decline of the City, major capital investments were required to provide a foundation upon which a revitalized community could be built. As there was much work to be done, it was not always possible to construct or upgrade the transportation facilities.

There is clear evidence that the investment that has been made in the City and the adoption of a controlled growth policy has been successful. Reestablishment of the Central Business District (CBD) as a regional shopping center as well as continuing its role as a government and business center is indicated by the 4th Street Mall. This recently developed area contains major new commercial establishments such as the Hilton Inn and Penney's and construction has just begun for Brandeis Department Store. Rehabilitation of the CBD within the framework provided by the Sioux City Community Workshop Concept Plan will receive continued emphasis.

Insuring that these concepts reach their full potential is dependent upon an efficient transportation network. Current demands have already burdened the existing facility indicating that additional capacity must be made available. As sound traffic engineering principles have already been applied to the existing roadway network, other avenues must be explored to enhance transportation.

Since traffic signals have as their primary function the assignment of right-of-way, significant efficiencies can be realized by conducting their operation in accordance to current demands within the system. Inefficient operation can result in needless stops and the creation of hazardous situations. These inefficiencies have real costs associated with them that are becoming increasingly severe. The cost of operating an automobile, the primary means of transportation in Sioux City, continues to rise as the energy crisis becomes more pronounced. Pollution is a continual problem that is sensitive to relatively small changes in transportation efficiency. Planned usage of the street network can be affected by use of signal system control strategies to emphasize streets designated as primary trafficways while discouraging traffic movement along selected routes to preserve neighborhood identity.

As transportation is an element that affects all persons, the Signal System Study is an integral part of the overall plan to make Sioux City a nice place to live and work. The ability to move people and goods in a safe and efficient manner with the least negative impact on the community is greatly influenced by signal operation. The installation and planned operation of the proper system provides <u>one of the tools</u> needed to <u>manage traffic</u> such that the goals of safety, efficiency and community integrity can be achieved.

STUDY APPROACH

This report represents the first phase of a multiphased project to improve the signal system operation in Sioux City. The project phases are:

- <u>Phase I</u> - Detailed system analysis and definition of the course of action to most completely satisfy the City's goals and objectives at the least cost.
- <u>Phase II</u> - Prepare a detailed system description and an implementation guideline of the selected system.
- <u>Phase III</u> - Develop plans, specifications, and cost estimates to permit equipment, materials, and services to be procured.
- <u>Phase IV</u> - Construction of the improved signal system. This may consist of a single implementation project to construct the total system or several implementation projects may be required to stage the project depending on the availability of funds.
- <u>Phase V</u> - Continued operation and maintenance of the improved signal system.

Study Area

The project study area is defined by the Sioux City City Limits and is shown in Figure 1. Within this area the City currently operates approximately 112 signals which were examined in detail during the study. Consideration was also given to the inter-relationship of traffic between Sioux City and South Sioux City for possible coordination of system operation between the two cities in the future.

Technical Advisory Committee

As this study defines the signal system improvements to be made and establishes the framework for subsequent phases of the project, care was taken to insure that all relevant factors were considered. A very important aspect of the study was the formation of a working Technical Advisory Committee to provide input at key points in the study. Members of the Technical Advisory Committee provided decision making representation from the Federal Highway Administration, Iowa Department of Transportation, Siouxland Interstate Metropolitan Planning Council (SIMPCO), and the City (Fire, Police, Transit, Auditorium, Data Processing, Engineering, City Manager's Office, and Traffic Engineering).

The project was structured such that JHK & Associates acted as a technical consultant to develop specific recommendations and the Technical Advisory Committee acted as the policy making body. Thus, the project was able to proceed in a logical sequence building upon an incremental decision process.

Work Plan

The project work plan is shown in Figure 2. Also shown are the stages of the project in which the Technical Advisory Committee were heavily involved.

The initial stages of the project were concerned with compiling and reviewing existing data. This included various traffic

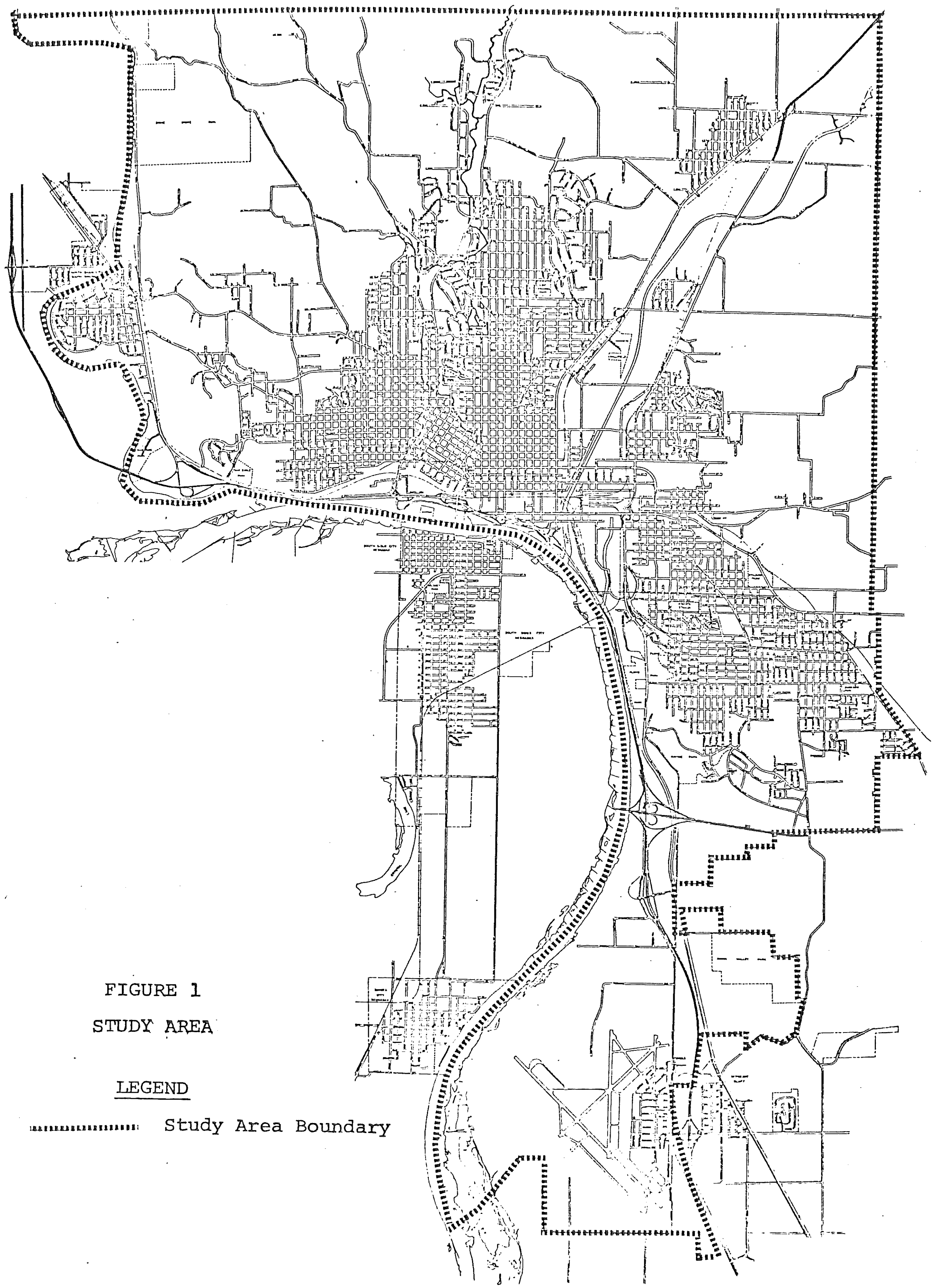


FIGURE 1

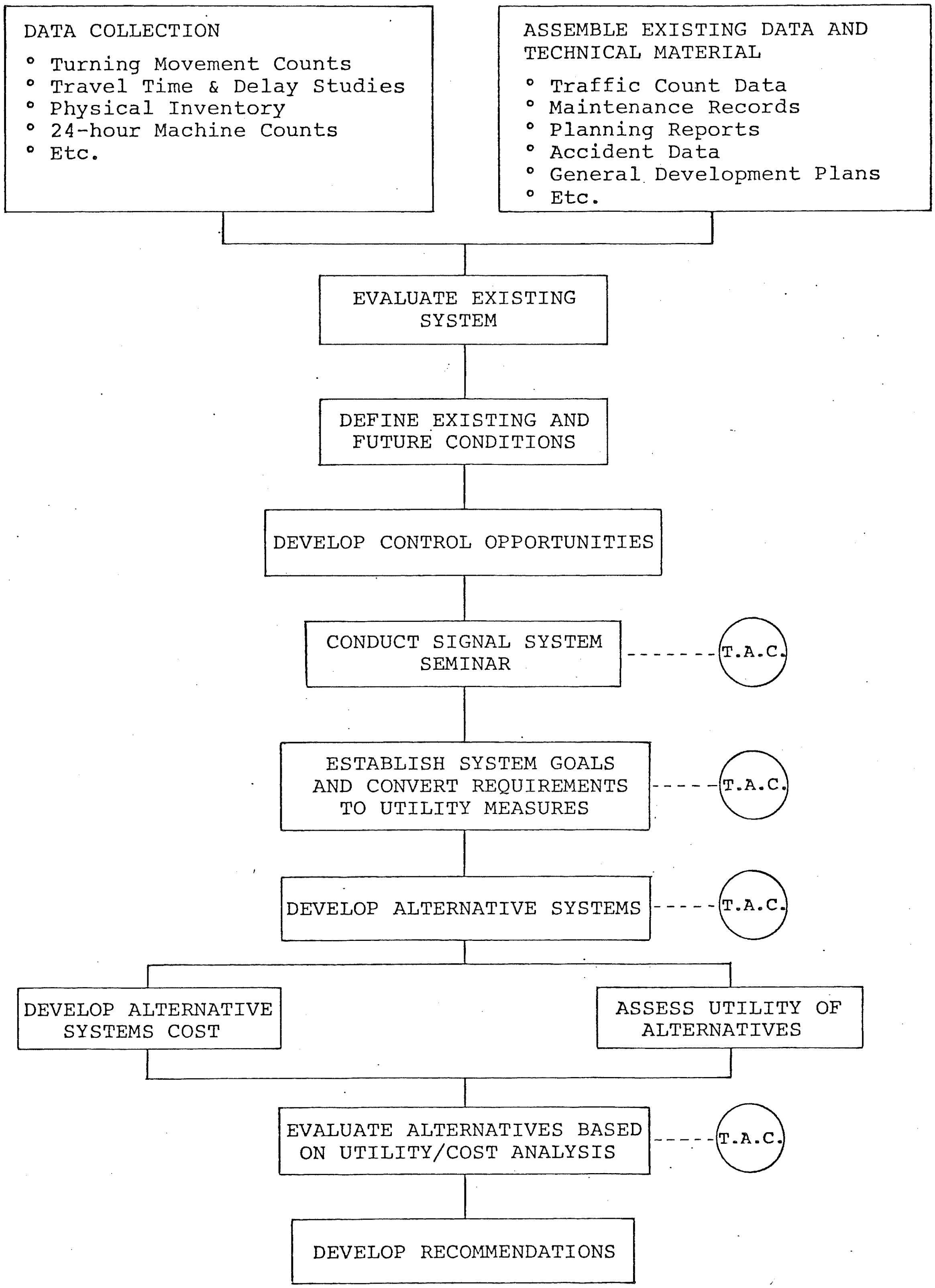
STUDY AREA

LEGEND

⁞⁞⁞⁞⁞⁞⁞⁞⁞⁞⁞⁞ Study Area Boundary

FIGURE 2

STUDY WORK PLAN



data as well as all studies and reports that were relevant. Additional data was collected as required to create the data file necessary for the project.

An extensive analysis of existing and future conditions, including an assessment of the existing signal system, was performed to establish the opportunities for signal control that were viable in Sioux City. A two day seminar was then held with all members of the Technical Advisory Committee participating. The analysis and findings were reviewed in detail resulting in defining system goals and conversion of the control opportunities into measures to be used to evaluate the system.

Alternative signal systems were then configured to address various aspects of the requirements defined. The systems were costed and their ability to meet the requirements determined. As a last step, the alternatives were evaluated and the benefits of the most effective system were determined. The study has resulted in defining the most cost effective approach for Sioux City.

II. EXISTING CONDITIONS

An analysis of existing conditions was performed to define the physical characteristics of the transportation network (e.g. street system, signal system, etc.) and to define the traffic flow characteristics as it interacts with the physical network. This analysis then provides the basis to investigate the changes that will occur and to permit their impact on future traffic characteristics to be estimated. Clearly defining the current and future traffic characteristics that the signal system must respond to are critical steps in the study. Over designing a system would result in unnecessary costs to the public for capabilities that are never used. On the other hand, even greater costs could result if the system did not provide needed functions or did not have the flexibility to accommodate changes. This analysis, which was the focal point of the Signal System Seminar, provided the foundation for subsequent tasks.

EXISTING SIGNAL SYSTEM

The existing signal system, consisting of 112 signals, is configured into three separate systems as shown in Figure 3. These systems are briefly described as follows:

- Central Business District System - The Central Business District System (CBD System) consists of pretimed controller equipment that has the capability of providing three dial, three offset per dial operation. However, system operation is limited by the communications network to one dial, one offset operation. Interconnection is accomplished by a single telephone pair except for a few locations served by city owned cable. The master consists of a device that transmits a periodic pulse to maintain synchronization and an interrupter to resynchronize signals over several cycles if they should become unsynchronized.

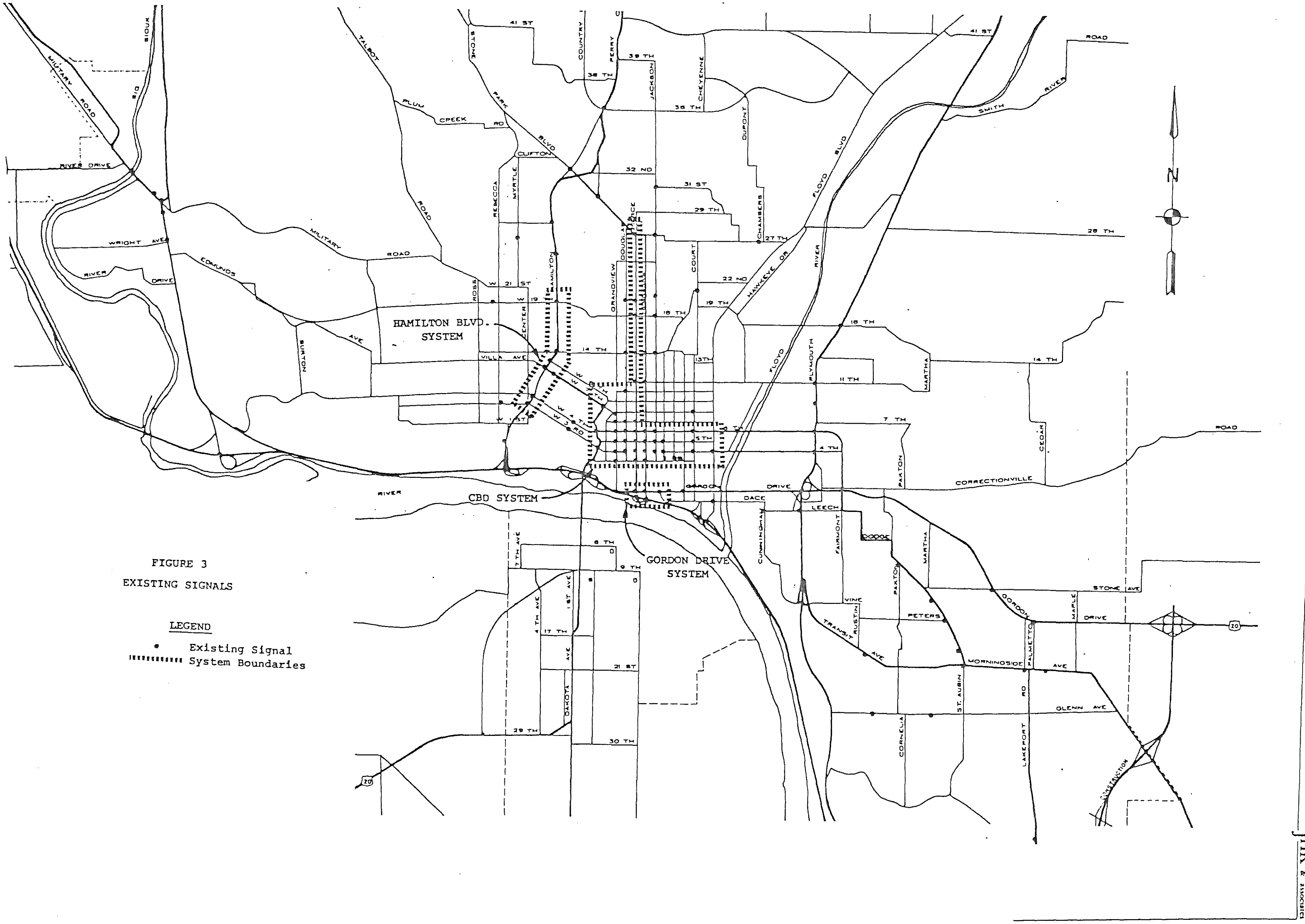


FIGURE 3

EXISTING SIGNALS

LEGEND

• Existing Signal

IIIIIIIIIII System Boundaries

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- Hamilton Boulevard System - The Hamilton Boulevard System consists of three dial, three offset per dial pretimed controller equipment. Three dial, single offset operation is selected by time clock. The signals are interconnected by city owned cable.
- Gordon Drive System - The Gordon Drive System is also a three dial, three offset per dial pretimed system operating in a single dial, single offset mode. Interconnection is provided by telephone circuits similar to the CBD System. Nighttime flashing operation at selected locations is performed by time clock.

The remainder of the signals consist of a mix of pretimed, semi-actuated, and full-actuated controller equipment operating in an isolated mode. A mixture of various models of equipment manufactured by Eagle Signal Co., Automatic Signal Co., and Crouse-Hinds is in use.

Although the signal controller equipment is generally well maintained a large portion of the equipment has been in service over 10 years. To assess the condition of existing equipment a review of the maintenance history of signal controller equipment hardware was performed. The review was based on actual experience as recorded in maintenance files. The primary objective was to identify factors that would impact use of existing equipment in any new and/or upgraded system.

It should be noted that the review concentrated only on non-scheduled maintenance (trouble call) activities as these provide indicators of chronic problems. Preventive maintenance activities, consisting of a twice a year cleaning and checking of pretimed controllers, are performed by the City in addition to the maintenance functions described herein.

The maintenance trouble call review covered the four year period from 1973 to 1976. As several signals were installed or removed during this period, a list of intersections was developed that were signalized (excluding flashers) during the entire period.

Only these locations were considered during the review to provide a consistent evaluation framework.

A yearly summary of non-scheduled maintenance calls by category for each signal was made and the totals for each category is shown in Table 1. From this it can be seen that approximately two-thirds of the trouble calls are the result of controller failures. In addition, the number of failures is increasing with a significant increase in 1976. On the other hand, the number of interconnect trouble calls is surprisingly small (considering that 55 signals are interconnected).

TABLE 1 - SUMMARY OF NON-SCHEDULED MAINTENANCE CALLS BY CATEGORY

	Category					
Year	Detector	Controller	Power	Interconnect	Wiring	Total
1973	34	142	29	18	3	226
1974	19	157	49	14	2	241
1975	28	158	31	14	6	237
1976	37	226	38	4	8	313

As an equipment reliability evaluation criteria, a level of non-scheduled maintenance based on experience was used. This was necessary as a standard measure of traffic equipment reliability relative to maintenance does not exist. This is due to many factors including substantial differences from agency to agency in equipment maintenance and repair procedures, system equipment mix, accounting procedures, etc.

Accordingly, the equipment at a location with one or fewer failures per year was considered as generally reliable. Equipment with a history of two failures per year, depending upon the type of failure, were considered marginal. Equipment with three or more failures per year were considered as high priority candidates for replacement. A summary of signal locations experiencing two or more non-scheduled maintenance calls per year is shown in Table 2.

TABLE 2 - SUMMARY OF NON-SCHEDULED MAINTENANCE CALLS BY FREQUENCY

	1973	1974	1975	1976	Average
Total Number of Signals	112	112	112	112	112
Total Number of Calls	226	241	237	313	254
Signals With Two or More Calls Per Year					
° Number of Signals	54	54	57	56	55
° Number of Calls	204	217	208	286	229
° Percentage of Total Signals	48%	48%	51%	50%	49%
° Percentage of Total Calls	90%	90%	88%	91%	90%
Signals With Three or More Calls Per Year					
° Number of Signals	37	37	30	42	37
° Number of Calls	172	185	166	250	193
° Percentage of Total Signals	33%	32%	27%	38%	33%
° Percentage of Total Calls	76%	77%	70%	80%	76%

Two conclusions were drawn from the summary. First, the trend over the four year period is consistent and slightly increasing, indicating that equipment reliability is degrading. A corrective plan of action developed in a timely manner by continuous monitoring of equipment failures is desirable. Second, approximately 33% of the intersections are generating 76% of the maintenance calls. Clearly, this indicates that any repair/upgrading program should give the highest priority to corrective action at these locations.

STREET NETWORK

Sioux City is the major agricultural and light industrial center for Northwest Iowa and Northeast Nebraska. As a result, numerous highways transverse the City. Interstate 29, a north-south route connecting Kansas City, Missouri to Winnepeg, Canada is the major highway. In contrast to many cities, however, the Interstate generally leaves the city intact* as it follows the north and east

* Although the Interstate separates the Missouri River recreational activities from the City.

bank of the Missouri River. U.S. Highway 75 connects with Interstate 29 and extends northward bisecting the CBD and the Morningside residential area. U.S. Highway 20 (Gordon Drive) is the only east-west highway transversing the City. It enters the City from the southeast and passes along the southern edge of the CBD prior to crossing the Missouri River at the Combination Bridge into South Sioux City, Nebraska. The Combination Bridge, which is being replaced by a new structure, was the only river crossing into Sioux City until the recent opening of the Interstate 520 Bypass route. The Bypass presently connects U.S. 20 on the Nebraska side of the river to Interstate 29 and Lakeport Drive in the Morningside area. Construction is presently underway to extend the Bypass to Gordon Drive.

These routes are characterized by a high percentage of truck traffic and out-of-state vehicles. They are also heavily used by local traffic; however, most of the local traffic is concentrated on short sections of these highways near the CBD.

The remainder of the street system in Sioux City is made up of arterial, collector, and residential streets that are generally defined within the context of a grid system. Exceptions to the grid system network include arterial streets such as Hamilton Boulevard, Wesley Way, and Morningside Avenue. Also the residential areas of Indian Hills, Kelly Park, and the area adjacent to Grandview Park have a street network that disrupts the prevailing grid pattern. Within the CBD grid, the area west of Pearl Street, maintains a grid pattern but has been rotated 45° about the primary CBD north/south street axis. This results in numerous five or six approach intersections along the boundaries. Due to low side street volumes, these intersections do not pose unusual control requirements.

LAND USE AND TRAFFIC GENERATORS

Sioux City has an estimated population of approximately 89,000 within an incorporated area of about 55 square miles. Of this, about 50 percent of the total land area is undeveloped. Most of the commercial and retail businesses are located in the CBD although some strip commercial development exists along Hamilton Boulevard and Gordon Drive. Industry is concentrated along both sides of the Floyd River between Floyd and Lewis Boulevard and south of the City near the airport between the bluff line and the Missouri River. There is also a major industrial complex on both sides of Hamilton Boulevard near Interstate 29.

As transportation patterns are affected by residential characteristics, a "broadbrush" analysis of the socio-economic distribution of population was conducted. From this it was determined that an ethnic segregation of residences (and employment) does not seem to exist in Sioux City. Although some Indian and Black residents dominate a portion of the area southwest of the CBD, the dominant factor in residential distribution appears to be economics. Most of the low to middle income residents tend to live near the CBD or the industrial areas while upper income residents tend to be concentrated in the extreme north and north central portions of the City. This investigation, prepared as a large scale display, provided substantial insight during the evaluation of existing and future traffic flow characteristics.

Sioux City has approximately 57 schools including three colleges; Briarcliff, Morningside and Western Iowa Tech Community College and three new public high schools which were opened recently. Most of the elementary and junior high schools are neighborhood type schools located away from major traffic carriers. In general, schools are located such that school speed limits on major signalized streets are not required and school attendance does not significantly affect traffic except at a few locations where pedestrian activity must be considered. School related traffic can, therefore, be accommodated within the context of "normal" traffic.

Vehicle trips within the City can be generally categorized into three groups -- commercial, recreational, and work related. The

CBD is the major commercial trip generator with Sunset Plaza Shopping Center on Hamilton Boulevard, the Morningside Shopping Area, Goldfines Department Store on South Highway 75, and KD Stockyard contributing to a lesser degree. The CBD is also a major traffic generator for work related trips as is the area surrounding the Stockyards south of Highway 20 and west of Highway 75.

The Stockyard area generates a large volume of truck traffic throughout the day. Although the truck traffic does not produce high peak traffic flows, traffic is somewhat unstable due to the continual arrival and departure of trucks. Consideration of truck traffic is an important factor in intersection geometric design and will play a role in signal operation.

The emerging industrial park south of Morningside and the TriView Industrial Complex are the other major work related traffic generators. The impact resulting from these complexes occur at the end of shifts between 3:30 and 4:30 PM.

Recreational trip generators include baseball or football parks, the City Auditorium, theaters, etc. Horse and dog race tracks are located in South Sioux City and North Sioux City, respectively. With the exception of the City Auditorium, these activities do not have a substantial impact on signal system operation due to their location and time of occurrence.

MAJOR TRAFFIC VOLUMES

An analysis of traffic volume characteristics in the City was conducted to identify growth trends and traffic variations. Data routinely collected by the City at permanent count locations and other locations counted on an "as-needed" basis was used. To supplement the existing data, the City collected data at 12 additional locations. This data file was expanded through intersection turning movement counts recently collected in anticipation of the Signal System study. To assist in the analysis, volume profiles were plotted to visually indicate traffic fluctuations by hour, by 15-minutes, by day, and by average weekday.

The highest volume streets or highways within the City generally carry less than 20,000 vehicles per day. Most of these are two-way, four-lane surface streets. Gordon Drive (Highway 20) has the most traffic in the City over an extended distance with traffic volumes of 24,000 vehicles per day near Nebraska Street and 22,000 near Fairmount Street. Other major traffic carriers include:

Street	Vehicles Per Day
Combination Bridge	31,000
Lewis Boulevard	18,000
Interstate 29	16,000
Hamilton Boulevard	16,000
Pierce	14,000
3rd Street	14,000
Nebraska	13,000
6th Street	13,000
Dace	12,000
5th Street	12,000
4th Street	11,000
Morningside	11,000
Transit	11,000
Jackson Street	11,000

Traffic volumes on most of the other collectors or arterials in the network typically range between 5,000 and 10,000 vehicles per day.

EXISTING TRAFFIC FLOW CHARACTERISTICS

A major task in the review of existing conditions consisted of a detailed investigation of traffic flow characteristics. Intersection turning movement data and directional volume data were analyzed to acquire an in-depth knowledge of the traffic flow characteristics on the street system. This analysis was performed for three time periods; 7 to 8 AM, 1 to 2 PM, and 4 to 5 PM which represent the AM peak, a typical off peak, and the PM peak period. Turning movement count data for each time period was plotted on large scale maps. Color coded overlays were then produced to show total volume per link (directional street segment between signals), major traffic flow, and major turning movement locations.

Analysis of this data, together with transportation planning data, determined the preferred routes and indicated travel demand. Hamilton Boulevard, 5th Street, 6th Street, Pierce Street, Gordon Drive, Lewis Boulevard, and Fairmount Street were identified as major routes carrying a high percentage of through traffic. These streets have traffic volume in excess of 500 vehicles per hour during most of the daylight hours. Nebraska Street, 18th Street, Dace (EB), and 4th Street (EB) are also vital links serving the predominant traffic flow during the PM peak hour.

The primary AM peak, off peak, and PM peak period traffic flow characteristics are shown in Figures 4, 5, and 6, respectively. The traffic flow characteristics tend to indicate a large number of through trips in the CBD. Through trip corridors include the Combination Bridge in conjunction with 5th and 6th Streets, and Pierce and Nebraska Streets combined with Gordon Drive.

The analysis identified unusually high turning movement volumes at numerous intersections in the CBD. This is due in part to the one-way street network and the circulatory characteristics of a CBD. Although most cities experience pronounced turning movements in the downtown area, turning movements in Sioux City are above average in both volume and proportion of locations. This situation makes system operation in Sioux City more complex since signal timing and preferential progression movements will require decisions that are somewhat subjective to select the high priority routes.

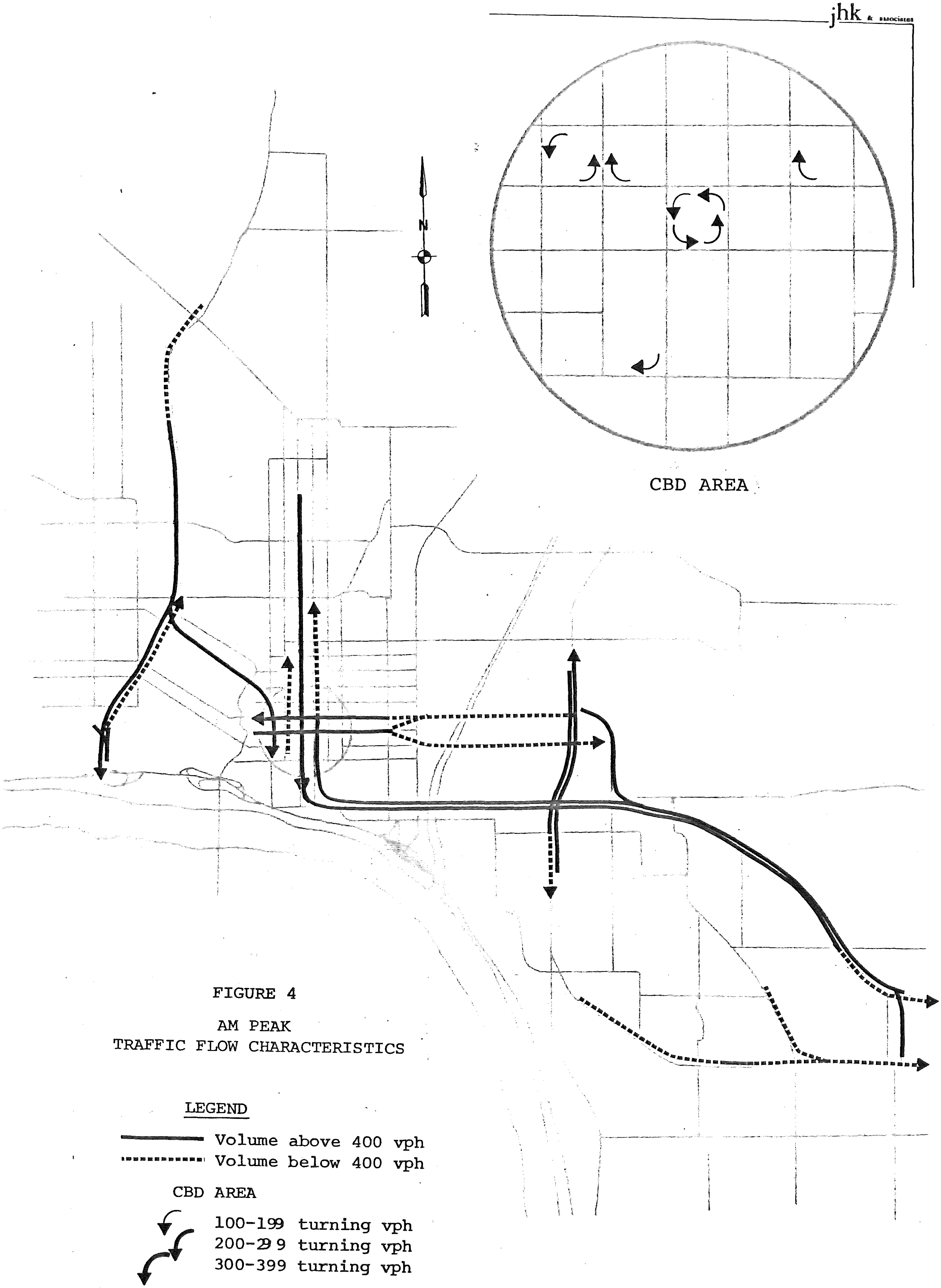

FIGURE 4

AM PEAK
TRAFFIC FLOW CHARACTERISTICS

LEGEND

Volume above 400 vph
Volume below 400 vph

CBD AREA

100-199 turning vph
200-299 turning vph
300-399 turning vph

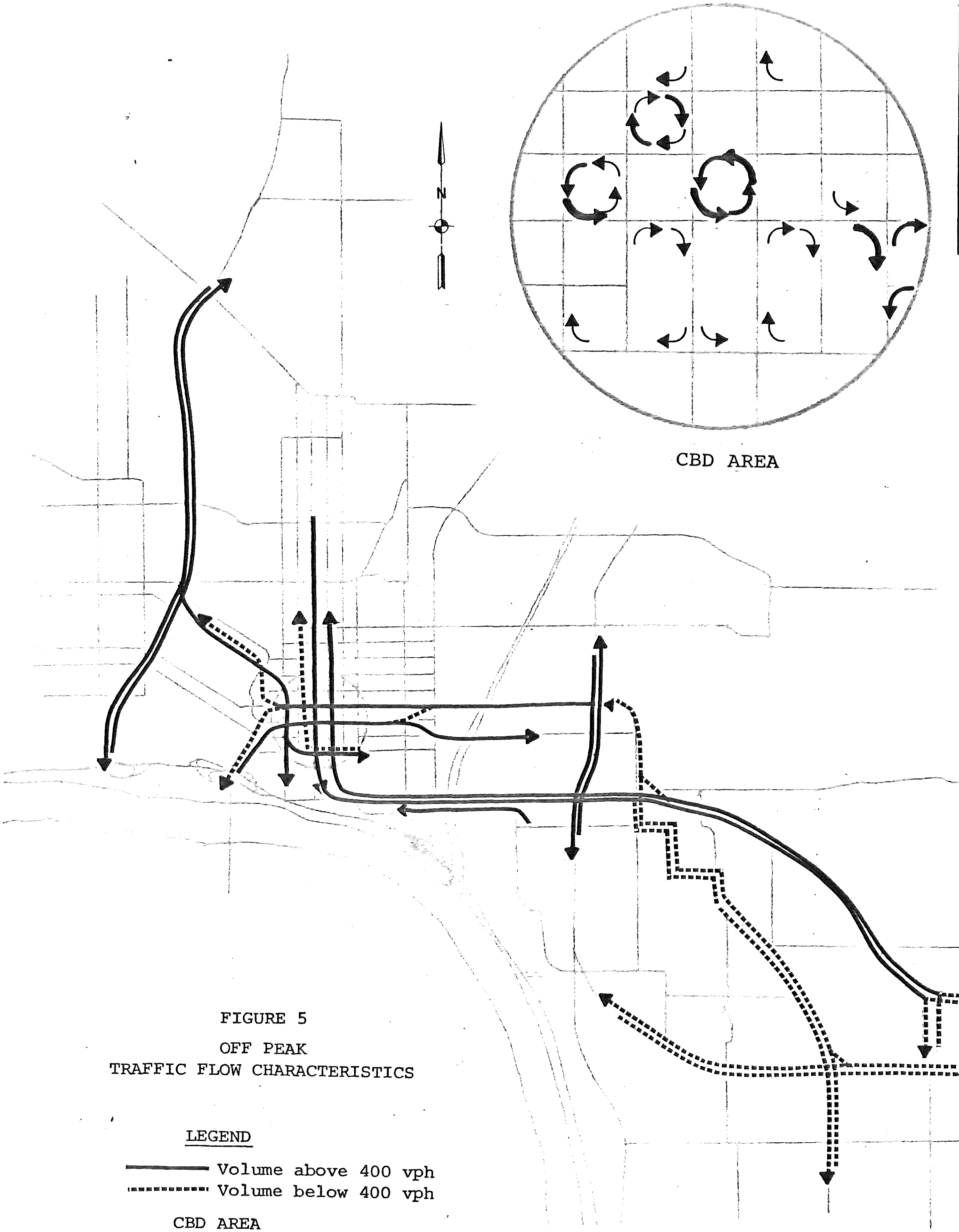

FIGURE 5

OFF PEAK

TRAFFIC FLOW CHARACTERISTICS

LEGEND

Volume above 400 vph

Volume below 400 vph

CBD AREA

100-199 turning vph

200-299 turning vph

300-399 turning vph

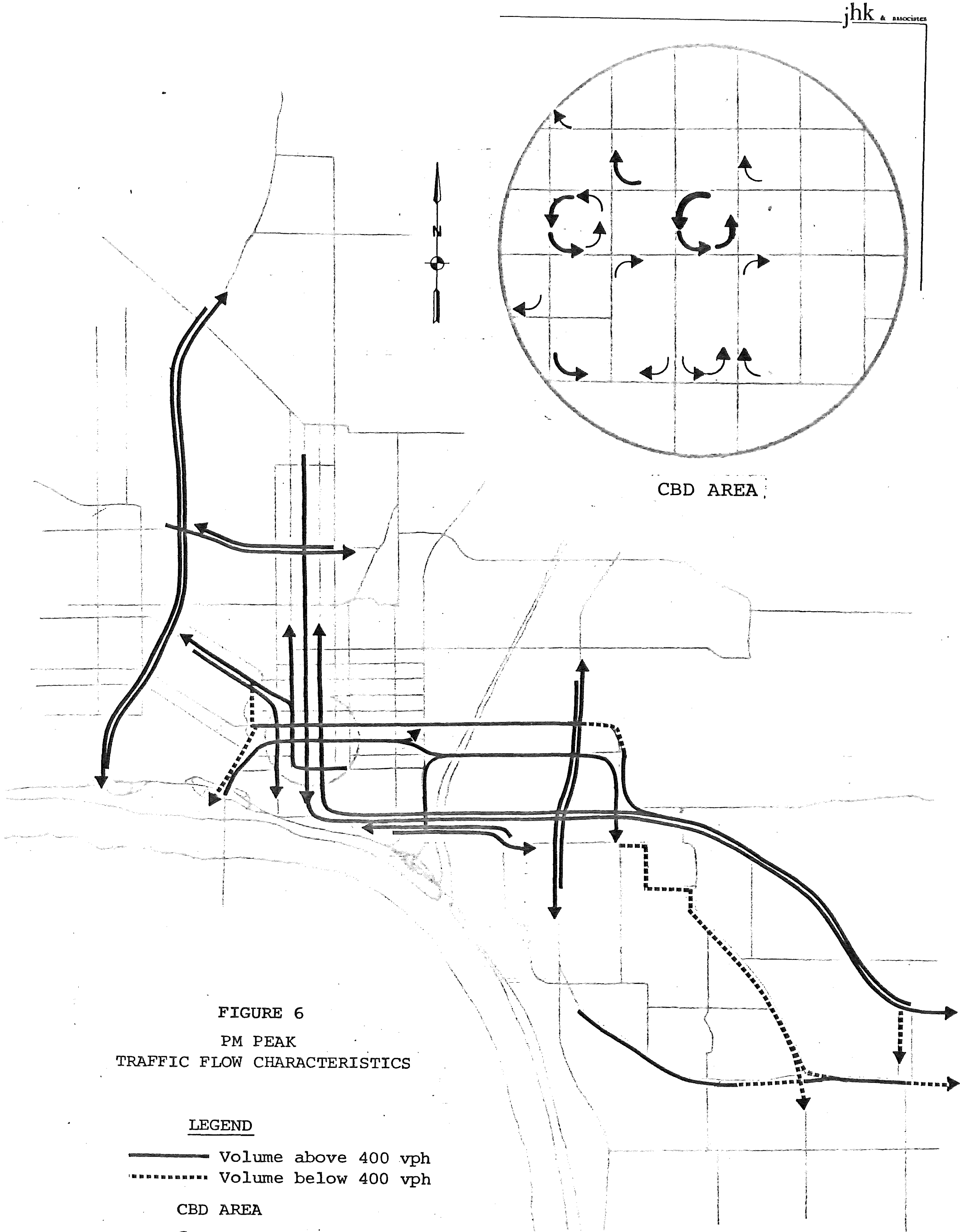

FIGURE 6

PM PEAK

TRAFFIC FLOW CHARACTERISTICS

LEGEND

Volume above 400 vph

Volume below 400 vph

CBD AREA

100-199 turning vph

200-299 turning vph

300-399 turning vph

During the AM peak, most streets experience unbalanced traffic flow with the CBD acting as the focal point. For instance, Hamilton Boulevard experiences a southbound preferential flow while Lewis Boulevard has a northbound flow. Although the heaviest turning movements occur in the CBD, the intersection of Morningside Drive at Transit Street, Fairmount at Gordon, and Floyd at 4th Street also experience significant turning movements.

Balanced traffic flow is generally observed throughout the network during the off peak periods. However, traffic volumes are relatively high in comparison to the AM peak although not as critical as in the PM peak period. The number of locations where turning movements occur in the CBD and the turning volume is greater in the off peak than in the AM peak, a phenomena which continues to increase through the PM peak. The major turning movements occur at:

- Nebraska at 5th, 6th, and 7th Streets
- Pierce at 5th, 6th, and 7th Streets
- Douglas at 5th, 6th, and 7th Streets
- Pearl at 5th and 6th Streets

The PM peak period is characterized by directional outbound traffic flow away from the CBD on most streets. The relative magnitude of directional traffic volumes are generally 10% to 30% higher than the off-peak period.

The traffic flow characteristics described above are useful in defining directional street travel patterns and the street segments which require special attention during signal system design and timing plan development. The total traffic flow characteristics, however, do not always indicate where the problem areas exist in the street system. For example, consider two one-way streets each carrying 600 vehicles per hour. Based on an analysis of total traffic, these streets would receive equal treatment. However, if one of the streets had three lanes while the other street had only one it is obvious that the single lane facility would require special consideration.

To determine the effects on vehicle concentration due to varying street widths in the network, color coded overlays were produced to depict lane volumes throughout the system. Total volumes in excess of 500 VPH and lane volumes in excess of 300 VPH were used as criteria to define street segments that were candidates for special consideration. A comparison of these findings is presented in Table 3. From this it can be seen that many streets which appear to be critical based on an examination of total volume do not meet the criteria when lane volumes are examined. Conversely, lower volume streets may become more critical due to limited number of traffic lanes.

TABLE 3 - COMPARISON OF TOTAL VOLUME TO LANE VOLUME AS AN INDICATOR OF PROBLEM AREAS

Street	Direction	Traffic Volumes Over 500 v/hr			Lane Volumes Over 300 v/hr		
		AM	Off Peak	PM	AM	Off Peak	PM
Hamilton	SB	X	X	X			
Hamilton	NB			X			
5th Street		X	X	X			
6th Street		X	X	X			
Pierce Street		X	X	X		X	X
Gordon	EB	X	X	X	X	X	X
Gordon	WB	X	X	X	X	X	X
Lewis	NB	X	X	X			
Lewis	SB	X	X	X		X	X
Fairmount	NB	X	X	X			
Fairmount	SB	X	X				X
Nebraska				X			
18th Street				X			X
Dace	EB			X			
4th Street	EB			X			
W. 7th Street	EB					X	X
W. 7th Street	WB					X	X
Floyd	SB				X		
Floyd	NB				X		X
5th Street						X	
Transit	EB				X	X	X
Transit	WB					X	X
Morningside						X	

DAILY VOLUME CHARACTERISTICS

An analysis of traffic peaking characteristics was conducted using directional 24-hour traffic counts which had been collected during the past two years. The volume data was plotted by 15-minute intervals and color coded by traffic direction. The plots were then located on a large scale map to provide a visual display. The time of occurrence, duration, and severity of peak traffic conditions were then determined by inspection. A typical volume profile graph is shown in Figure 7.

In general, the peak traffic periods occur at approximately the same time throughout the network. The AM peak occurs between 7:30 and 8:30 AM and the PM peak period begins about 4:30 and ends at 5:30 PM. The highest peak 15 minutes usually occurs between 8:00 to 8:15 AM and between 5:00 to 5:15 PM. After the AM peak, traffic volumes drop to their lowest daytime level at about 9:30 to 10:00 AM. Traffic then increases and reaches a noon time peak and then remains relatively constant. There is a general increase in traffic beginning about 3:30 PM reaching a pre-peak level around 4:15 PM. The PM peak period builds rapidly starting about 4:30 PM reaching the highest volume at 5:15 PM. Traffic volumes then decrease rapidly until 5:45 PM at which time the reduction is more gradual.

With few exceptions, the traffic volume profiles of conflicting intersection approaches "tracked" each other; that is, their peaks and valleys occurred at the same time. This indicates that control techniques that reallocate signal cycle split on a cycle-by-cycle basis (critical intersection control) would be of little value. A noticeable exception is Hamilton Boulevard and TriView due to the Zenith shift change at 3:30 PM.

An examination of daily variations was made by plotting five day traffic counts. From this it was determined that the time occurrence of the peak periods is relatively constant throughout the week. Daily variations in traffic volume were noted, as was

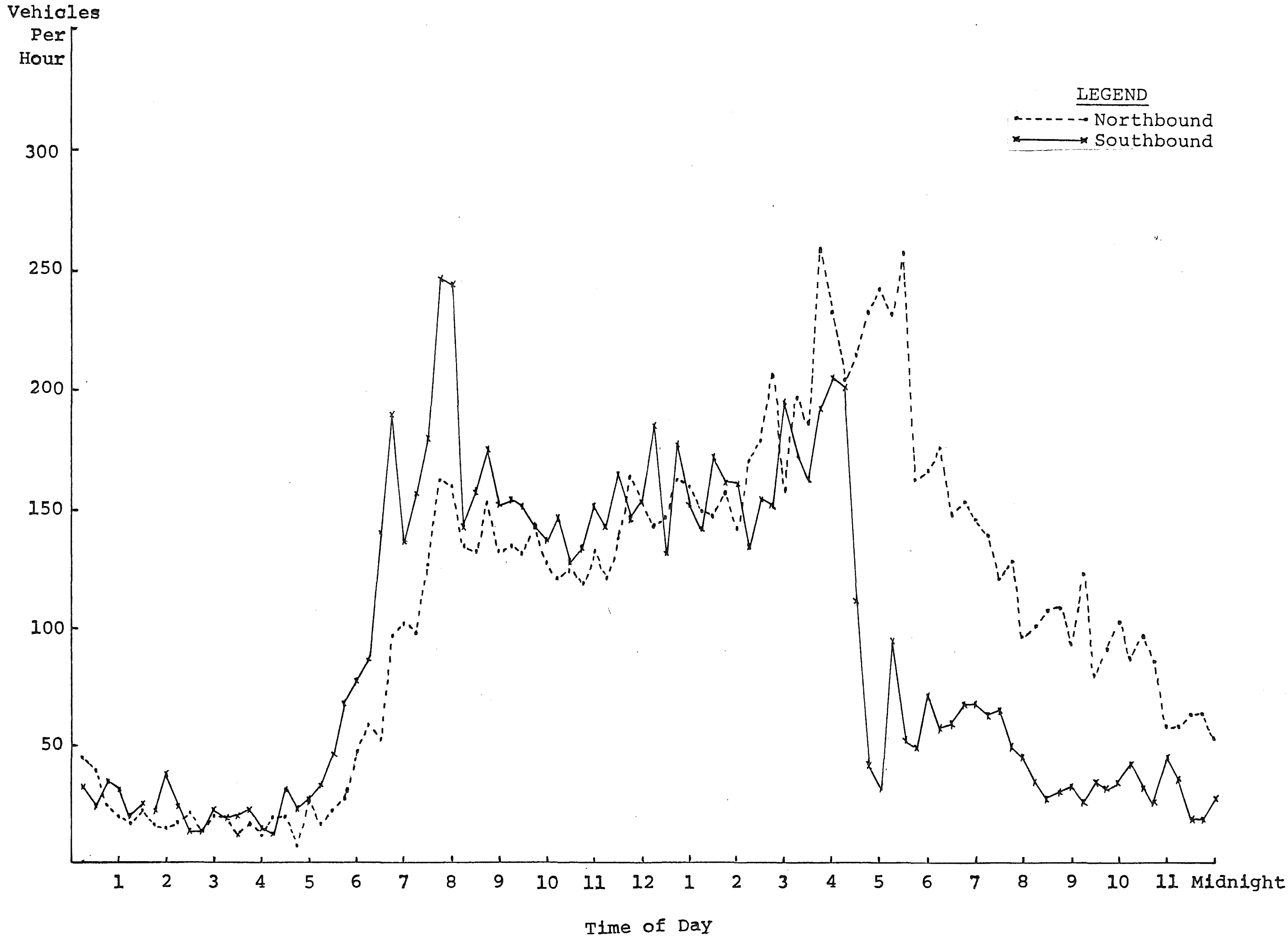

FIGURE 7
TYPICAL VOLUME PROFILE

expected. The lowest volumes occur on Monday and the highest on Friday, again as expected. Little variation was noted on Tuesday through Thursday. An example of typical weekly traffic variation is shown in Figure 8 which shows the five day average volume and the highest and lowest volumes experienced during the week. Locations near colleges or shopping centers generally experienced more variation in traffic than the example shown.

Saturday traffic was found to be similar to weekday traffic except that the AM and PM peak is less pronounced. Within the CBD traffic volumes from about 10:00 AM to 6:00 PM are similar to weekday midafternoon traffic volumes with a peak occurring about 2:00 PM. Sunday traffic, however, is very light throughout the City.

TRAVEL TIME STUDY

Average travel time (or speed) within the system was investigated to provide a performance indicator of the existing system operation. Limited travel time and delay studies were conducted on nine routes by the City and JHK & Associates during the week of April 11, 1977. The results of this study, summarized in Table 4, indicates that a vehicle traveling over one of these routes would be delayed from one to three minutes. This means that if the roadway carried 13,000 vehicles per day, the total delay could be in excess of 600 hours.

The delay or wasted time experienced on each route is shown graphically in Figure 9. Excess delay is shown, by direction, by indicating as excess travel time the difference between the distance a vehicle could have traveled at the desired speed and the distance actually traveled in the same time interval.

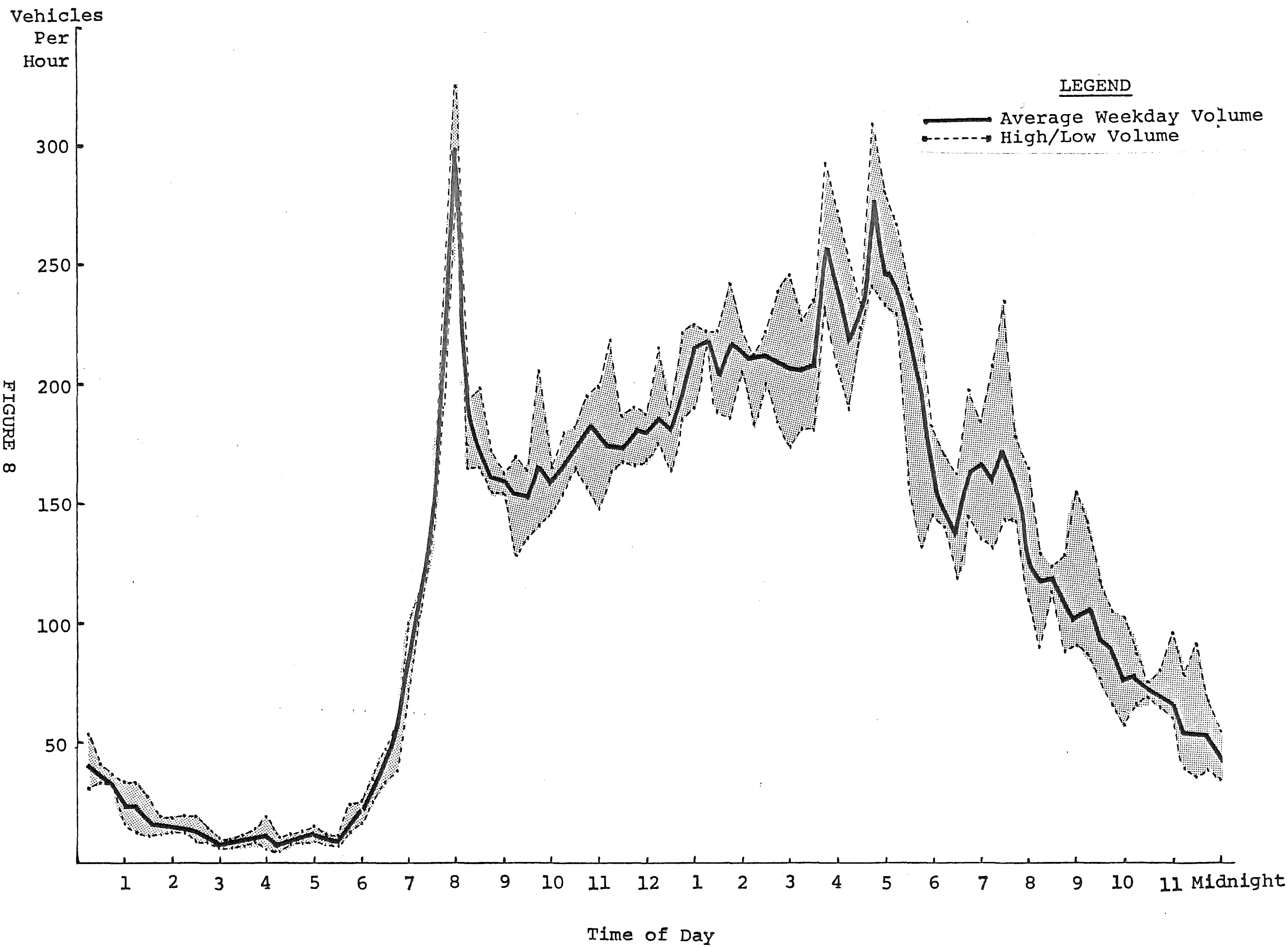

FIGURE 8
TYPICAL WEEKDAY TRAFFIC VARIATIONS

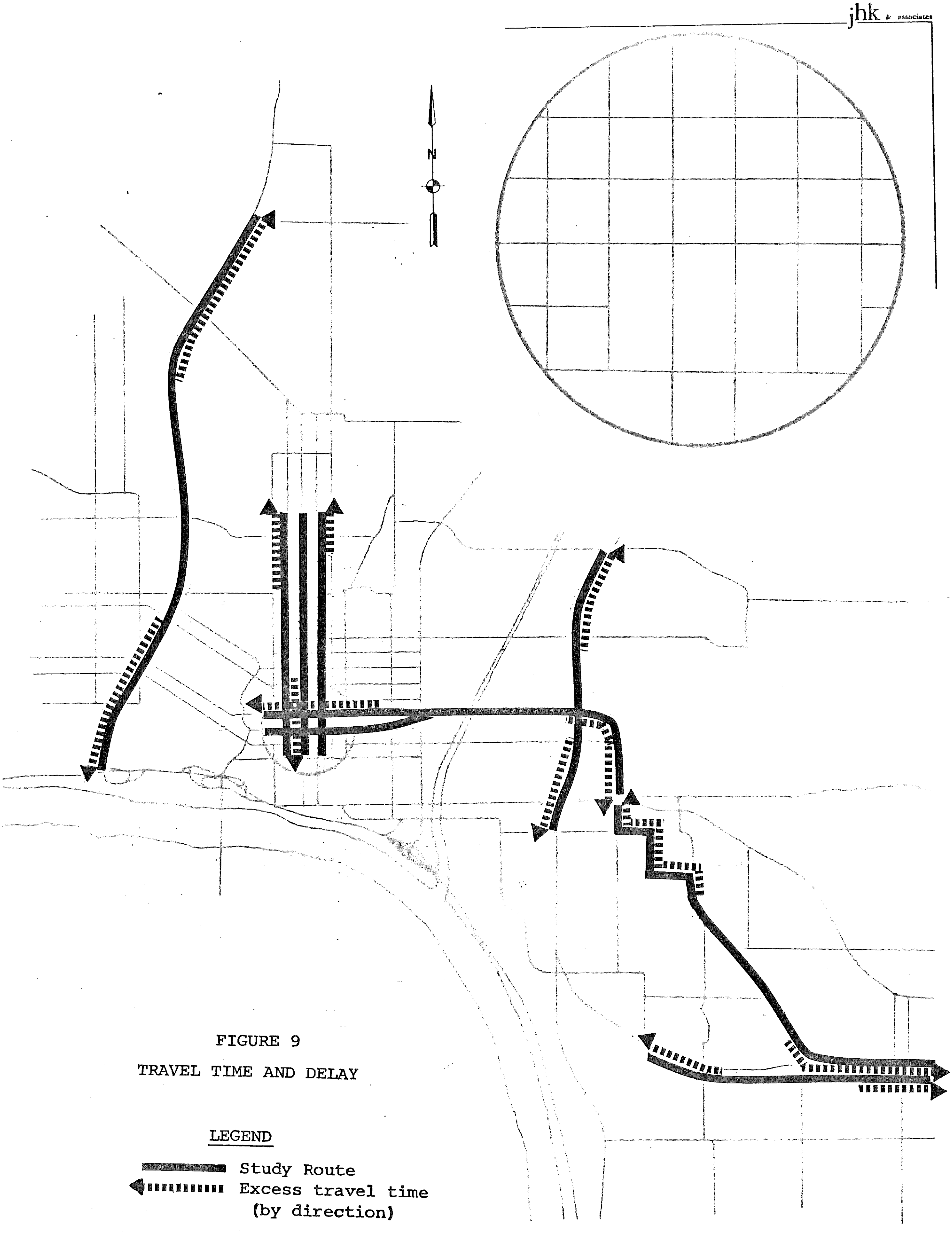

FIGURE 9

TRAVEL TIME AND DELAY

TABLE 4 - TRAVEL TIME AND DELAY STUDY SUMMARY

Route	Direction	Average Speed (MPH)	Average Stopped Delay (Sec/Veh)	Excess Travel Time (Min/Veh)
Douglas	NB	19.0	46	1.3
Pierce	SB	19.5	39	1.4
Nebraska	NB	22.5	4	0.9
6th Street	EB-WB	21.6	51	1.8
5th - 6th Streets	EB-WB	20.7	68	2.0
Lewis	NB	22.1	52	1.5
Lewis	SB	22.5	68	1.4
Morningside - Transit	EB	22.2	33	1.2
Morningside - Transit	WB	22.7	35	0.9
Morningside	WB-NB	21.0	63	2.1
Morningside	SB-EB	20.1	83	2.5
Hamilton	NB	22.9	81	2.7
Hamilton	SB	25.2	83	2.0

SPECIAL EVENTS

An investigation was made of special events (e.g. sports events, concerts, etc.) that would have an impact on traffic flow and affect system operation.

City Auditorium

The City Auditorium, located south of 3rd Street between Pierce and Pearl is the major entertainment facility in the CBD. The auditorium has a permanent capacity of approximately 2700 seats and can be modified to seat as many as 5100 people. The auditorium offers a wide variety of entertainment including hockey, basketball, concerts, the circus, special displays, sports shows, and other activities. These events are offered seven days a week during the day and evening. Frequently joint activities, such as a dance and a hockey game, are offered at the same time. The following are typical event attendance:

Event	Attendance
Hockey	2000
Basketball	600 to 4000
Circus & Ice Capades	3500
Boat Shows, Sport Shows, Etc.	6000*
Flea Market (Saturday)	600 to 1000**
Dance	400 to 500
Concert	5100

Approximately six to nine major concerts are scheduled each year. The Ice Capades and Shriner's Circus are scheduled yearly and have three shows per day for over a week. In addition, there are 25 to 30 lesser events per year that have attendance of approximately 3,000 persons.

Parking for 640 vehicles is available adjacent to the auditorium and additional parking is available on the street or in private lots nearby. Traffic can generally be cleared after an event in less than 20 minutes and police traffic control is not used. However, major event traffic is at a critical level and increased attendance would overload the system.

The auditorium will be expanded by the construction of an arena having a seating capacity in excess of 10,000. This will be complemented by a City parking ramp having a capacity for 2000 vehicles. The arena will be opened in approximately 5 to 7 years and will substantially increase attendance at the auditorium complex. Increased traffic control measures, including signal operation, will be required to accommodate the additional traffic generated by the increased attendance.

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* In a 5 to 6 hour period

** Over a 6 hour period

Rivercade Festival

The Rivercade Festival is a week long event held in July of each year. It is initiated by a two-hour parade and is characterized by shows, displays, and other festivities concentrated in the Marina area. As the event draws approximately 30,000 persons per day, it significantly impacts traffic in the CBD area. Although not supported by data, it is reasonable to assume that special timing plans could improve traffic flow during this event.

Roberts Public School Stadium

The Roberts Public School Stadium is located in the Morningside area west of Morningside Drive. This stadium is used by the three high schools during football season with games scheduled three nights a week during this period. Although the stadium is not immediately adjacent to signalized intersections, traffic on Morningside Drive and Transit are affected.

Evening Shopping

Merchants within the CBD remain open two nights a week for evening shopping. The most intense activity occurs on Friday night and tends to make the duration of the PM peak longer than normal. Promotion of the evening shopping by providing convenient access is necessary if the CBD is to maintain its status as a regional shopping center.

Other Activities

Several other entertainment centers such as the dog and horse race tracks in North Sioux City and South Sioux City, respectively, the Hawkeye Ball Field, and private school sports centers were investigated to determine their impact on traffic flow. However, it was determined that these activities did not appreciably affect traffic flow in Sioux City.

TRANSIT

Sioux City Transit currently operates 13 regular routes within the City to provide service within a quarter mile of almost 95% of the population. Service is provided every half hour during the peak periods and every hour during the off peak. All bus lines extend from a central transfer point in the CBD. In addition to the regular service special services are offered to the handicapped and elderly, service to nursing homes on selected routes, and service to Dakota City and Sargent Bluff.

The operation of the transit facility has been satisfactory within the existing street network and signal operation. However, the central transfer point will be relocated and there is concern as to the ability of the signal system to accommodate buses re-entering the network during the peak demand periods.

EMERGENCY VEHICLES

A primary concern in the operation of emergency vehicles (Police, Ambulance, and Fire) is the hazard resulting when emergency vehicles enter an intersection against a red light. The available accident data involving emergency vehicles from 1947 to 1977 was investigated to determine actual experience. A summary of the accident history by type of emergency vehicle is shown in Table 5.

TABLE 5 - SUMMARY OF EMERGENCY VEHICLE ACCIDENT EXPERIENCE

	Fire			Ambulance			Police		
Period	No.	Injuries	Fatals	No.	Injuries	Fatals	No.	Injuries	Fatals
1947-1957	7	8	2	1	0	0	N/A	N/A	N/A
1957-1967	8	0	0	0	0	0	N/A	N/A	N/A
1967-1977	6	9	1	5	8	1	24	18	0

N/A - Not Available

From this it can be seen that the accident rate for fire apparatus has been relatively constant during this period with an average of one accident per two years. There has been an increase in the accident rate for ambulances with the current accident rate approximately the same as for fire apparatus. Although the data did not permit the accident trend for police units to be determined, they are involved in the most accidents averaging 2.4 accidents per year.

As the preemptive operation of signals can be used to facilitate the movement of emergency vehicles under certain conditions, discussions were held with the Fire Chief and the Chief of Police. From this the following conclusions were reached:

- Due to the mobility of police units, preemptive signal operation was not seen as useful. A continuing personnel training program was considered the primary factor to insure safe and efficient movement of police units.
- Ambulance movement from South Sioux City to St. Luke's, St. Joseph, and St. Vincent Hospitals was seen as the only ambulance service that presented a problem where signal preemption may be of benefit. However, this service is provided by private firms and occurs no more than two times a week indicating that preemptive operation by means of devices located onboard the vehicle is not practical. Preemptive operation initiated by the city communications dispatchers could not be performed without increasing the number of staff and making a capital investment to modify the communications facility. It was, therefore, concluded that the most effective operation could be achieved through Police assistance.
- Due to the ability to define routes that will be repeatedly used the movement of fire apparatus could be enhanced by signal preemption. In addition, the size of fire apparatus tends to result in severe accidents.

To determine the frequency of exposure of fire apparatus to hazardous conditions, the number of vehicle movements in response to fire alarms during 1976 was summarized and is shown in Table 6.

Station 4, located at Hamilton Boulevard and Stone Park Boulevard, responds to an average of 2.5 alarms per day. Station 1 located at 5th Street and Water Street and Station 3, located at 6th Street and Iowa Street respond to an average of 1.4 and 1.5 alarms per day.

TABLE 6 - SUMMARY OF 1976 FIRE ALARMS

Station	Total Alarms	Ave. Alarms Per Day
1	502	1.4
3	556	1.5
4	918	2.5

The accident rate per miles traveled for fire apparatus assigned to these stations was computed using the accident experience from 1967 to 1977 and the vehicle miles driven during 1976 expanded to a ten year period. This resulted in a rate of one accident per 8000 vehicle miles. In view of these findings, techniques to improve the safety of fire apparatus are an important consideration in the system evaluation and design.

ACCIDENT ANALYSIS

Intersection accident records for the years 1973 to 1976 were investigated to define the overall accident picture and to permit an assessment of the accident experience frequently related to signal system operation to be made. From this it was determined that one-half of the signalized intersections are in the City's Hazard Category*. These high accident locations are shown in Figure 10.

As the accident records for the three year period 1973 to 1975 included data on accidents occurring on the intersection approaches as well as those occurring within the intersection, this data was

* Five or more accidents per year that are correctable by signals.

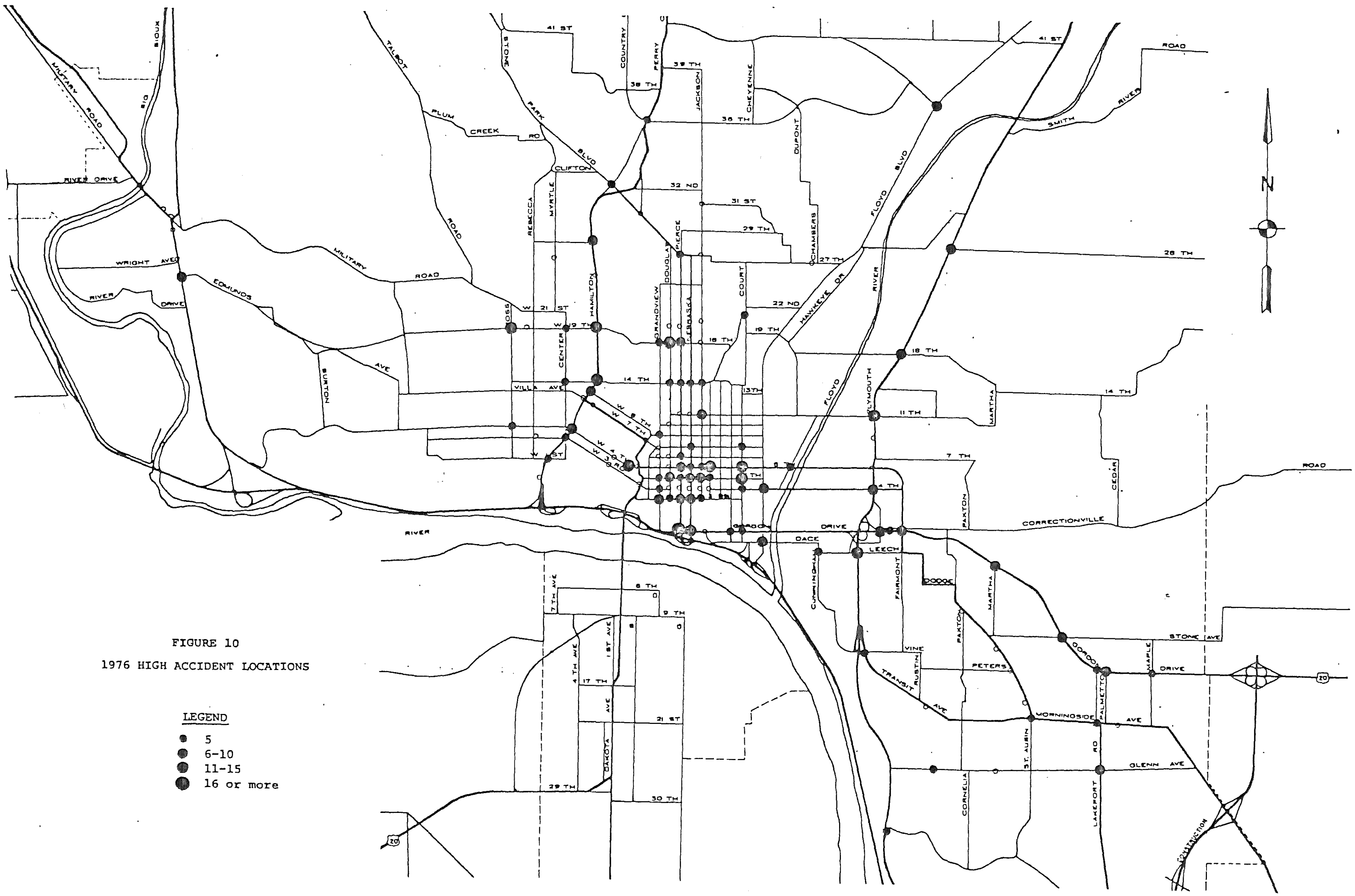

FIGURE 10

1976 HIGH ACCIDENT LOCATIONS

LEGEND

- 5
- 6-10
- 11-15
- 16 or more

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used for accident type analysis. The accident rates occurring within the intersection was first compared to the 1976 data to determine any significant trend changes. As only minor differences were noted, it was determined that excluding the 1976 data would not affect the systemwide analysis.

For the three year period a location-by-location accident profile was developed and summaries of accident experience by type was made. This included the types of accidents affected by signal operation (right angle, rear-end, and left turn), and all others. An average for the three year period was then computed and is shown in Table 7. From this it can be seen that 80% of the accidents are signal related. In addition, over 50% involved turning movements.

TABLE 7 - SUMMARY OF AVERAGE YEARLY ACCIDENTS BY TYPE

	Total	Right Angle	Rear End	Left Turn	Other
Number	493	187	137	70	99
Percent of Total	100%	38%	28%	14%	20%

During this analysis it was noticed that signals in the CBD appeared to have a higher number of rear-end accidents than in the rest of the City. It was felt that this was occurring due to the effects of signal progressions or the delayed walk signal operation in conjunction with high traffic volumes, heavy turning movements, and a large number of pedestrians.

To investigate this in more detail eight high accident signal locations in the CBD that had the delayed walk signal operation were selected for evaluation. It was determined that these intersections experienced an average rate of 11.6 accidents per year versus 10.3 for the remaining signals in the system. Also, 34% of the accidents at these eight locations are rear-end as compared to a system average of 28%. It was considered significant that the percentage of rear-end accidents exceeds 50% at the four signals at the intersection of 5th and 6th Streets with Nebraska and Pierce Streets.

A linear regression analysis was performed to investigate any relationship between accident experience and equipment reliability. The intersection trouble call (non-scheduled maintenance) record was used as the measure of equipment reliability. This analysis indicated that there is a positive relationship with a correlation coefficient of .29. This indicates that more than just a casual relationship exists between equipment reliability and accident experience and that this is a partial explanation of accident history.

INCLEMENT WEATHER

As inclement weather affects "normal" traffic flow characteristics, data from the U.S. Weather Bureau was investigated. A summary of the average number of days in which fog, rain, snow and ice is experienced by month is shown in Table 8. Precipitation of .01 inches or more occurs on 27% of the days of the year and snow and ice of one inch or more occurs on 3% of the days.

TABLE 8 - INCLEMENT WEATHER SUMMARY (Average 1941 to 1970)

	Days With			
Month	Fog	Thunderstorms	Precipitation	Snow & Ice
January	3	*	7	2
February	3	*	7	2
March	2	1	9	2
April	1	4	10	*
May	1	7	11	*
June	1	9	11	0
July	1	9	9	0
August	1	8	9	0
September	1	5	8	0
October	2	2	6	*
November	2	*	5	1
December	3	*	7	2
Yearly Average	19	45	98	10

* Less than 1/2 day

An investigation was also performed to determine the relationship between accidents and weather conditions. The percentage of total yearly accidents by roadway condition is shown below:

Roadway Condition	Percentage of Accidents
Dry	68%
Ice	10%
Wet	22%

From this it can be seen that the percentage of accidents occurring during icy conditions is greater than the percentage of times ice or snow conditions occur indicating a more hazardous situation.

III. FUTURE TRAFFIC CONDITIONS

An effective traffic control system must have sufficient flexibility to accommodate future traffic conditions. However, providing flexibility implies that the system initially has unused capabilities and that these capabilities were provided at an additional cost. Therefore, it is necessary to make an assessment of future traffic characteristics to determine what impact, if any, they will have on a system installed to meet today's needs. The system should have reserve capabilities to meet future requirements; however, providing capabilities beyond this level is not cost-effective.

The analysis of future traffic conditions consisted of a review of programmed capital improvement projects, projects recommended as part of the long-range transportation planning activities, estimated future growth, and discussions with various officials within the City.

CAPITAL IMPROVEMENT PROGRAM

The Technical Supplement to the 1977-82 Capital Improvement Program was reviewed to determine programmed improvement projects that would affect traffic flow characteristics. This investigation was supplemented by a review of the 1990 Sioux City Urban Area Transportation Improvement Program to determine other unprogrammed improvement projects proposed to achieve the long-range transportation goals of the City. A summary of this review, indicating the project status (under construction, programmed, planned, or proposed), is shown in Figure 11. The following is a general description of these significant projects.

> Hamilton Boulevard, W. 26th Street to Stone Park - Widen Hamilton Boulevard to provide left turn storage lanes and upgrade signalization. Under construction.

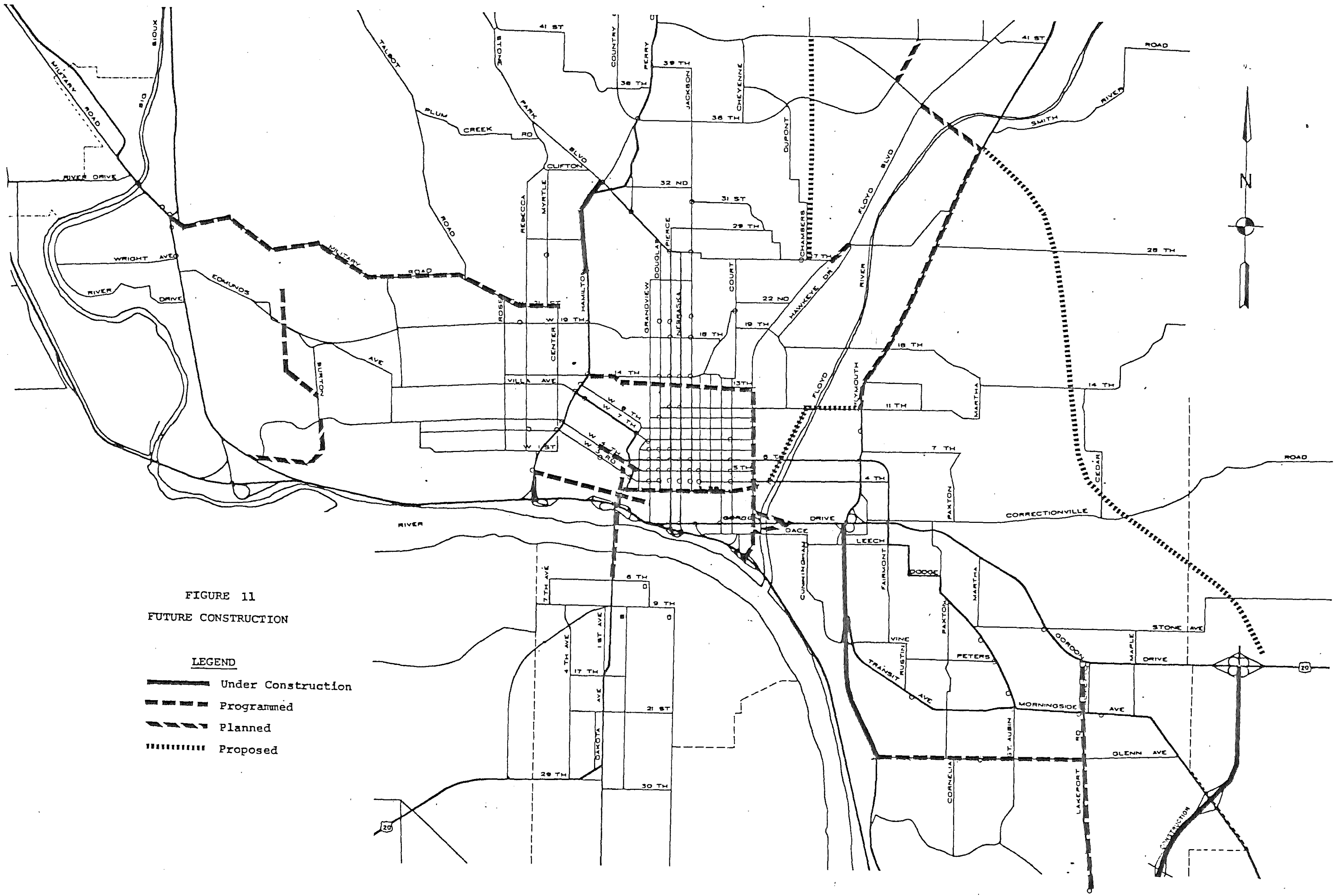

FIGURE 11
FUTURE CONSTRUCTION

LEGEND

- Under Construction
- Programmed
- Planned
- Proposed

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Lakeport Street, I-20 to Gordon Drive - Widen to four lanes and provide an improved one-way connector to Palmetto at Morningside Ave. The project is programmed in three phases to be completed in 1981.

Lewis Boulevard (U.S. 75), Leech Ave. to Glenn Ave. - Reconstruction and new alignment between Glenn and Transit Ave. Scheduled completion 1978.

Combination Bridge Replacement - Replacement of the existing combination bridge with a new bridge and a three-level interchange. Scheduled completion 1981.

3rd Street Connector, Pearl Street to Wesley Way - Construction and realignment of 3rd Street to the north end of the Combination Bridge Improvement Project. Scheduled completion 1978.

Glenn Ave., Lewis Boulevard to Lakeport Street - Widening and channelization of Glenn Ave. Programmed for 1982.

Innerloop, Genevia to McDonald - Construction of a portion of the Innerloop to provide four lanes with channelization. Scheduled 1978 to 1980.

Innerloop, Virginia to 10th and Floyd - Construction of a portion of the Innerloop to provide four lanes with left turn lanes. Scheduled for 1981.

W. 3rd Street to 5th Street Connector - Construction of a connector between W. 3rd to 5th Street to permit the 5th and 6th Street one-way pair to connect with W. 3rd and W. 4th to facilitate east-west movement beyond Hamilton Boulevard. Scheduled for 1981.

Innerloop, McDonald to Virginia - Construction of a portion of the Innerloop to provide four lanes along 13th Street with left turn lanes. Scheduled for 1982.

Innerloop, Wesley Way at 3rd to 13th Street - Construction of the west leg of the Innerloop to provide a north-south by-pass for the downtown area. Program scheduled indefinite.

3rd Street to 4th Street Connector - Construction of a four-lane connector between 3rd and 4th Streets between Court Street and Floyd Boulevard. The facility will provide east-west access and is a part of the Innerloop plan. Scheduled for 1980.

Outer Drive, Floyd Boulevard to Lewis Boulevard (U.S. 75) Extension of the northern segment of Outer Drive to connect with Lewis Boulevard. This is integral part of the total Outer Drive concept. Programming has been deferred.

Floyd Boulevard, 5th Street to I-29 - Reconstruction of Floyd Boulevard to provide four traffic lanes between I-29 and 5th Street with ramp connectors to Gordon Drive. This is an integral part of the Inner-loop concept. Programming has been deferred.

4th Street Viaduct - Widening of the 4th Street Viaduct between Floyd and Hoeven to provide a four lane facility. Scheduled for 1981.

Interstate 520, Lakeport to Gordon Drive - Construction of a 1.9 mile segment of freeway to extend I-520 to Gordon Drive. Programmed for 1982.

Floyd Boulevard, 5th Street to 10th Street - Reconstruction of Floyd Boulevard to provide four lanes with left turn lanes as part of the Innerloop. Programming has been deferred.

3rd Street, Court to Pearl Street - Reconstruction of 3rd Street to provide four lanes with left turn lanes. This project is an integral portion of the Innerloop to provide downtown access. Project is scheduled for 1979.

W. 4th Street, Burton to Riverside - Construction of a replacement for W. 4th Street to provide a connector to Riverside Drive. Project schedule has been deferred.

Sunnybrook Drive Extension - A two-lane extension of Sunnybrook to meet Freeway 520. This project schedule has been deferred.

Lewis Boulevard, 11th Street to Outer Drive North - Reconstruction of Lewis Boulevard (U.S. 75) to provide driveway control, turn lanes and median. Project schedule has been deferred.

Sunnybrook Extension, Freeway 520 to Lincoln Way - Construction of a two-lane facility between Freeway 520 and Lincoln Way to serve as a collector. Project schedule has been deferred.

Floyd Boulevard, 27th Street to 28th Street and 33rd Street to 38th Street - Widening of Floyd Boulevard at these locations to provide four lanes with left turn lanes. This would permit four lane operation for the total length of Floyd Boulevard. Project schedule has been deferred.

Ruston Drive Extension, Outer Belt to 41st Street - Extension of Ruston Drive as a two-lane collector between 41st Street and the Outer Drive. Project schedule deferred.

Lincoln Way Extension, Lakeport to Sunnybrook - Construction of a two-lane facility to serve as a collector between Lakeport and the future extension of Sunnybrook. Project schedule deferred.

Military Road, Center Street to Riverside Boulevard - Widening and resurfacing of Military Road to provide 31 foot width with curbs. The project is significant in that Military Road is a major east-west arterial that is badly deteriorated. Project programmed for 1979.

Gordon Drive Extension, Pearl to Hamilton - This is an extension of Gordon Drive to provide an east-west connector along the Gordon Drive Corridor. Project schedule has been deferred.

Burton Street, W. 14th Street to W. 23rd Street - Relocation of Burton Street to provide north-south access. Project scheduled for 1981.

In addition to the review of the 1977-82 Capital Improvement Program, the 1990 Sioux City Urban Area Transportation Improvement Program dated December 1975 was also reviewed. From this review three additional projects were identified that, if implemented, would have impact on traffic characteristics in Sioux City.

Outer Drive, Lewis Highway to Gordon Drive - This facility would complete the Outer Drive facility to provide circumferential access to the areas north, east, and south of the CBD.

Buckwater Drive Extension, Floyd Boulevard to 41st Street - This facility would serve as a four-lane arterial to provide access to the northern portion of the City.

Hoeven Drive Extension - A four-lane extension of Hoeven Drive between 11th Street and 18th Street is proposed to provide improved north-south access and to provide improved truck circulation and access to the adjacent areas which have a large concentration of truck terminals.

The Sioux City Central Area Traffic Flow and Roadway Improvements Study and the Sioux City Community Work Shop Concept Plan were also reviewed to determine if there were additional projects under consideration that would affect future traffic conditions. Although these reports provided more detailed information concerning proposed projects in the CBD, they are generally contained in the projects previously described.

ESTIMATED GROWTH

To assess future traffic conditions in Sioux City, it is necessary to estimate population growth within the design life of the system. As it is generally agreed that ten years is a realistic design life for a signal control system (although the actual life of the system is expected to extend beyond this) growth trends within the City to 1990 were estimated. Sources used for these estimates included U.S. Census Bureau Data; Commercial Land Use Study, Report No. 4 dated March 1, 1976; SIMPCO General Plan Volume A dated 1971; the 1990 Urban Area Transportation Improvement Program Report; and Updated Population Estimates provided by SIMPCO.

Frequently growth estimates are made based on historical trends that are corrected to account for changing conditions such as land use, industry incentives, etc. Sioux City is somewhat unique in that historical growth patterns do not appear to provide a reliable indicator to estimate future population. For example, between 1950 and 1960 the City experienced a 6% growth rate. However, due to adverse economic conditions, the population declined by 3.6% between 1960 and 1970. This down-turn has been reversed and the City has experienced about a 1% increase in population from 1970 to 1975.

Population growth was thus estimated using an average consensus value based on the referenced data sources. From this, it would appear that a population growth of about 20% will occur in the period 1975 to 1990. This represents a growth rate of a little less than 1% per year during the 15 year period.

The major growth is expected to occur in the northeast area of the City, generally defined by the area north of 18th Street and east of Douglas, and to the south of the City in an area generally located to the south of Glenn Ave. and bounded by the Missouri River on the west. In the northeast area, a 60% growth is expected by 1990 representing about 10,000 additional residents. Estimates of growth in the south are more varied, ranging from approximately 35% to 100%. This translates into an estimated population increase of from 3,000 to almost 10,000 residents. The CBD, including the adjacent area to the north, and the Riverside area are expected to have the least growth. The remainder of the City is expected to have a generally uniform growth pattern.

ANTICIPATED FUTURE TRAFFIC CONDITIONS

Based on the review of programmed and proposed improvement projects, the estimated growth patterns, and the SIMPCO Metropolitan Area Alternate 4, Year 2000 Traffic Projections, an assessment of future traffic conditions as related to traffic signal system operation was performed. The assessment included an estimate of future signal locations to permit system size and physical configuration to be established. The investigation also included an assessment of the system flexibility required to meet future traffic requirements. The following is a brief description of the findings of this review.

° Traffic flow characteristics within the CBD will be substantially altered as a result of the proposed improvements. Total traffic volumes within the CBD are expected to remain at about the current level. However, trip purpose and traffic flow characteristics are expected to change substantially. In addition, several periods of change will be experienced due to the phased implementation of proposed projects.

Completion of the new Combination Bridge together with the realignment of 3rd Street and the 3rd Street/4th Street Connector is expected to place more emphasis on 3rd Street -- particularly for through traffic having South Sioux City and the northeast or east portion of the City as its origin/destination. The realignment of W. 3rd Street to 4th Street will have a similar effect and both projects will tend to reduce the number of turning movements within the CBD.

In a similar manner the improvement of Wesley Way from the Combination Bridge to 13th Street is expected to divert north-south through trips that currently use Douglas or Nebraska Street. Completion of the Innerloop would also tend to remove many of the trips now being made from the southeast to the north areas of the City. The Innerloop will also tend to remove through east-west trips that currently use 6th Street. However, the attraction for through east-west trips on the Innerloop will be substantially reduced for trips originating in the southeast portion of the City by the extension of Gordon Drive to TriView. It is also expected that the extension of Gordon Drive would divert trips destined for the Morningside area that are currently using I-29 or CBD streets.

As these projects will be staged, the future traffic patterns cannot be precisely predicted. For example, if the Innerloop were completed before the improvements to 3rd Street and Gordon Drive were made, a totally different traffic pattern would develop than if the 3rd Street/Gordon Drive improvements were completed before the Innerloop. A similar situation would also occur by the staging of 3rd Street improvements and the realignment of W. 3rd when compared to the completion of Gordon Street Extension.

The analysis thus indicates that the CBD traffic control system must respond to substantial changes in traffic conditions and that frequent signal timing updating will be required.

- Traffic patterns in the Morningside Area will also undergo substantial changes. The upgrading of Lakeport, the improving and realigning of Lewis Boulevard, and roadway improvements on Glenn Avenue will tend to emphasize these facilities and deemphasize Morningside Drive. The Lakeport improvement as well as the extension of I-520 are also expected to increase usage of Gordon Drive.

  These projects will require installation of several new signals (and the possible removal of several signals on Morningside Drive) which will result in reconfiguring system boundaries. This indicates that a system installed in this area must have expansion capabilities, the ability to be easily reconfigured and the ability to have the timing easily updated.

- Other streets having significant changes are Lewis Boulevard and Hamilton Boulevard. Due to growth in the northeastern portion of the City and improved access provided by the extension of Outer Drive North, traffic volumes on Lewis Boulevard will increase from 14,000 to 17,000 vehicles per day to over 25,000 vehicles per day. In a similar manner, traffic on Hamilton Boulevard will increase from 14,000 to 16,000 vehicles per day to over 20,000 vehicles per day.

- Completion of the Outer Loop would increase usage of 36th Street. Traffic volumes would increase from approximately 4,000 vehicles per day to 10,000 to 13,000 per day. However, as this is primarily a residential area few additional new signals would be required due to these increased volumes.

An investigation was performed to provide an indicator of where new signals may be required to meet future traffic conditions. From this investigation, it is estimated that approximately 50 additional intersections will be signalized by 1990 based on estimated growth patterns, completion of the planned and proposed improvement projects, including the Outer Drive, and by limiting the development of major retail trade to the CBD. The majority of the new signal installations in the CBD would result directly from the Innerloop. A large concentration of new signals would also be required in the Morningside area primarily along Lakeport, Gordon, and Lewis. The remainder of the signals would be distributed throughout the City.

IV. SYSTEM DEFINITION

The analysis of existing and future conditions provides the framework to generally define the system. This section provides an overview of the system configuration considerations unique to Sioux City which are the basis for defining requirements to be considered in the evaluation of systems.

SUBSYSTEMS

As the signal system study is an areawide investigation of all signals in the City, it is necessary to group them into smaller systems, or subsystems, for operational analysis purposes. A subsystem is defined as an area which experienced homogeneous traffic signal control requirements. The subsystem boundaries were defined based on signal spacing, type of network (i.e. arterial or grid), traffic flow characteristics, and an analysis of timing requirements.

Initial subsystem boundaries were defined based on the existing street geometry, signal location, and existing traffic conditions. A second investigation was then made to define modifications to the initial subsystem boundaries or additional subsystems that will be required to accommodate future changes in the street network, new signal locations, and future traffic characteristics.

The primary objective of the subsystem boundary definition is to define areas in which all signals provide maximum operational efficiency when subjected to a common control strategy. This is a major step in defining the requirements that the upgraded traffic control system should accommodate. In subsequent analysis each system defined is investigated independently to determine its specific requirements such that the best overall traffic control strategy can be developed.

Initial Subsystem Boundaries

The initial subsystem boundaries were developed by first considering physical barriers and grouping signals that appeared to be interrelated (e.g. closely spaced). Within each group so defined, the cycle length requirements were then investigated to determine whether compatible cycle lengths could be used in the total area. This was performed by considering the minimum cycle length required to meet pedestrian crossing times. The cycle length was then computed at selected key intersections for the AM, PM, and off peak periods using Webster's formula for optimum cycle length to reduce delay. The optimum signal cycle lengths, modified as required based on minimum pedestrian cycle length requirements, were then compared within the area to determine whether the initial grouping was properly configured or if it should be subdivided.

Cycle lengths of adjacent areas were also compared to determine if they experienced similar requirements throughout the entire day which would indicate that the two areas should be combined. Where requirements were totally different or were similar during only portions of the day, two separate subsystems were defined.

Where adjacent subsystems were defined that experienced similar cycle requirements during portions of the day, they were examined to determine if there was an interaction of traffic between them and if the interconnecting roadway characteristics (distance between signals, grade, side friction, etc.) was such that operating the two subsystems as a single subsystem (i.e. interfacing of subsystems) was desirable to reduce boundary disruptions.

The above analysis was supplemented by computer timing program SIGART and SIGRID. SIGART is an arterial timing program that computes all possible two-way progressions within a speed range defined by the user. SIGRID is a grid network timing program that computes signal offsets to minimize a delay function based on the desired speed, traffic volume on each link of the network, and the importance assigned to each link. From this analysis, nine subsystems were defined to meet existing conditions and are shown in Figure 12. The following describes the general characteristics of each subsystem.

Riverside Subsystem - The Riverside Subsystem is defined as a small arterial system remotely located from all other subsystems in the City. Traffic is predominantly southbound during the morning and northbound during the PM peak, although less pronounced. The SIGART timing analysis indicated that good two-way progression can be achieved and substantial benefit would be realized by interconnecting the signals.

Hamilton Boulevard - The Hamilton Boulevard street network has been defined as two arterial subsystems; the North Subsystem and the South Subsystem. Although these two subsystems should be interfaced during the peak periods when preferential flow differentials exist, the SIGART analysis indicated that superior performance could be realized during balanced flow conditions by permitting them to operate separately. The cycle lengths producing the most efficient two-way progression bands in the North Subsystem are not complementary to the requirements of the South Subsystem. However, the peak period optimal cycle lengths are quite similar.

Central Subsystem/CBD Subsystem - These two subsystems were developed in concert and the area was initially considered as a single subsystem. Both areas have similar optimal cycle length requirements and show similar geometric constraints when evaluated through computer timing program SIGRID. However, optimal operation requires that two subsystems be considered for the area due to differing traffic characteristics. The Central Subsystem is essentially a north-south corridor providing access to and from the CBD. This traffic is characterized by many through trips and very low turning volumes. On the other hand, the CBD Subsystem is a mixture of north-south and east-west through trips as well as a high percentage of CBD oriented trips. The area is characterized by heavy turning volumes and requires a traffic control strategy somewhat different than required by the Central Subsystem. As a final consideration, the

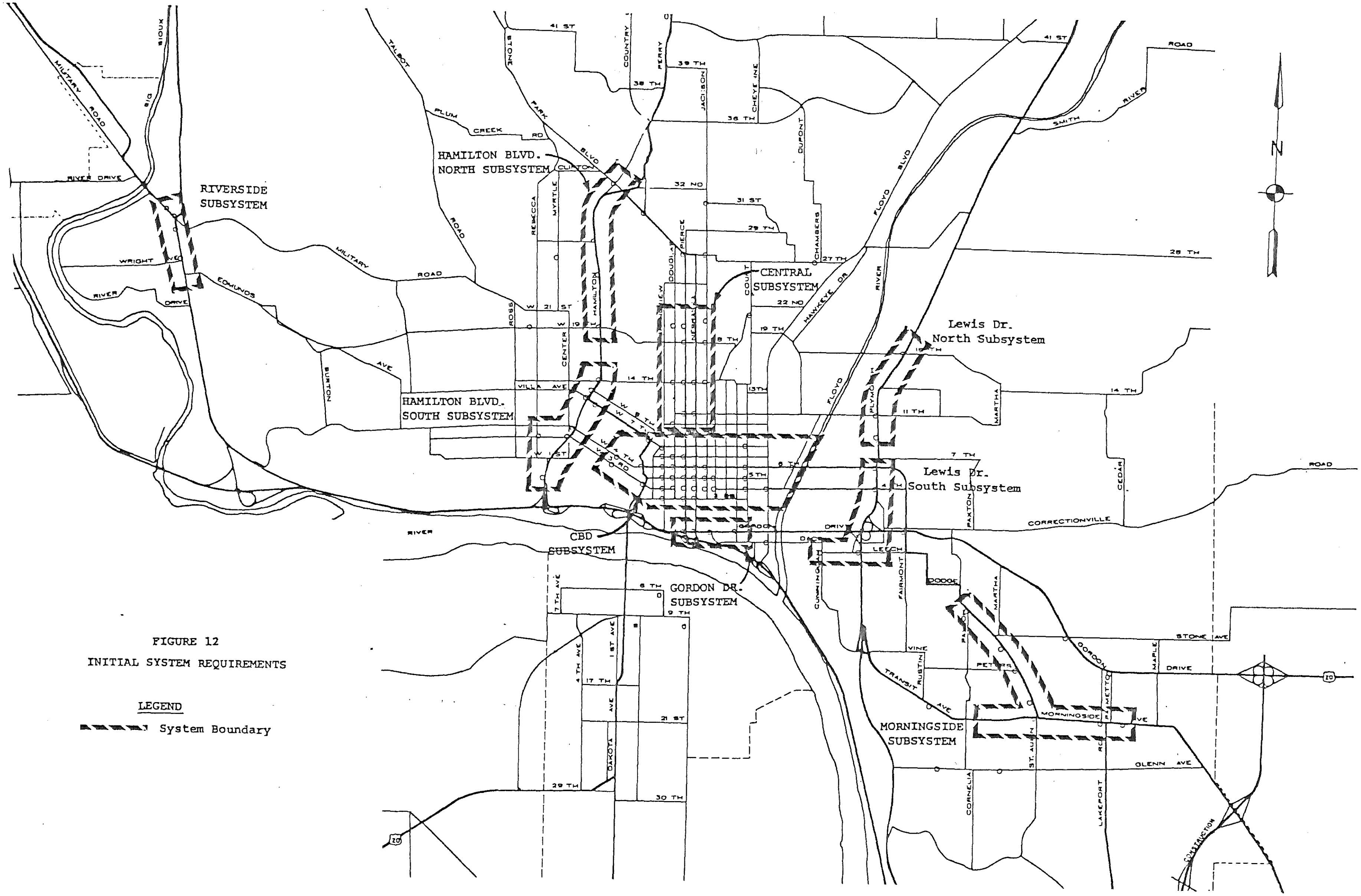

FIGURE 12

INITIAL SYSTEM REQUIREMENTS

LEGEND

System Boundary

CBD Subsystem will require a longer off peak and nighttime cycle length than that required in the Central Subsystem due to the cycle length constraints imposed by the delayed walk indications used in the CBD. It should be noted that there is a requirement to interface the CBD Subsystem with both the Central Subsystem and the Hamilton Boulevard South Subsystem. This will facilitate traffic movement between these subsystems during the peak periods.

Gordon Drive Subsystem - The Gordon Drive Subsystem is defined as an arterial type system. The SIGART analysis indicated that reasonably good two-way progression can be provided. The optimal cycle length calculations and the traffic flow analysis also indicate that this system should have the ability to interface with the CBD Subsystem during portions of the day.

Lewis Boulevard Subsystem - The Lewis Boulevard network has been divided into two subsystems, the North and the South Subsystems. The SIGART analysis of this arterial system indicated that greater efficiencies in two-way progression could be realized in the North Subsystem than would be realized if the two systems were combined. However, adding the North Subsystem to the South Subsystem does not degrade efficiency of the South Subsystem. In view of this and since similar optimal cycle lengths are required in both subsystems during portions of the day, the subsystems should have the ability to be interfaced.

Morningside Subsystem - The Morningside Subsystem consists of two arterial streets, Morningside and Transit, that should be operated as a single subsystem. It should be pointed out that the SIGART analysis indicated that this subsystem will provide the greatest efficiency during preferential traffic flows. Extensive use of actuated controller equipment to permit unused green time to be returned to the arterials will be required to realize a satisfactory level of efficiency during balance flow conditions.

The remaining signals should not be included in initial system operation. These signals are remotely located and do not directly interreact with the subsystems defined above. The analysis indicates that greater efficiency can be obtained by isolated, full-actuated operation.

Future Subsystems

Based on the analysis of future traffic flow conditions, supplemented by computer timing program SIGART, an assessment of future subsystem boundary requirements was made. As this assessment was based on estimated future signal locations, it is expected that some on-going modification of these boundaries will be required. However, the analysis is of sufficient precision to establish future subsystem requirements.

The future subsystem requirements are shown in Figure 13. The modifications and additions to the initial subsystems are as follows:

Central Subsystem - The Central Subsystem would be modified by extending the eastern boundaries to include new signals at Floyd and 11th and at 13th and Court due to the Innerloop. In addition, system retiming will be required to emphasize the Innerloop facility. It should be noted, however, that the SIGART analysis indicated considerable difficulty in developing good two-way progression along 13th Street due to the close signal spacing. This factor should be considered during the design of the Innerloop.

Combination Bridge Subsystem - The three level diamond interchange signals to be installed at the north end of the Combination Bridge has been defined as a separate subsystem. Independent system operation for this facility is indicated due to the complexity of the configuration and special operation requirements. This subsystem, however, should have the ability to interface with the CBD subsystem during portions of the day.

CBD Subsystem - The southern boundary of the CBD Subsystem would be expanded to include the signal at Pearl and the Gordon Street extension. It would be desirable, however, to have the ability to assign this signal to either the CBD Subsystem or the Gordon Drive Subsystem based on traffic conditions.

Lewis/Transit Subsystem - The three signals to be located at the ramp configuration of Lewis at Transit is defined as a separate subsystem. During portions

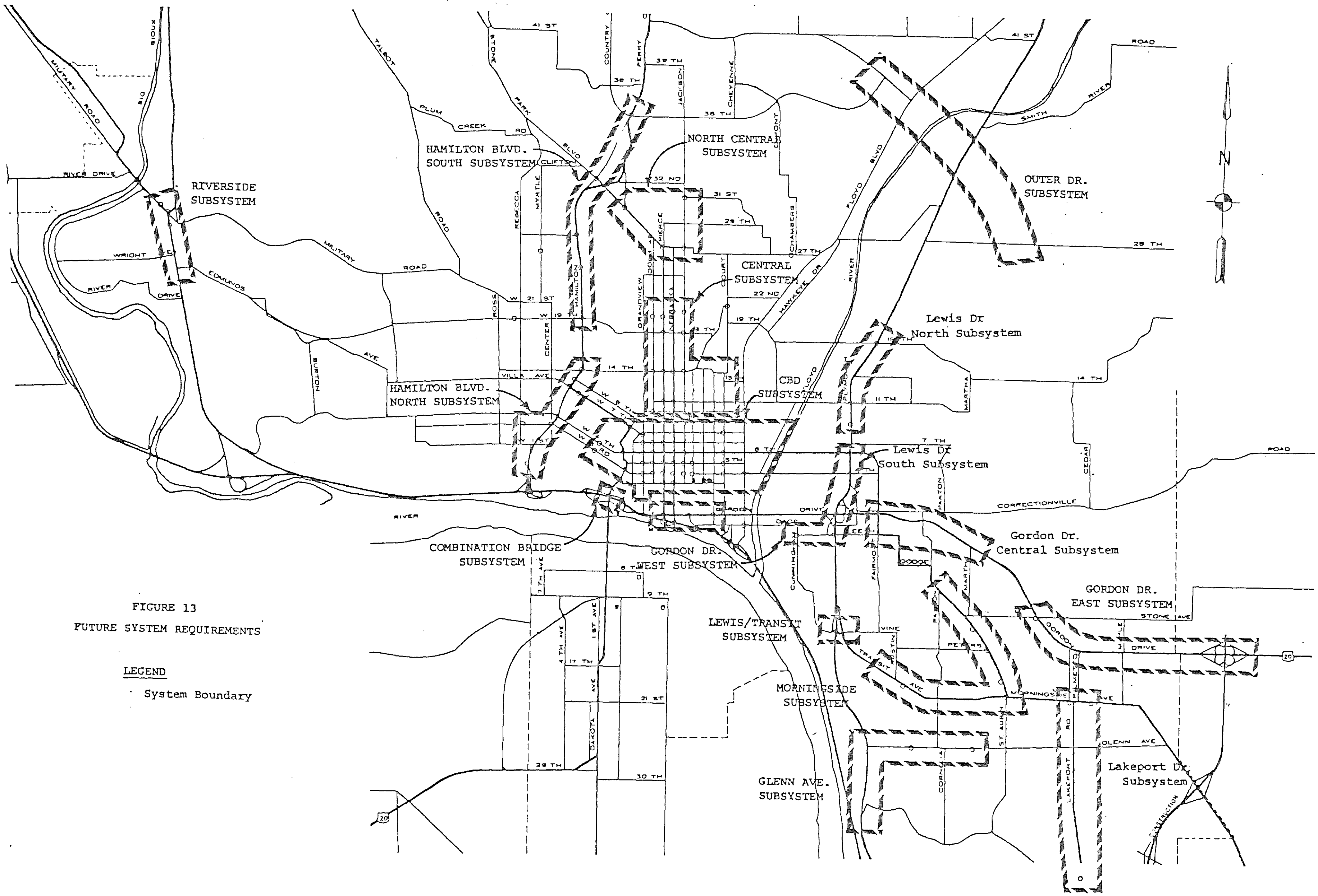

FIGURE 13

FUTURE SYSTEM REQUIREMENTS

LEGEND

System Boundary

of the day it would be desirable to interface this with the Morningside Subsystem to facilitate northbound Transit to Lewis traffic flow.

Morningside Subsystem - The Morningside Subsystem would be modified to delete those signals east of Transit and to extend the western boundary on Transit to include a possible new signal at Fairmount.

Lakeport Subsystem - The signals on Morningside at Lakeport and Cedar would be reassigned from the Morningside Subsystem to a new Lakeport Subsystem that would extend to I-520.

Gordon Drive Subsystem, Central/East - Due to increased signal density two new subsystems will be required on Gordon Drive. As good two-way progression can be provided by treating both subsystems as a single subsystem, they should have the ability to be interfaced. However, maximum flexibility will be realized by providing two systems to permit the Gordon Drive East Subsystem to be interfaced with the new Lakeport Subsystem.

Glenn Avenue Subsystem - Glenn Avenue was defined as a future subsystem due to the excellent two-way progression indicated by the SIGART analysis. Providing good east-west movement together with the Lewis Extension is expected to de-emphasize the Morningside route.

Outer Drive Subsystem - This subsystem would be required in the event at-grade intersections are built on Outer Drive in lieu of the interchanges proposed on the Urban Area Transportation Improvement Program. System operation would be required due to the high speeds expected on this facility.

North Central Subsystems - Increased signal density in the North Central area, particularly in the vicinity of St. Luke's Medical Center, indicates that system operation will be required. In addition, SIGART analysis along Stone Park and Jackson indicates that excellent two-way progression can be developed. This subsystem should have the ability to interface with the Hamilton Boulevard North Subsystem.

Hamilton Boulevard North Subsystem - This initial subsystem will require expansion to include the signal at 36th Street.

A summary of the subsystem characteristics including the type of controller operation required is shown in Table 9.

TABLE 9 - SUBSYSTEM CONFIGURATION SUMMARY

Subsystem	Signals Exist.	Signals Future	Controller Type	Interface With Subsystem
INITIAL SYSTEM				
Riverside	4	5	Actuated	None
Hamilton				
° North	5	5	Actuated	Hamilton South
° South	9	10	Actuated	Hamilton North CBD
Central	13	23	Pretimed/ Actuated	CBD
CBD	36	41	Pretimed	Hamilton South Central Gordon Dr. Combination Bridge*
Gordon Dr.	4	4	Pretimed	CBD
Lewis				
° North	3	3	Actuated	Lewis South
° South	4	6	Actuated	Lewis North
Morningside	8	9	Actuated	Lewis/Transit* Lakeport
FUTURE SYSTEM				
Combination Bridge		1	Actuated	CBD
Central Gordon Dr.		4	Actuated	East Gordon
East Gordon Dr.		4	Actuated	Central Gordon* Lakeport
Lewis/Transit		3	Actuated	Morningside
Lakeport		9	Actuated	Gordon Dr. East* Morningside
Glenn Ave.		4	Actuated	
North Central		6	Actuated	Hamilton North Central
Outer Drive		4	Actuated	

* Future Subsystem

In addition to the previously defined subsystems, there is sufficient interaction of traffic between Sioux City and South Sioux City across the Combination Bridge to coordinate the operation of the signals within the two cities. To promote efficient operation between the two cities the Sioux City Signal System should have the ability to control signal operation in South Sioux City.

In view of the time consuming administrative details that would be involved in a multi-city, multi-state system operation, it is recommended that this project proceed without reaching a commit-tment to include or exclude signals in South Sioux City in the modernized system. However, during system design consideration should be given to future operation of these signals and conduit space should be included in the new Combination Bridge construction project to permit communications cable to be installed at a later date.

SIGNAL TIMING PLANS

Identifying the number of different signal timing plans to be used in each subsystem is an important step in defining the capabilities required of a signal system. Where there are good indications that a large number of timing plans are required consideration should be given to a very capable system -- perhaps one using adaptive control strategies. If only a few timing plans are required, a less capable system may be a better alternative unless there are other factors that define the need for a complex system.

A detailed signal timing analysis was performed to provide an indicator of the number of timing plans that would be required in Sioux City on a recurring basis to accommodate traffic during a "typical day". This included an analysis of cycle length and split requirements for various time periods supplemented by computer timing programs SIGART and SIGRID.

All subsystems except the CBD and Central Subsystems experience traffic characteristics that clearly define the need for distinct timing plans to accommodate the AM, PM, and off peak periods. The analysis also indicated that there may be a need for transitionary timing plans between the peak and off peak periods and a plan for the noon time peak.

The timing plan requirements within the CBD and Central Subsystems were more difficult to identify. Distinct differences in cycle and split requirements for the peak periods and the off peak were evident. However, there were many similarities between the AM peak and the PM peak in terms of cycle length and split that initially indicated that the same plan may be applicable for both periods.

To determine if there were substantial differences between the AM and PM peak timing plan requirements an analysis using computer timing program SIGRID was performed. SIGRID computes a performance index measure, delay propensity, to indicate the tendency of a strategy to produce delay. A control strategy was developed for the PM peak period which experiences the heaviest traffic condition. This strategy was then evaluated using the AM peak period traffic volumes and traffic characteristics. A comparison of the resulting delay propensity showed that use of the same timing plan during both periods would tend to generate excess delay indicating the need for unique plans. The analysis also indicated, however, that a strong case could not be built for many additional control strategies beyond an AM, PM, and off peak period plan.

SYSTEM FLEXIBILITY

An important aspect of the system is consideration of the flexibility required to accommodate future conditions. To define these requirements an estimate of the level of flexibility required in each subsystem was made. The items considered were the modifications to subsystem boundaries and the level of signal retiming that would be required. Signal retiming requirements were defined as major, a total retiming of the subsystem; and minor, changes in the split or offset at only a few signals in the subsystem. An estimate of how often it will be necessary to perform major signal retiming for each subsystem as well as an estimate of the number of minor adjustments required for each year was made. A summary of these estimated requirements is shown in Table 10.

TABLE 10 - SYSTEM FLEXIBILITY

System	System Boundary Modifications	Retiming Major (Frequency)	Retiming Minor (No. Per Year)
INITIAL			
Riverside	None	3-5 yrs.	1-2
Hamilton			
° North	Expansion	2-3 yrs.	3-4
° South	None	3-5 yrs.	2-3
Central	Expansion	2-3 yrs.*	3-4*
CBD	Expansion	1-1/2-2 yrs.	6-8
Gordon Dr.	None	2-3 yrs.	2-3
Lewis			
° North	None	3-4 yrs.	2-3
° South	Expansion	2-3 yrs.	3-4
Morningside	Major Reconfiguration	1-1/2-2 yrs.	3-4
FUTURE			
Combination Bridge	None	1-2 yrs.	5-6
Central Gordon Dr.	None	2-3 yrs.	1-2
East Gordon Dr.	None	2-3 yrs.	1-2
Lewis/Transit	None	2-3 yrs.	2-3
Lakeport	None	1-1/2-2 yrs.	4-5
Glenn Ave.	None	2-3 yrs.	1-2
North Central	Expansion	2-3 yrs.	1-2
Outer Drive	None	2-3 yrs.	1-2

* More when Innerloop completed.

SUMMARY OF SYSTEM DEFINITION CHARACTERISTICS

To provide a framework for development of alternative signal systems to be evaluated and to provide a basis for the evaluation process the primary characteristics identified during the study have been summarized. These functions were discussed in detail during the Signal System Seminar and expanded to provide the measures to define the most effective approach. These characteristics, or requirements, are briefly described within seven categories.

Subsystems

1. Initial Subsystem Boundary Configuration - The initial signal system should have the capability for operating eight subsystems. The system should also have the ability to be expanded to operate 16 subsystems in Sioux City and the signals located in South Sioux City.

2. Coordination Between Subsystems (Interface) - During portions of the day there is an interaction of traffic between certain subsystems. The engineering analysis indicated that traffic coordination to reduce boundary disruption between the following systems is beneficial in the initial system.

   - Hamilton North with Hamilton South
   - CBD with Hamilton South, Central, and Gordon Drive
   - North Lewis with South Lewis

   Additional system interface requirements were also defined for future system operation.

3. Ability to Dynamically Reassign Signals From One Subsystem to Another - The engineering analysis indicated that as a minimum the signals at Hamilton and 24th Street and at Pearl and Gordon Drive Extension should have the ability to be reallocated from one subsystem to another during various periods of the day. This would permit use of more efficient timing plans to accommodate changing traffic conditions.

Timing Plans

1. Repetitive Signal Timing Plans - The traffic flow analysis identified the need to provide a minimum of four signal timing plans within each subsystem for efficient traffic operations. These plans would be developed to accommodate the following conditions:

   ° Nighttime

   ° AM Peak Period

   ° Off peak Period

   ° PM Peak Period

   These plans are required on a repetitive basis to meet "normal" daily traffic conditions. In addition, the off peak plan would provide an adequate level of service for Saturdays and a combination of the Nighttime and off peak timing plans would be utilized on Sunday and Holidays.

2. Reserve Timing Plan Capabilities - The traffic flow analysis revealed that traffic characteristics during the off peak are continually changing from the Post-AM Peak Period to the Pre-PM Peak Period. In other words, the Off peak traffic conditions during the early portion of the day resemble the AM Peak Period while those during the latter part of the day resemble the PM Peak Period while a "balanced" Off peak Period only exists for a period of two to three hours. This indicates the desirability of providing two additional daily timing plans to provide a transition between the AM Peak Period and the generally balanced Off peak Period and a transition plan between the Off peak Period and the PM Peak Period.

   Also, due to the commercial development within the CBD two additional timing plans may be required in the CBD Subsystem and the Central Subsystem to accommodate evening shopping activities. These capabilities are specified as reserve capacity as the requirement was defined through engineering judgement supported by analysis rather than being readily defined through analysis as was the case with the repetitive signal timing plan requirement.

3. Repetitive Special Events Timing Plans - The engineering analysis indicated that there are frequent events at the City Auditorium that significantly impact traffic. In addition, the City Auditorium complex will be expanded which will increase event attendance. Special events timing plans designed to accommodate the unusual traffic characteristics after an event are required. Additional pre-event timing plans will also be required for major activities at the expanded complex.

   A similar requirement exists in the Morningside Subsystem due to the concentrated usage of the Roberts Public School Stadium.

   Selection of post-event special event timing plans at the City Auditorium should be accomplished by manual intervention. Selection of plans for the Morningside System should be performed by traffic responsive operation.

4. Infrequent Special Event Timing Plans - Several events occur in Sioux City on an infrequent basis that have significant impact on traffic characteristics. These events include Rivercade, parades, etc. and are sufficiently well defined to permit unique signal timing plans and control strategies to be developed to enhance traffic operations.

5. Inclement Weather Timing Plans - The analysis indicates that motorist safety will be increased by providing three inclement weather timing plans designed to minimize the number of stops occurring during ice or snow conditions. Additional benefit can be realized by providing timing plans for wet conditions as travel speed can be reduced up to 15% during rain.

Timing Plan Selection

1. Initial System Timing Plan Selection Technique - Traffic conditions within the CBD Subsystem and the Central Subsystem are such that signal timing plans can be selected efficiently based on time-of-day. The time-of-day selection procedure requires scheduling by day-of-week to accommodate nighttime shopping activities and weekend traffic conditions.

The remaining subsystems, due to their arterial characteristics, require traffic responsive timing plan selection for efficient operation. In addition, the Hamilton Boulevard South Subsystem requires a time-of-day override to permit isolated signal operation at TriView and selection of a northbound preferential timing plan in the remainder of the system due to the traffic impact resulting from the afternoon Zenith shift change.

2. Future Traffic Responsive Capabilities in CBD and Central Subsystems - Although existing traffic conditions within these subsystems are sufficiently predictable to permit signal timing plans to be selected on a time-of-day basis, the analysis of future conditions tends to indicate that this predictability may become unstable during the design life of the system.

3. Critical Intersection Control (CIC) - No need was identified for this mode of optimizing signal operation within the normal timing plan provided.

Intersection Controller Operation

1. Replacement of Outdated Equipment - The analysis indicated that much of the controller equipment outside of the CBD should be replaced due to excessive maintenance.

2. Controller Operation - Several items relating to local controller operations were defined as follows:

   ° Mode of Operation: Pretimed controller operation is required in the CBD Subsystem, the Gordon Drive Subsystem, and in the Central Subsystem (with the exception of selected locations requiring actuated operation). The remainder of the Subsystems require actuated controller operation with the controller being held in the primary phase until permitted to serve side street demand at a prescribed time.

   ° Signal Phasing: The system should have the ability to accommodate the existing phasing including the signal phasing that will be required at the signal installed as part of the Combination Bridge project.

- Actuated Controller Phase Control: The system should provide control for each actuated phase such that its maximum green time is independently timed.
- Pedestrian Considerations: At actuated signals the system should have the ability to accommodate pedestrians at low volume pedestrian locations without constraining the cycle length for the remainder of the system.

3. Special Controller Operation - In addition to the controller operations defined above, the analysis indicated unique conditions where additional benefits can be realized by remotely altering the controller mode of operation. This capability would consist of the ability to place signals on flash either as a regularly scheduled event, such as nighttime flash, or during ice and snow conditions to provide snow routes. The second mode change would be to degrade the normal response of actuated controllers during snow or ice conditions.

4. Local Preemption - Local signal preemption near railroad crossings and at two locations to permit fire apparatus to exit safely from the station are to be provided and accommodated by the system.

Flexibility

1. Ease of Timing Plan Updating - The analysis of future traffic conditions indicated that the CBD, Central, and Morningside Subsystems would require substantial signal retiming to accommodate changing traffic characteristics. The ability to easily implement new timing plans and the ability to implement experimental plans will be important in maintaining a high level of service within these subsystems.

2. System Boundary Reconfiguration - The system should have the ability to modify subsystem boundaries in the Morningside, Central, and Hamilton North Subsystems. The system should also have the ability for future operation of 16 subsystems with additional consideration to be given to operation of signals in South Sioux City.

3. System Expansion - Within the design life of the system it is estimated that approximately 50 additional signals will be required due to

street improvements and growth. The location of these signals within the City will require that they be included in the system to maintain efficient operation.

4. Adaptability to Changes in the CBD and Central Subsystems - The engineering analysis indicates that substantial changes will occur within the CBD and Central Subsystems due to new commercial activity and street improvements. As the street improvement projects will be staged, numerous changes in traffic flow characteristics will occur that must be accommodated by the system.

Surveillance

1. Permanent Count Station Data - Directional total traffic volume data collected on 15-minute increments is required at a minimum of 13 permanent count stations. Data reduction and summarizing should either be performed automatically or collected in a format suitable for processing by the City Data Processing Department.

2. Measures of Effectiveness - In view of the many changes that will occur in the future, there is a need for the system to collect traffic data and produce measures of effectiveness to describe the system performance characteristics. The measures of effectiveness determined to be meaningful include traffic volume, occupancy, speed, stops, and delay. The measures of effectiveness would be made available for analysis by engineering personnel but would not be directly used by the system to make corrective actions.

3. Equipment Monitoring - To insure controller equipment is operating in accordance with the control strategy in effect, automatic monitoring and failure reporting of controller equipment is required. Proper controller operation affects not only the quality of traffic flow but also impacts motorist safety. The monitoring of actuated controller equipment should include determining that there was side street demand that was not being served by the controller.

   As the system detectors would be used for traffic responsive selection of timing plans, to provide measures of effectiveness, and to provide supplementary data for off-line analysis, the validity of the data should be determined automatically by the system. The check should include "false calls" as well as failure to detect vehicles.

As the proper operation of actuated signal controllers is dependent upon correct operation of the intersection vehicle detectors, they should be monitored in a similar manner.

Coordination With Other Systems

1. Fire Route Preemption - A fire route preemption operation, providing a moderate level of route flexibility, was defined to facilitate movement of fire apparatus within the CBD and along the congested area adjacent to Sunset Plaza Shopping Center on Hamilton Boulevard. These routes are shown in Figure 14. The preemptive system is structured to promote safety and reduce response time.

   A non-dedicated preemptive system is acceptable provided Fire Department personnel has knowledge if the service is not available and provided that the service is available at least 95% of the time.

2. Transit - As all of the City's transit lines connect at a single point in the CBD, every hour approximately 15 buses will attempt to enter the street network within a five minute period. Efficient operation of the transit system requires modification of the normal signal timing plans during this period to permit the buses to depart from the station in accordance to their route schedule. The need for preemptive operation of signals for transit operation was not defined.

3. Freeway Operations - The need to provide freeway (I-29 or I-520) operations interface with the signal system was not defined. However, the surveillance aspects of the signal system should provide traffic data collection at freeway off-ramps and at selected mainline locations.

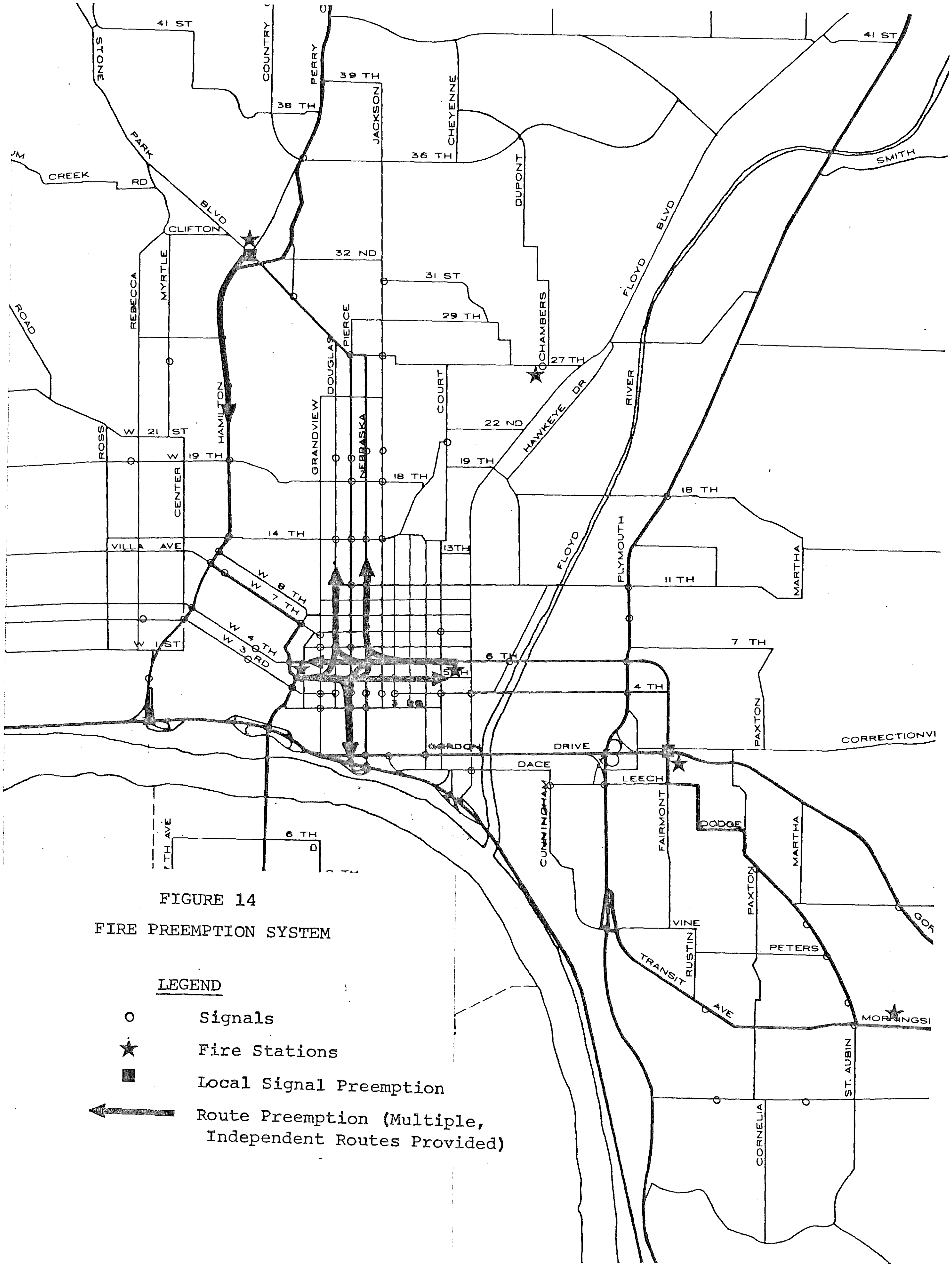

FIGURE 14

FIRE PREEMPTION SYSTEM

LEGEND

- o Signals
- ★ Fire Stations
- ■ Local Signal Preemption
- ← Route Preemption (Multiple, Independent Routes Provided)

V. CANDIDATE SIGNAL SYSTEMS

During the past decade there has been substantial activity in signal system development. New traffic control concepts and techniques have been developed by traffic engineers, researchers, and manufacturers. As a result, numerous alternative signal systems can be configured by combining various traffic control strategies and types of hardware. As an evaluation of all of the possible system configurations would cloud the decision process, it is necessary to define the range of realistic system alternatives that are viable candidates for implementation in Sioux City. Thus, the objective in candidate system development is to define a limited number of system approaches where each approach, when considered individually, is a good choice.

As candidate development requires an initial screening of system concepts, a set of standards is required to structure the process. The procedure used to develop candidates in Sioux City was based on system analysis procedures which incorporated the influence of local conditions. Each alternative was measured against a set of standards to determine whether it deserved further consideration as a candidate system. The criteria used is briefly described as follows:

- Permit Competitive Procurement - To encourage procurement of the system at the lowest possible cost, it is necessary to insure that it can be provided by more than one supplier and/or contractor. To achieve this objective, candidate capabilities are generally defined in functional terms. This was done rather than specifying the exact procedure or giving detailed hardware characteristics as this would tend to define a system supplied by a specific vendor. As a result, some "brand name" systems that would be contained within a candidate description may have one or more features in addition to those stated for the candidate. However, these features, although important, are not of sufficient significance to qualify them as a unique candidate.

- <u>Meet Specific Requirements</u> - The candidate systems were developed to meet specific requirements that had been identified for Sioux City. Systems designed to provide substantially smaller or greater capabilities than those required to meet the condition defined in Sioux City were not considered as a candidate system. For example, systems designed to provide second or third generation control strategy were not considered as this was not an identified need.
- <u>Permit Differences to be Investigated</u> - Within the criteria previously stated, only those systems that had distinct differences in capabilities or configuration characteristics were defined as candidate systems. This permits the difference in system capabilities to be measured in terms of incremental utility and cost.
- <u>Represent Optimum Configuration Within Concept</u> - The candidate systems consist of a blend of control strategies and hardware configurations structured to provide an optimum level of operation within each category. To the extent possible, systems that do not provide the level of capability required to totally satisfy a requirement were configured to minimize the negative impact. As an example, the subsystem boundaries were modified to minimize impact when passing from one system to another for candidate systems that do not have interface capabilities.

In addition, candidates were configured to utilize existing equipment to the fullest extent possible. All candidates were configured to upgrade controller equipment identified during this study as requiring replacement.

Due to the system size and the physical arrangement of signals in the system, it was determined that there were no indications that a detailed investigation of a "centralized" versus a "distributed" system was warranted. In this context, centralized refers to the system master performing all control functions directly whereas in a distributed system the master performs selected control functions with additional decision capabilities, data accumulation, and control implementation performed by remote "slaves". The distributed system is most applicable where signals are "clustered", resulting in high signal density, but the signal groups are widely separated. As this condition does not exist in Sioux City the candidate systems are generally configured around the centralized concept. Candidate Six deviates from this general rule to the extent that the signal controller provides a higher level of intelligence than is provided by other candidates; however, it still conforms to the centralized concept.

CANDIDATE SYSTEM DESCRIPTION

Six candidate systems were defined for evaluation in complexity from a conventional three dial, three offset per dial system providing grid and arterial network control to a computer based system utilizing microprocessor controllers incorporating a "tailored" software package. As described previously, each candidate was developed considering specific requirements.

The existing system was not included as a candidate system for evaluation purposes. The system was excluded as a candidate as the analysis provided conclusive evidence that efficient signal operation in Sioux City requires greater capabilities than can be provided by the existing system. The existing system is included in the evaluation process, however, to permit the "no build" alternative to be considered.

Candidate 1

Candidate 1 is configured to make maximum utilization of traditional control system concepts. The CBD Subsystem and the Central Subsystem would be combined to operate as a single system. Three dial, three offset per dial, pretimed control would be provided by installing a new communications facility and expanding the capabilities of existing controller equipment or replacing incompatible equipment as required. The Gordon Subsystem would also be expanded to provide three dial, three offset per dial, pretimed control as an independent system.

Timing plan selection in both systems would be made by time-of-day. Time-of-day selection in the combined CBD Subsystems would be accomplished by means of a program drum to permit plan selection to be programmed on a day-of-week basis. Timing plan selection in the Gordon Subsystem, however, would permit selection only for week days and weekends.

The remaining signals would be controlled by means of arterial type systems. Existing pretimed controller equipment and unusable actuated controller equipment would be replaced with solid-state controller equipment. System operation would be achieved by means of three dial, three offset per dial coordination units that are interconnected to supervise the operation of actuated controllers. In each subsystem, cycle and offset selection would be made by means of traffic responsive masters. The subsystems provided by the arterial systems would conform to the boundaries previously described except that the Lewis North and South Subsystems were combined as were the Gordon Central and East Subsystems.

Fire lane preemption would be provided for five routes by means of preemption devices installed at each signal. The routes would be selected by push buttons located in Stations 1, 3, and 4.

In configuring Candidate 1, the primary emphasis was to satisfy the daily timing plan requirements, to provide the basic mode of controller operation, to provide timing plan selection by the required technique, and to provide a reasonable compromise of the subsystem boundary requirements previously defined. In addition, the primary future system boundary reconfigurations and expansion capabilities to accommodate anticipated future signals would be considered during system design to the greatest extent possible. However, unanticipated growth patterns and changes in future traffic conditions could result in conditions that are not easily accommodated by this Candidate.

Candidate 2

Candidate 2 is also a combination of system approaches but differs from Candidate 1 in that increased emphasis is placed on providing additional capabilities in those subsystems that are highly interactive and which will undergo the greatest change in the future. Signal operation in the CBD, Central, North Central (future), Gordon Drive, Hamilton North, and Hamilton South Subsystems would be controlled by means of a limited centralized computer system. Limited in this case is a relative term as the system would have substantially more capabilities in these subsystems than that provided by Candidate 1. However, the system is primarily control oriented and would not provide the same level of traffic surveillance and reporting capability or flexibility available from some of the more complex systems available.

Either a small mini-computer or several microprocessors would serve as the master. With a limited computer system, timing plans are generally developed by selecting cycle length, split, and offset from independent files stored by the master. As a wide range of cycle lengths and as many as six offsets and five splits are available, the system has the ability to provide more timing plans than are available from Candidate 1 (although there is still a timing plan interdependency due to developing a plan by selection of a cycle, a split, and an offset in lieu of selecting a specific timing plan).

The boundaries of these six subsystems would be configured as required. The system would also provide subsystem interfacing to permit coordinated movement between adjacent subsystems. Subsystem boundaries could be altered and new signals added as required. Signal timing in these subsystems could be updated centrally rather than making the changes at the controller as required with Candidate 1.

Limited traffic surveillance data would be gathered from system sampling detectors. The measures of effectiveness would include volume, occupancy, and speed. This data would be available as either an aggregate of the sampling stations or 24-hour summaries at selected locations (normally a maximum of 10 detectors). In addition, pretimed controller operation would be monitored for proper operation.

Timing plan selection would be performed by traffic responsive operation for the Hamilton, North Central, and West Gordon subsystems. Timing plan selection within the CBD and Central Subsystems would be performed by a time-of-day program for each day of the week. The system would have the capabilities for future traffic responsive timing plan selection in the CBD and Central Subsystems by the installation of detectors and additions to the data base when required.

Existing pretimed controller equipment would be incorporated by the addition of a second dial and the appropriate modifications to permit the computer to control the dial during on-line operation. During off-line operation the existing dial would be used for back-up. Existing pretimed controllers and unacceptable actuated controllers in the arterial subsystems would be replaced by solid-state actuated controllers. These would be incorporated into the system by means of an interface to supervise the controllers. During on-line operation the controller would be held in the main street green until a yield command is issued by the master. The system would have the capability of controlling the maximum time of up to sequential three side street phases by means of force-off commands.

The remaining subsystems would be controlled by means of arterial systems as described in Candidate 1. Fire lane preemption would also be provided as described in Candidate 1.

Candidate 2 was configured to provide the expanded timing plan requirements in the CBD for special events, etc. and to permit subsystem boundaries to be configured as required. In addition, it would permit subsystems interfacing, provide monitoring of controller equipment, and provide a minimum level of traffic surveillance data within the area controlled by the computer system. This candidate, when compared to Candidate 1, permits the implications of emphasizing an improved level of service within the CBD and adjacent area to be evaluated.

Candidate 3

Candidate 3 expands the limited computer system described in Candidate 2 to provide control of the total system. The operational characteristics would be identical to that described for the limited computer system in Candidate 2 to provide a uniform level of capability to all areas of the City.

Candidate 3 would permit proper configuration of all subsystems, permit subarea boundary modifications, provide the signal timing flexibility required for the Morningside area and provide systemwide traffic and equipment surveillance capabilities. Candidate 3, when compared to Candidate 2, permits the implications of providing computer control for the total system to be assessed.

Candidate 4

This Candidate is similar to Candidate 3 in that all signals would be placed under computer control. It differs, however, in that the system would be configured using the Urban Traffic Control System (UTCS) Fortran IV program developed by the Federal Highway Administration. The major differences between this system and Candidate 3 is the use of a larger and more capable mini-computer, operating pretimed controllers through cam control rather than dial control, providing increased traffic surveillance capabilities (particularly the number of locations) and using a software program developed and supported by the Federal Highway Administration.

Existing pretimed controllers would be modified to permit the computer to directly control the cam shaft. The existing controller dials would be used to provide backup when the system is off-line. Actuated controllers would be incorporated by the computer holding them in main street green and permitting them to yield to side street demand at a prescribed time. Side street maximum green times would be timed by the local controller.

The operations and functions described in "Urban Traffic Control Systems Fortran IV Software Documentation" dated September 1973 would be modified only as required for input/output control to permit the control panel to be deleted. As such, the system would not have the capabilities of incorporating local preemption or fire lane preemption. The system, however, has extensive documentation and is the basis for continued research by the Federal Highway Administration. This candidate permits a comparison of the implication of using a limited computer based system developed in the private sector (Candidate 3) versus a potentially more flexible system that has undergone extensive operational testing and evaluation.

Candidate 5

Candidate 5 consists of program modifications to expand the capabilities of Candidate 4 in those areas the requirements identified for Sioux City are not satisfied. Pretimed controller operation would remain unchanged from that provided by Candidate 4. However, actuated controller operation would be enhanced by supplementing the yield and hold commands with force-off commands that would be directed to each phase to explicitly control the duration of side street greens. The system would provide under software control ten fire lane preemption routes and local preemption would be accommodated. The ability to modify actuated controller operation for inclement weather conditions or to provide remote flash at selected locations would be provided. Controller monitoring would be expanded to permit increased detection of actuated controller failures.

Traffic surveillance capabilities would be expanded by providing an estimate of stops and delays as well as the volume, occupancy, and speed data provided by Candidate 4. Additional flexibility in surveillance data report format would be provided in terms of type of report, data collection period, number of locations, and report generation frequency. Enhanced special events timing plan operation would insure a return to normal system operation after a special event without the need for operator intervention.

These modifications would be made within the concepts contained in the UTCS Fortran IV program. This candidate permits an assessment of a system structured to accommodate to a great extent most of the conditions encountered in Sioux City.

Candidate 6

Candidate 6 closely resembles Candidate 5 except that all controller equipment would be replaced with microprocessor type controllers. The hardware/software configuration would also be altered to permit the additional local intersection intelligence provided by the microprocessor to be efficiently utilized. The major functional differences from Candidate 5 would be in terms of additional flexibility and capability to accommodate future conditions. The system would also provide additional flexibility in surveillance data analysis and report generation flexibility.

Due to the advanced hardware technology used, this candidate would place less reliance on the UTCS Fortran IV system concepts. This candidate thus permits an assessment of the impact of utilizing advanced technology within the Sioux City environment.

VI. CANDIDATE SYSTEM EVALUATION

Of paramount importance in evaluating candidate systems is insuring that the process is performed within a consistent framework. The evaluation must also include all factors unique to Sioux City that have an influence in the decision process.

In an ideal situation where all factors can be expressed in tangible terms (e.g. dollars) an adequate method of selecting the "best" alternative would consist of calculating the dollar cost and dollar benefit and selecting the one that provides the highest return per dollar invested. However, this method is not sufficiently comprehensive to evaluate signal systems due to their complex nature. Although the cost of each alternative can be estimated, the performance characteristics or "benefits" to be realized from each alternative are both tangible and intangible. Tangible characteristics are those properties provided by a system that can be expressed in quantifiable terms. Typically, these properties are related to specific traffic operations functions performed, such as the number of timing plans, system size, mode of controller operation, etc. Intangible characteristics are those properties that cannot be expressed in quantifiable terms. The intangible properties are related to system maintainability, flexibility, implementation characteristics, etc.

To permit all factors to be considered in the decision process a utility/cost analysis was used to assist in the evaluation of candidate systems in Sioux City. This procedure differs from benefit/cost in that the value or benefit of a system is measured by a proxy value termed "utility". The process requires that comprehensive goals associated with the various tangible and intangible system characteristics be established. The goals are then weighted by the user to reflect their relative importance within the decision making process. As these goals are broadly conceived, it is necessary to more fully describe each goal by means of system requirements or "utility measures". The utility measures for each goal are then weighted to establish their relative importance within the goal.

The next step is to determine the degree each candidate system satisfies the utility measures. This is accomplished by rating each candidate system on a scale of 0 to 10 to describe its ability to satisfy each utility measure. The candidate system scale value is then multiplied by the utility measure weight and summed to provide a utility value for the goal considered. This represents the ability of each alternative system to meet the goal. The goal values are then multiplied by the goal weight and summed to indicate each candidate system's total "utility". Thus, the rating process integrates the tangible and intangible aspects of system evaluation and reflects the user's values. The resulting effectiveness of the candidate systems, or utility, allows a direct comparison of systems on an equivalent basis, even when they have diverse characteristics.

Candidate systems are compared using the ratio of system utility divided by the estimated system cost. In the simplest case, the "best" system is the candidate system with the highest ratio value. As a final step, the incremental utility and costs between alternative systems is compared to select the most effective approach.

EVALUATION GOALS

The evaluation goals were developed by the Technical Advisory Committee during the Signal System Seminar based on the results of the analysis of existing and future conditions which defined viable control strategies and operational features that were desirable in Sioux City. Defining the evaluation goals was the first step in establishing an analytical framework for system evaluation.

During this process JHK & Associates acted primarily in an advisory capacity acting on insight provided by the City Transportation Department, State, Federal Highway Administration, and SIMPCO, with additional input provided by other departments and agencies within the City that are not directly concerned with transportation issues. The resulting goals are briefly described as follows:

Goal 1 Traffic Operations: The traffic operations element consists of those functions that directly affect on-the-street signal operation. This is the most visable aspect of the system and includes several objectives, such as:

° Improve the quality of traffic flow on the network to reduce driver frustration;

° Reduce motorist delay at signalized intersections;

° Provide the most efficient signal operation in terms of cycle length, split and offset to provide the highest level of service, within the constraints of physical geometrics, under all traffic conditions;

° Minimize those factors, particularly stops, which contribute to accidents at signals; and

° Reduce fuel consumption and pollutants for transportation related activities.

To meet this goal the system must have sufficient capabilities to provide the necessary control strategies. This includes proper configuration of the system, adequate timing plan capabilities, and the ability to select timing plans by the most efficient technique.

Goal 2 Traffic Engineering Analysis: This consists of those functions necessary to provide the interface between the engineer and the signal system to permit a high level of operation to be maintained. The goal objective is to provide a record of system events and a feedback of system operation, such as traffic characteristics and the relative performance of the system, to the engineering staff. The intent of this capability is to provide the means to permit early identification of problems such that corrective action can be accomplished quickly.

Goal 3 Flexibility and Auxillary Services: The objective of this goal is to insure that the traffic control system has sufficient reserve capabilities to accommodate future traffic conditions and to satisfy ancillary control functions that complement the traffic operations goal. Items of particular interest are:

° The ability to respond easily to new traffic flow characteristics in the CBD that will result due to new commercial development and roadway improvements;

- The ability to permit new timing plans to be easily implemented; and
- The ability to incorporate new signals in the system.

Goal 4 Maintenance Operations: This goal has as its primary objective reducing down-time of system components due to equipment failure to a minimum. Achieving this objective reduces motorist exposure to conditions that are unsafe. It also eliminates additional delay that results due to equipment malfunctions that disrupt efficient traffic flow. Included in this goal is the continued monitoring of equipment to verify correct operation.

Goal 5 Implementation Characteristics: As the construction activities necessary to implement a new system will disrupt normal traffic flow for an interim period, the goal objective is to perform the transition within the shortest period of time. This objective can best be met by the installation of a system using proven technology and one that is compatible to the existing system.

Goal Weighting

Each of the goals were independently weighted by members of the Technical Advisory Committee. The composite weighting was then discussed to arrive at a consensus of the relative importance each goal should have in the decision process. The following goal weights resulted from this group participation:

Goal	Weight
Traffic Operations	33%
Traffic Engineering Analysis	18%
Flexibility and Auxillary Services	18%
Maintenance Operations	18%
Implementation Characteristics	13%
TOTAL	100%

The traffic operations goal is considered almost twice as important as any of the other individual goals. However, the remaining goals are of equal importance with the exception of the slightly lower weight given to implementation characteristics. The weighting indicates the obvious importance of the traffic operations aspect of a system, however, the combined weighting of the remaining goals brings significant perspective into the decision process. The importance placed on traffic operations is tempered by the need to implement a system that can be efficiently operated and maintained as well as one that has a high probability of reaching an operational status at a minimum level of disruption.

UTILITY MEASURES

The goals previously defined are too broad in scope to perform an evaluation of alternative signal systems. To permit the differences between alternatives to be assessed, it is necessary to refine the goal definition by describing their component parts. This is accomplished by means of "utility measures" which describe the objectives to be satisfied within each goal.

The utility measures were developed from the system requirements defined through analysis, discussions with officials, and reviewed during the Signal System Seminar. System requirements in this sense refers to a specific level of capabilities selected from the numerous traffic signal control opportunities available that have been quantified based on local conditions as described in previous sections of this report. Thus, system requirements refer to a specific level of capabilities, but they do not represent the <u>lowest level capabilities that must be provided</u> in view of the incremental cost and benefit associated with them. Structuring the requirements as utility measures permits the necessary trade-offs to be performed to permit the most cost-effective approach to be selected.

The resulting utility measures were initially assigned to the evaluation goals by JHK & Associates. These were then reviewed by the Technical Advisory Committee and finalized. The following describes the utility measures for each goal:

<u>Goal 1 - Traffic Operations</u>

° <u>Initial Subsystem Boundary Configuration</u> - The signal system should have the capability to initially operate eight subsystems.

- Coordination Between Subsystems (Interface) - The system should provide for coordination of subsystems as required to reduce boundary disruptions.
- Repetitive Signal Timing Plans - The system should provide the required number of timing plans for normal daily traffic.
- Reserve Timing Plan Capabilities - The system should have the capabilities to provide timing plans in addition to those required on a repetitive basis for late shopping and to provide peak period transition plans.
- Signal Timing Plan Selection Technique - The selection of timing plans should be accomplished by time-of-day, day-of-week in the CBD and by traffic responsive techniques elsewhere.
- Fire Route Preemption - Preemptive operation of signals for the safe movement of fire apparatus should be provided.
- Controller Operation - Signal controller operation providing the required mode, phasing, and type of actuated control should be accommodated.
- Special Controller Operation - The system should permit modification of the normal operation of actuated controller during ice or snow conditions.
- Local Preemption - The preemptive operation of signals in response to local conditions should be provided.

Goal 2 - Traffic Engineering Analysis

- System Operations Event Record - To permit internal analysis and to provide records for legal purposes, the system should provide a record of various system events. These events would include timing plan changes, emergency vehicle route preemptions, etc.
- Permanent Count Station Data - The system should automatically collect traffic data at locations designated as permanent count stations.
- Traffic Surveillance Measures of Effectiveness Data - The system should automatically process vehicle detection data to produce measures to describe system effectiveness.
- Surveillance Report Format and Generation Flexibility - This refers to the system providing flexibility to permit scheduling measures of effectiveness reports, determining the data collection intervals, and in altering the format of the reports on a request basis.

- Real-Time Data Collection for Data Processing Analysis - This refers to the ability of the system to collect and log real-time events, such as the aspect of signal controllers and/or sampling detector actuations, on a mass storage media for off-line analysis by Data Processing.
- Freeway Traffic Surveillance - The traffic surveillance aspects of the system should include freeway off-ramps and selected main-line locations.

Goal 3 - Flexibility and Auxillary Services

- System Boundary Reconfiguration - The system should provide for the modification of sub-system boundaries and the future operation of at least 16 subsystems.
- System Expansion - The system should be expandable to incorporate new signals without major modification.
- Inclement Weather Timing Plan - The system should permit use of timing plans developed for inclement weather conditions.
- Adaptability to Changes in the CBD and Central Subsystems - The system should have sufficient flexibility to complement the improvement projects planned for the CBD.
- Repetitive Special Events Timing Plans - The system should permit use of timing plans for infrequent major events in the City.
- Future Traffic Responsive Capabilities in CBD and Central Subsystems - Future traffic responsive timing plan selection should be available without major modification to the system.
- Accommodate Transit Transfer Point Demand - Flexibility should be provided to assist transit operation at the central transfer point.
- Ability to Dynamically Reassign Signals From One Subsystem to Another - The system should permit reallocation of signals between subsystems as required.
- Ease of Timing Plan Updating - The system should permit modifications of timing plans to be easily and quickly accomplished.

Goal 4 - Maintenance Operations

- Monitor Proper Operation of Controller Equipment - The system should identify malfunctions of pretimed and actuated controller equipment.
- Monitor Proper Operation of System Detectors - The system should identify system detector failures and provide a back up strategy for traffic responsive operation.
- Monitor Proper Operation of Intersection Detectors - The system should identify failures of intersection detectors at actuated controller locations.
- Equipment Failure Permanent Log - A permanent copy of hardware failures identified should be provided by the system. This would provide historical data necessary to determine equipment maintenance trends and provide records for legal purposes.
- Level of Increased Maintenance Technology Required - This refers to the additional technical skills that would be required by maintenance personnel in order to maintain the system. A system that can be maintained without requiring the development of new maintenance skills will best meet this objective.
- Familiarity With Equipment - This relates to the maintenance personnel having experience in maintaining identical or very similar types of equipment. Achieving this objective permits hardware maintenance to be performed more efficiently.
- Level of Outside Maintenance Assistance Required - Certain systems can be maintained by City personnel without any outside assistance. Other systems, particularly those using computer technology, would require that service contracts be acquired to insure proper equipment operation. The objective is best met through a system minimizing outside maintenance requirements.

Goal 5 - Implementation Characteristics

- Equipment Availability - To reduce the implementation time and to insure that the benefits of the new system can be realized at the earliest possible date, systems using currently available equipment components are desired.

- Reliance on Proven Technology - This refers to the level to which hardware and software based on proven techniques is incorporated into the system. Use of "off-the-shelf" items reduces the uncertainty with regard to reliability of operation and with predictability of implementation schedules.
- Operations Personnel Educational Requirements - This refers to the level of additional training required by personnel responsible for operating the system to permit them to use the system at its designed level of efficiency. This includes updating the system as required due to street network changes and changes in land use. Minimizing the additional educational requirements insures that there is staff time available for normal duties and also insures continued operation of the system in the event trained personnel assume new responsibilities.
- Maintenance Personnel Educational Requirements - This is identical to the previous measure with respect to maintenance personnel.
- Implementation Impact - This refers to the ability of the system to be implemented in such a manner that degraded signal operation is minimized during construction. The compatability of the new system to the existing system and the level of new component testing required are factors that affect this objective.

Utility Measure Weighting

Within each goal the utility measures were independently weighted by members of the Technical Advisory Committee. The composit weight of each utility measure was then subjected to an analysis by JHK & Associates to determine whether the relative importance of each measure was consistent with objectives stated by the Committee during the course of the project. The analysis was directed to determine whether there were extreme deviations in the utility measure weighting process that would bias the decision procedure. As a result of this analysis, significantly deviant scores were excluded and the utility measure weights were readjusted until an appropriate balance was established. The resulting utility measure weights for each of the evaluation goals is shown in Table 11.

TABLE 11 - GOALS AND UTILITY MEASURES

Goal/Measure	Weight (Within Goal)
TRAFFIC OPERATIONS (30%)	
° Initial boundary configuration	15
° Coordination between subsystems	14
° Repetitive timing plan	16
° Reserve timing plan capabilities	10
° Timing plan selection techniques	10
° Fire route preemption	8
° Controller operation	14
° Special controller operations	6
° Local Preemption	7
TRAFFIC ENGINEERING ANALYSIS (18%)	
° Operations event record	20
° Permanent count station data	15
° Surveillance MOE data	26
° Surveillance report format	19
° Real-time data collection	10
° Freeway traffic surveillance	10
FLEXIBILITY AND AUXILLARY SERVICES (18%)	
° System boundary reconfiguration	16
° System expansion	11
° Inclement weather timing plans	8
° Adaptability to CBD and Central System changes	16
° Repetitive special events	9
° Infrequent special events	6
° Future traffic responsive in CBD and Central System	5
° Transit transfer point demand	10
° Dynamically reassign signals from one subsystem to another	4
° Ease of timing plan updating	15
MAINTENANCE OPERATIONS (18%)	
° Monitor controller operation	20
° Monitor system detectors	15
° Monitor intersection detectors	15
° Equipment failure permanent log	13
° Level of increased maintenance technology required	15
° Familiarity with equipment	12
° Level of outside maintenance assistance required	10
IMPLEMENTATION CHARACTERISTICS (13%)	
° Equipment and software availability	25
° Proven technology	20
° Operations personnel educational requirements	20
° Maintenance personnel educational requirements	20
° Implementation impact	15

To permit the relative importance of the utility measures to be examined, they were normalized and ranked in descending order of importance as shown in Table 12. It should be noted that several items, such as equipment and software availability, have a greater impact on the decision process than might be expected while others are lower. However, these results are consistent with the utility/cost approach in that the procedure is specifically structured to permit the user to place increased emphasis on those factors that are considered of greater importance due to local experience.

CANDIDATE SYSTEM RATING

Each of the candidate systems, and the existing system, was rated as to its ability to fulfill the functions or level of performance defined by the utility measures. The candidates were assigned a score from 0 to 10 for each measure, with a 0 indicating that the candidate does not provide capabilities, or utility, in this area and a 10 indicating that the measure is fully met. An important criteria of the rating process is to assign a value of 10 to a candidate <u>if it just achieves the measure</u> even though other candidates exceed the requirements described by the measure. In other words, the value assigned represents the candidates ability to meet the measure and <u>does not indicate a relative rating or comparison of one candidate against another</u>. This insures that candidates that have capabilities in excess of those necessary to meet the requirements defined in Sioux City are evaluated only in respect to identified needs.

The candidate utility was developed for each goal by multiplying the candidate score by the utility measure weight, summing each weighted utility value, and multiplying this by the goal weight. The total utility for each candidate is then obtained by summing the goal utility values. The utility score for the candidate systems and the existing system is shown in Table 13. Additional detail concerning the utility score development is presented in Appendix A.

TABLE 12 - NORMALIZED UTILITY MEASURE WEIGHTS

Measure	Goal	Weight
Repetitive Timing Plans	I	5.28
Initial Boundary Configuration	I	4.95
Surveillance MOE	II	4.68
Coordination Between Subsystems	I	4.62
Controller Operation	I	4.62
Operations Event Record	II	3.6
Monitor Controller Operation	IV	3.6
Surveillance Report Format	II	3.42
Reserve Timing Plan Capabilities	I	3.3
Timing Plan Selection Technique	I	3.3
EQuipment and Software Availability	V	3.25
System Boundary Reconfiguration	III	2.88
Adaptability to CBD Changes	III	2.88
Ease of Timing Plans Updating	III	2.7
Monitor System Detectors	IV	2.7
Monitor Intersection Detectors	IV	2.7
Level of Increased Maintenance Technology Required	IV	2.7
Permanent Count Station Data	II	2.7
Fire Route Preemption	I	2.64
Proven Technology	V	2.6
Operations Personnel Educational Requirements	V	2.6
Maintenance Personnel Educational Requirements	V	2.6
Equipment Failure Permanent Log	IV	2.34
Local Preemption	I	2.31
Familiarity With Equipment	IV	2.16
System Expansion	III	1.98
Special Controller Operations	I	1.98
Implementation Impact	V	1.95
Transit Transfer Point Demand	III	1.8
Level of Outside Maintenance Assistance	IV	1.8
Freeway Traffic Surveillance	II	1.8
Real Time Data Collection	II	1.8
Repetitive Special Events Timing Plan	III	1.62
Inclement Weather Timing Plans	III	1.44
Infrequent Special Events	III	1.08
Future Traffic Responsive Operation	III	.9
Dynamic Signal Reassignment	III	.72
TOTAL WEIGHT		100.0

GOAL I - Traffic Operations

GOAL II - Traffic Engineering Analysis

GOAL III - Flexibility and Auxillary Services

GOAL IV - Maintenance Operations

GOAL V - Implementation Characteristics

TABLE 13 - SUMMARY OF CANDIDATE UTILITY VALUES

Goal	Existing System	CANDIDATE 1	2	3	4	5	6	Maximum
Traffic Operations	64	160	223	293	235	323	330	330
Traffic Engineering Analysis	0	0	65	94	118	170	180	180
Flexibility & Auxillary Services	21	35	108	130	137	171	179	180
Maintenance Operations	67	61	99	115	106	121	122	180
Implementation Characteristics	130	121	80	67	78	55	29	130
TOTAL	282	377	575	699	673	840	840	1000

A review of the candidate utility value summary permits several observations to be made. The existing system received a rating of only 282 out of a possible utility rating of 1,000 indicating that it does not satisfy many of the requirements defined in Sioux City. The major strength of the existing system is in relationship to implementation characteristics. Since the system is existing, it receives a perfect score. However, this system meets only 20 percent of the traffic operations goal and 12 percent of the flexibility and auxillary services goal. Although the existing system receives a good rating in increased maintenance skills, familiarity with equipment, and outside maintenance requirements, it provides only 67 utility points in the maintenance operations goal since there are no hardware monitoring capabilities. The existing system, and Candidate System 1, received zero points in traffic engineering analysis since surveillance capabilities are not provided.

Candidate System 1 provides substantially more utility in traffic operations than the existing system due to the interconnection of signals and increased timing plan capabilities in the CBD. These increased traffic operations capabilities are reflected by a gain over the existing system of 95 points for a total utility rating of 377. Candidate System 1 receives a lower score in the maintenance operations goal than the existing system due to the installation of additional hardware to achieve coordinated system operation. However, the system has only a small negative impact on the implementation characteristics goal.

Candidate System 2 represents a substantial gain in utility over Candidate 1 or the existing system. The increased traffic operations capabilities, the traffic engineering analysis provided by the surveillance element, the additional flexibility, and the monitoring of equipment provided by use of a computer in the CBD provides substantially more utility than is lost due to its more adverse implementation characteristics.

By providing the benefits of computer control to the entire system Candidate 3 receives 124 more utility points than Candidate 2. This system provides increased utility in all goals except implementation characteristics.

On the other hand, Candidate 4, which also utilizes a computer for control of the entire system, receives a lower utility score than Candidate System 3. This is due to restraints in providing the required level of actuated controller operation, the inability to accommodate signal preemption, restraints in timing plan selection, and other characteristics of the system which affect its ability to meet the traffic operations goal. Candidate System 4 receives a higher utility score than Candidate System 3 in traffic engineering analysis due to its ability to provide traffic data from more detectors and the ability to develop a greater number of measures of effectiveness. It also receives a higher score in implementation characteristics due to the reliance on proven technology. However, the higher scores in these two goals are not great enough to offset the utility lost in traffic operations.

Candidate Systems 5 and 6 both have a utility rating of 840, the highest rating achieved. These systems almost fully satisfy the traffic operations, traffic engineering analysis, and flexibility and auxillary services goals. They also provide the highest utility in the maintenance operations goal. However, they are the most difficult candidates to implement which is reflected in their reduced utility in implementation characteristics. Candidate System 6 receives the lowest value in implementation characteristics due to its reliance upon new technology.

CANDIDATE SYSTEM COST ESTIMATES

Cost estimates were made for each of the candidate systems and the existing system. The existing signal system was not included as a candidate system as it fell far short of providing the basic operational requirements identified. However, the cost and utility of the existing system was developed to provide a frame of reference during the evaluation and to permit the not build or "do nothing" alternative to be investigated.

In this case, the "do nothing" alternative is somewhat of a misnomer in that a capital investment as well as a recurring cost is required to maintain the existing level of performance. The capital investment is required to replace aging control equipment and recurring costs are required for equipment maintenance.

All estimates were made within a consistent framework to fairly represent the cost for equipment installation, initial set-up, continued operation, and maintenance over a ten year period for each system. A detailed breakdown of the major component cost estimates is presented in Appendix B.

The cost estimates were made based on the following assumptions:

- The initial installation contract would include approximately 86 intersections defined as requiring immediate system operation.
- The initial installation would be performed by a contractor with the City and/or State providing only supervisory services.
- All system components would have a minimum ten year design life.
- Ten year costs were reduced to a common basis representing an equivalent immediate investment by converting the annual cost to present worth value at a 7% discount rate.

greatest utility per dollar invested. The next highest rating is attained by the existing system even though it provides the lowest total utility. This finding is not unexpected, however, as the present worth cost of the existing system is approximately one-half the cost of the least expensive candidate system (Candidate System 1) due to the substantial cost required to interconnect signals. Candidate Systems 6 and 3 would appear to be the next best choices, in that order, while Candidate System 1 is the worst choice.

TABLE 15 - UTILITY/COST COMPARISON

System	Utility Value	Present Worth Cost (Thousands)	Utility/Cost Ratio
Existing	282	997.5	.283
Candidate 1	377	1,990.4	.189
Candidate 2	575	2,536.2	.227
Candidate 3	699	2,671.4	.262
Candidate 4	673	2,782.5	.242
Candidate 5	840	2,623.7	.320
Candidate 6	840	3,113.8	.270

A comparison of the absolute utility/cost ratio is not sufficient to determine which of the alternatives represents the best investment for Sioux City. This determination is made by comparing the incremental utility and the incremental cost to implement each of the candidate systems in lieu of continued operation of the existing system. The resulting incremental utility/cost ratio for each of the candidate systems is shown in Table 16.

TABLE 16 - EXISTING SYSTEM INCREMENTAL UTILITY/COST COMPARISON

Existing System To	Incremental Utility	Incremental Cost (Thousands)	Incremental Utility/Cost
Candidate 1	95	992.9	.096
Candidate 2	293	1,538.7	.190
Candidate 3	417	1,673.9	.249
Candidate 4	391	1,785.0	.219
Candidate 5	558	1,626.2	.343
Candidate 6	558	2,116.3	.264

From this comparison, it can be seen that Candidate System 5 provides the greatest incremental utility per investment dollar of any of the candidate systems. It also has a higher incremental utility/cost ratio than the utility/cost ratio of the existing system and is the only candidate to do so. Candidate System 6 provides the next highest incremental benefit, however, the total utility is the same as Candidate System 5 and requires an additional investment of almost $500,000. Candidate System 3 represents the next highest return, however, the incremental utility is less than Candidate System 5 while the incremental cost is approximately the same. Candidate System 1 provides the poorest return on investment.

Based on these findings, Candidate System 5 clearly represents the most effective system, including continued operation of the existing system. Candidate System 5 provides the most capabilities in terms of satisfying the requirements in Sioux City per dollar invested and provides an increased rate of return when compared to the existing system. The analysis indicates that there are only two viable courses of action available to the City -- either the existing system should be upgraded as required to maintain the current level of operation or the City should implement Candidate System 5.

VII. BENEFITS

The previous analysis has shown that Candidate System 5 represents the best investment alternative to meet the system requirements. However, implementation of Candidate System 5 requires an expenditure of $1.6 million more than would be required to retain the existing system. It is, therefore, necessary to determine whether the additional expenditure is justified from an economic viewpoint. This requires a comparison of estimated cost to the potential benefits to the motorist.

Benefits to be realized from a modernized traffic signal system will accrue from many sources. Direct benefits include reduced fuel consumption, improved air quality, increased safety, increased motorist comfort, reduced travel time, and others. Indirect benefits include such items as managing traffic to meet community objectives, increased maintenance efficiency, and postponing major roadway improvement projects by increasing the transportation network efficiency.

As several of these benefits are not easily translated into monetary terms, the economic evaluation performed considered only the factors of reduced travel time, stops, and accidents that are anticipated by implementing Candidate System 5.

TRAVEL TIME

In an urban environment travel time generally represents the major transportation cost component. Reducing the time spent in transportation activities provides a direct benefit to the community as the time can be spent in more profitable activities such as work, recreation, etc.

A very conservative approach was used to estimate travel time benefits to be realized by the installation of Candidate System 5. The analysis considers only the savings resulting during the

STOPS

The number of times a motorist is required to stop during his trip affects vehicle operating cost, safety, and convenience. Signal timing that accommodates traffic demand and travel desires can significantly reduce the number of stops. To estimate the benefits expected by implementing Candidate System 5 only the vehicle operating cost associated with a stop was considered.

The number of stops occurring in the existing system during the weekday peak hours was computed, based on the stops probability of .30 determined from the travel time studies. From the findings reported in before and after evaluations of similar signal system modernizations, the number of stops expected after implementation of Candidate System 5 was computed based on a stops probability of .25. The difference between the stops estimated for the existing system and Candidate 5 was converted to a user benefit considering a vehicle operating cost of $.02 per stop* and computing the yearly savings. From this it is estimated that the reduction in stops by implementing Candidate System 5 will result in an annual savings of $85,000. This estimate is as follows:

Existing System Daily Peak Hour Stops (p = .3)	70,000
Candidate System 5 Daily Peak Hour Stops (p = .25)	53,000
Daily Reduction in Stops	17,000
Daily Cost Savings	$340

Annual Savings

Daily Savings x 250 Work Days = Annual Savings

$340 x 250 = $85,000

ACCIDENT REDUCTION

Although improved signal system operation will tend to reduce all types of accidents involving a non-erratic signalized

* National Safety Council

intersection conflict (e.g. right angle, left turn, etc.) only those accidents involving rear-end collisions were considered in estimating benefits.

Although there is a direct relationship between stops and rear-end accidents it was conservatively estimated that only two-thirds of the stops resulted in a situation that contributed to rear-end collisions. Thus, Candidate System 5 would reduce rear-end collisions by almost 11% or 15 accidents per year.*

To establish the benefits resulting from the accident reduction, the Iowa D.O.T. developed an estimate of the cost associated with a rear-end collision based on data from the National Safety Council (1975) and data from 1974-75 rural and urban accidents experienced in Iowa. As the cost derived included rural accidents, it was reduced by 15% to reflect the reduction in severity of urban accidents.

From this an average cost of $1,500 per rear-end accident was estimated. This results in an estimated yearly savings of $22,500 by the installation of Candidate System 5.

BENEFIT/COST

A benefit/cost ratio was computed by comparing the estimated benefits from reduced travel time, stops, and accidents to the estimated additional cost required to implement Candidate System 5. The total estimated annual benefit of $726,700 was converted to a 10 year benefit considering a 1% growth in vehicle usage corresponding to anticipated population growth. This was then divided by the incremental 10 year present worth cost of implementing Candidate System 5 as follows:

$$\frac{\text{10 year benefit}}{\text{10 year incremental present worth cost}} = \frac{\$7,603,900}{\$1,626,200} = 4.68$$

* Over a three year period there were an average of 137 rear-end accidents per year.

As a benefit/cost ratio of 4.68 represents an excellent return, a benefit/cost ratio considering the total 10 year present worth cost of Candidate System 5 was computed as follows:

$$\frac{\text{10 year benefit}}{\text{10 year present worth cost}} = \frac{\$7,603,900}{\$2,623,700} = 2.90$$

The total system cost benefit/cost ratio of 2.90 provides an additional indicator of the economic benefits to be realized by implementing Candidate System 5.

OTHER BENEFITS

In addition to the benefits resulting from the implementation of Candidate System 5 described above, the system will result in improved air quality and fuel conservation. Although well beyond the scope of this study, an estimate of improved air quality was made based on other studies. The improvement in traffic flow quality by installing Candidate System 5 is estimated to result in a reduction of Carbon Monoxide and Hydrocarbons by approximately 1%.

It is also estimated that the improvements will result in a four to five percent reduction in fuel consumption during the peak hours. As previous studies have shown that the relative delay savings experienced during the peak hours will also apply to the off-peak periods, an estimate of daily fuel savings was made.

Assuming an average vehicle mileage of 14 miles per gallon, based on the estimated number of vehicle miles driven daily, approximately 23,600 gallons of fuel is consumed daily in the system. A five percent reduction in fuel consumption would result in a savings of 1,180 gallons of fuel daily. This translates into a yearly savings of almost 300,000 gallons. At current market values, this represents a savings of over $100,000 per year -- a benefit that is certain to increase as fuel supplies diminish.

VIII. RECOMMENDATIONS

Based on the extensive evaluation performed, it is JHK & Associates' recommendation that the City undertake a program to actively implement Candidate System 5. This System is a cost-effective approach to meet the goals and identified needs of the City. A high level of capabilities in traffic operations, traffic engineering analysis, and in flexibility and auxillary services is provided with only a minor impact on maintenance operations. The System has some adverse implementation characteristics, however, it is within an acceptable tolerance and the negative impacts can be minimized through project planning.

Meeting the traffic operations goal is important in that it permits the City to extract additional capacity from the existing street network at a relatively low cost. Viewed within another context, the traffic operations capability, together with the flexibility provided by the system, will permit the City to maintain at least the existing level of performance ten years from now. This is an important consideration since traffic congestion expected in ten years, due to population growth and revitalization of the Central Business District, will be severe if only the existing system operation is provided.

In addition, this system provides benefits beyond those associated with the normal day-by-day operations. For example, the appeal of attending activities at the City Auditorium would be increased as the system would improve access. The safety of Fire Department personnel and the motoring public will be increased by providing preemptive signal operation. Monitoring signal equipment will have a compound effect in that this feature provides assurance that the system is operating in accordance with the planned strategy and that motorist exposure to unsafe conditions due to equipment malfunctions is reduced. The traffic surveillance aspect of the system provides the necessary feedback required to efficiently operate a control system. This features is not and cannot be provided by the existing system.

Viewed from an economics sense, Candidate System 5 represents an excellent investment in the community. The analysis indicates that this system will provide a minimum of $2.90 return for every dollar invested. As a continued investment in the existing system is mandatory to maintain at least the current level of service, it is perhaps of more significance to note the return per additional dollar invested to implement Candidate System 5. Every dollar invested in Candidate System 5, in lieu of continuing the existing system operation, returns a minimum of $4.68 to the community. This represents an excellent investment choice.

IMPLEMENTATION

The work required to construct the system will represent a major undertaking by the City. Although the project could be staged, it is recommended that the initial construction project include as much of the initial system as funding will permit. Due to the complexity and interactive nature of the system components, the installation of the majority of the system under one project permits a more thorough checkout than is possible with a piecemeal installation. Successful implementation also requires that a high level of project administration be maintained which can be performed more effectively and economically on a single project.

Contracting Procedure

The initial system construction project should be performed by a single installation contract by a systems contractor having prime contractor responsibility. The work should be conducted in accordance to detailed plans and specifications and be competetively bid. A qualified consultant should be retained by the City during implementation to act on the City's behalf in monitoring the contractor's work and providing assistance in testing, system integration, timing and data base development, inspection, and supervision.

City Force Account Work

Although there may be some apparent cost savings by performing work with city forces (e.g. installation of cable, detectors, etc.), all construction work should be performed by the Contractor. This insures that there is no misunderstanding as to who is responsible for the various items of work and that the Contractor is not dependent upon others for maintaining the project schedule.

The City should limit project involvement to developing the various traffic data required, preparing the system data base, and supervising testing and inspection. However, the project specifications should be written such that the City could participate in all phases of the construction such that personnel are totally familiar with all aspects of the system when it is completed.

Contracting Agency

Discussions concerning construction contracting procedures with the State indicated that the City normally acts as the contracting authority with the State providing assistance in bid advertising, letting, and providing advisory services during implementation. The administration of a computerized signal implementation project is generally more time consumming than a highway project of the same dollar value. This will require additional City capabilities provided either by temporary additions to the staff or consultant services that are not included in the cost estimates.

As an alternative, the State could act as the contracting authority with the City providing local assistance. It is, therefore, recommended that this subject be investigated further during the system design.

Implementation Staging

It is estimated the initial system implementation project will cost $1,708,000 as shown in Table 16. It should be noted, however, that almost $400,000 of this work represents controller equipment and intersection detection upgrading that should be performed now -- with the existing system.

TABLE 16 - ESTIMATED INITIAL CAPITAL COST

	Component	Cost (Thousands)
1.	Master Site Preparation	$ 20
2.	Master	162
3.	System Integration	60
4.	Timing and Data Base Development	42
5.	Controller Equipment	235
6.	Intersection Detection	171
7.	System Detection	134
8.	Communications	645
9.	Test Equipment	12
10.	Spares	17
11.	Inspection and Supervision	55
12.	PS&E	45
13.	Implementation Assistance	100*
14.	Training	10
	TOTAL	$1,708

In the event it is necessary to stage the project due to funding limitations, it is recommended that emphasis be placed on procurring the central equipment and controller equipment. As an interim measure, the system communications facility, which is estimated to cost $645,000 for a city owned cable network, could be provided by a mixture of city owned cable and telephone cable. Under this arrangement, a city owned network would be built in the CBD with communications to the remaining signals provided by Northwestern Bell Telephone at an annual cost of approximately $10,000. This would result

* Assumes State is contracting agency.

in an estimated reduction in initial construction costs of $300,000.

Construction of cable facilities to provide communications to locations initially using telephone cable could then be performed over several years. This could be accomplished by the City as part of the capital improvement program and as part of other construction projects.

Thus, the initial project should include as a minimum the installation of all master equipment and provide the foundation of a city owned cable system. Controller modifications, installation of new controller equipment, and installation of intersection and system detectors should be configured to optimize improvement realized within funding constraints.

Implementation Schedule

It is estimated that the initial implementation project will require between 18 and 24 months to complete, depending on the number of signals that are included in the project. As the project will require a substantial amount of field construction activity, the project time will also be affected by weather conditions. Before the implementation project can be let, it will be necessary to develop construction documents including plans, specifications, and estimates. In view of these factors and the project review time that will be required, a target date of fall 1978 to let the project would be most advantageous to the City and is an achievable goal. This would permit completion of the project in 1980.

To permit this schedule to be met, it would be necessary to combine the Phase II and Phase III work described as follows into a single project:

- Phase II - Prepare a detailed system description and an implementation guideline of the selected system.
- Phase III - Develop plans, specifications, and cost estimates to permit equipment, materials, and services to be procured.

This work should result in the design of the total system, including the communications network, and the construction documents for the initial implementation project. Subsequent construction work, that may be necessary due to staging, would then be performed to complete those portions of the system design that were not accomplished in the initial project.

Funding

The signal system improvement project is expected to qualify for Federal Aid Urban System funds which are administered by the Iowa Department of Transportation. In addition to this funding source, the Economic Stimulus Act of 1977 provided $10 million funding for the Traffic Control Signalization Demonstration Program authorized by Section 146, Federal Highway Act of 1976. Although these funds, which provided 100 percent funding, have been committed, an additional $20 million has been included in recommendations for Fiscal Year '78.

The Sioux City signal system system improvement project is felt to meet the criteria for a signal demonstration project. The project would seem to be of interest in that it is a labor intensive project and would demonstrate the use of modern traffic control technology in a typical Midwestern City. In view of this potentially favorable funding source, it is recommended that the City actively proceed into the design phase such that its status will increase the attractiveness of the project.

OPERATIONS AND MAINTENANCE

Continued operation and maintenance of the recommended system will require several long-term committments by the City. First, an additional traffic operations staff position at a semi-professional level will be required. This position, tentatively designated as Systems Specialist, will be required to insure that the capabilities offered by the system are utilized and to perform the analysis and operations tasks that are necessary to maximize system efficiency. Although the system would have the capabilities to operate essentially unattended, it will degrade in time if the recommended support is not provided. This would be particularly true in the CBD and Morningside areas due to the many changes that are expected. Although the system has the flexibility to accommodate these changes, engineering support is required to perform the system modifications.

Second, an additional maintenance position is required to provide dedicated electronics bench and field trouble-shooting capabilities. This position would be divorced from construction activities and normal day-by-day maintenance. Although this position is mandatory for maintenance of the recommended system, it is the opinion of JHK & Associates that these capabilities are currently required. Thus, this is a current need that must be provided if the recommended system is implemented.

Last, it would be necessary for the City to enter into an agreement with either the computer manufacturer or the systems supplier for the continued maintenance of the computer and peripherals. It is expected that daily periodic maintenance would be performed by the Systems Specialist, however, it would not be practical for the City to undertake total maintenance of the computer. As an interim measure, communications hardware should also be repaired by the vendor until such time that the City's maintenance forces have acquired sufficient experience to maintain this complex equipment. It is expected that outside maintenance of communications hardware will be required for a maximum of two years -- depending upon the background and capabilities of the electronics technician.

It is estimated that the support required to operate and maintain the recommended system will increase the current annual budget by $43,000. This estimate is shown in Table 17. It should be noted, however, that the electronics technician staff position is currently needed and does not actually indicate a cost that is a direct result of implementing the recommended system. This position should be added even if the system is not modernized.

TABLE 17 - ESTIMATED OPERATION AND MAINTENANCE BUDGET INCREASE

Item	Annual Cost
Systems Specialist	$14,000
Electronics Technician	11,000
Computer Maintenance Contract	15,000
Interim Communications Maintenance	3,000
TOTAL	$43,000

To insure that operation and maintenance personnel are knowledgeable in the system operation, the system implementation should include staff training. The training requirements would include factory training on equipment and "hands on" training during construction. This training should be included as part of the requirements of the system implementation project to be provided by the prime contractor, equipment suppliers, and the Consultant. This training will permit the City to assume full responsibility and operate the system without outside assistance other than that previously described.

The increased operation and maintenance cost are more apparent than real. The modernized system will reduce trouble call maintenance which will permit personnel to perform other activities that cannot be done now. Based on the experience of other Cities, it is expected that the system will also promote a higher level of staff efficiency, pride, and professionalism. This factor alone can produce high dividends to the public.

APPENDIX A
CANDIDATE UTILITY

Table A-1 through A-5 presents a summary of the development of utility values for the existing system and each candidate signal system. These tables present, for each evaluation goal, the utility measure score attained by the systems and the resultant system utility. The total utility value for the goal and the weighted utility value is also shown.

TABLE A-1 TRAFFIC OPERATIONS UTILITY

Utility Measurement	Weight	Existing System		CANDIDATE 1		2		3		4		5		6	
Initial Boundary Configuration	15	(2)*	30**	(5)	75	(7)	105	(10)	150	(10)	150	(10)	150	(10)	150
Coordination Between Systems	14	(0)	0	(0)	0	(5)	70	(10)	140	(10)	140	(10)	140	(10)	140
Repetitive Timing Plan	16	(2)	32	(8)	128	(9)	144	(10)	160	(10)	160	(10)	160	(10)	160
Reserve Timing Plan Capabilities	10	(0)	0	(0)	0	(5)	50	(10)	100	(10)	100	(10)	100	(10)	100
Timing Plan Selection Techniques	10	(0)	0	(9)	90	(9)	90	(10)	100	(8)	80	(10)	100	(10)	100
Fire Route Preemption	8	(0)	0	(5)	40	(5)	40	(5)	40	(0)	0	(10)	80	(10)	80
Controller Operation	14	(4)	56	(5)	70	(6)	84	(7)	98	(4)	56	(9)	126	(10)	140
Local Preemption	7	(10)	70	(10)	70	(10)	70	(10)	70	(0)	0	(10)	70	(10)	70
Special Controller Operations	6	(1)	6	(2)	12	(4)	24	(5)	30	(4)	24	(9)	54	(10)	60
Total Utility Value			194		485		677		888		710		980		1,000
Goal Weight			.33		.33		.33		.33		.33		.33		.33
Weighted Utility Value			64.0		160		223		293		234		323		330

* (x) - Candidate Score

** x - Candidate Utility

TABLE A-2 TRAFFIC ENGINEERING ANALYSIS UTILITY

Utility Measure	Weight	Existing System	CANDIDATE 1	CANDIDATE 2	CANDIDATE 3	CANDIDATE 4	CANDIDATE 5	CANDIDATE 6
Operations Event Record	20	(0)* 0**	(0) 0	(6) 120	(8) 160	(9) 180	(10) 200	(10) 200
Permanent Count Station Data	15	(0) 0	(0) 0	(3) 45	(5) 75	(7) 105	(10) 150	(10) 150
Surveillance MOE Data	26	(0) 0	(0) 0	(5) 130	(7) 182	(8) 208	(10) 260	(10) 260
Surveillance Report Format	19	(0) 0	(0) 0	(2) 38	(3) 57	(5) 95	(8) 152	(10) 190
Real-Time Data Collection	10	(0) 0	(0) 0	(0) 0	(0) 0	(0) 0	(8) 80	(10) 100
Freeway Traffic Surveillance	10	(0) 0	(0) 0	(3) 30	(5) 50	(7) 70	(10) 100	(10) 100
Total Utility Value		0	0	363	524	658	942	1,000
Goal Weight		.18	.18	.18	.18	.18	.18	.18
Weighted Utility Value		0	0	65	94	118	170	180

* (x) - Candidate Score

** x - Candidate Utility

TABLE A-4 MAINTENANCE OPERATIONS UTILITY

Utility Measure	Weight	Existing System	CANDIDATE 1	2	3	4	5	6
Monitor Controller Operation	20	(0)* 0**	(0) 0	(5) 100	(7) 140	(6) 120	(8) 160	(10) 200
Monitor System Detectors	15	(0) 0	(0) 0	(6) 90	(7) 105	(8) 120	(8) 120	(10) 150
Monitor Intersection Detectors	15	(0) 0	(0) 0	(5) 75	(7) 105	(5) 75	(8) 120	(10) 150
Permanent Maintenance Failure Log	13	(0) 0	(0) 0	(5) 65	(6) 78	(8) 104	(10) 130	(10) 130
Level of Increased Maintenance Technology Required	15	(10) 150	(8) 120	(5) 75	(5) 75	(3) 45	(2) 30	(1) 15
Familiarity With Equipment	12	(10) 120	(10) 120	(7) 84	(7) 84	(7) 84	(7) 84	(1) 12
Level of Outside Maintenance Assistance Required	10	(10) 100	(10) 100	(6) 60	(5) 50	(4) 40	(3) 30	(2) 20
Total Utility Value		370	340	549	637	588	674	677
Goal Weight		.18	.18	.18	.18	.18	.18	.18
Weighted Utility Value		67	61	99	115	106	121	122

* (x) - Candidate Score

** x - Candidate Utility

TABLE A-5 IMPLEMENTATION CHARACTERISTICS UTILITY

Utility Measure	Weight	Existing System	CANDIDATE 1	2	3	4	5	6
Equipment and Software Availability	25	(10)* 250**	(10) 250	(8) 200	(7) 175	(8) 200	(5) 125	(3) 75
Proven Technology	20	(10) 200	(10) 200	(7) 140	(6) 120	(9) 180	(6) 120	(4) 80
Operations Personnel Educational Requirements	20	(10) 200	(10) 200	(5) 100	(4) 80	(4) 80	(3) 60	(1) 20
Maintenance Personnel Educational Requirements	20	(10) 200	(8) 160	(5) 100	(4) 80	(4) 80	(3) 60	(1) 20
Implementation Impact	15	(10) 150	(8) 120	(5) 75	(4) 60	(4) 60	(4) 60	(2) 30
Total Utility Value		1,000	930	615	515	600	425	225
Goal Weight		.13	.13	.13	.13	.13	.13	.13
Weighted Utility Value		130	121	80	67	78	55	29

* (x) - Candidate Score

** x - Candidate Utility

APPENDIX B
COST ESTIMATES

Cost estimates were developed for each of the candidate systems and the existing system for a ten-year period and are shown in Tables B-1 through B-7. A ten-year time frame for cost comparison was used since this is considered a minimum system design life. The estimated costs reflect both the capital improvement investment required and the operating expenses associated with each system. The total annual cost was then reduced to present worth by the application of a seven percent discount rate. The last column of each table presents the ten year cost for each category, the total cost, and the present worth cost.

TABLE B-1 EXISTING SYSTEM - TEN YEAR COST ANALYSIS
(Thousands)

	Year 1	2	3	4	5	6	7	8	9	10	Total
CAPITAL COST											
1. Master Site Preparation											
2. Master											
3. System Integration											
4. Timing and Data Base Development	5	5									10
5. Controller Equipment	72	148	22	22	22	22	22	22	26	26	404
6. Intersection Detection	56	115	22	22	22	22	22	22	17	17	337
7. System Detection											
8. Communications											
9. Test Equipment		6									6
10. Spares		10									10
11. Inspection and Supervision	10	20									30
12. PS&E	15										15
13. Implementation Assistance	6	15									21
14. Training	2	2									4
TOTAL	166	321	44	44	44	44	44	44	43	43	837
RECURRING COST											
1. Master Maintenance											
2. Controller Maintenance			14	15	17	18	19	21	22	23	149
3. Detector Maintenance											
° Intersection			10	11	12	13	14	15	16	17	108
° System											
4. Communications Maintenance			1	1	1	1	1	1	1	1	8
5. Telephone Rental	2	2	2	2	2	2	2	2	2	2	20
6. Operations Personnel	9	9	5	5	5	5	5	5	5	5	58
7. Interim Maintenance	24	24									48
TOTAL	35	35	32	34	37	39	41	44	46	48	391
TOTAL	201	356	76	78	81	83	85	88	89	91	1,228
Present Value Factor (7%)	1.0	0.9346	0.8734	0.8163	0.7629	0.7130	0.6663	0.6227	0.5820	0.5439	
Present Value	201	332.7	66.4	63.7	61.8	59.2	56.6	54.8	51.8	49.5	997.5

TABLE B-2 CANIDATE 1 - TEN YEAR COST ANALYSIS
(Thousands)

	Year 1	2	3	4	5	6	7	8	9	10	Total
<u>CAPITAL COST</u>											
1. Master Site Preparation											
2. Master	16	16		6	6	6		6		6	62
3. System Integration											
4. Timing and Data Base Development	9	10									19
5. Controller Equipment	156	235	31	31	31	31	31	31	33	33	643
6. Intersection Detection	56	115	22	22	22	22	22	22	17	17	337
7. System Detection	13	25		8	8	8		8		8	78
8. Communications	142	288		7	7	7	7	7	7	7	479
9. Test Equipment	6										6
10. Spares		10									10
11. Inspection and Supervision	16	32									48
12. PS&E	30										30
13. Implementation Assistance	12	23									35
14. Training	2	2									4
TOTAL	458	756	53	74	74	74	60	74	57	71	1,751
<u>RECURRING COST</u>											
1. Master Maintenance			2	2	3	3	3	4	4	5	26
2. Controller Maintenance			22	23	25	26	27	29	30	31	213
3. Detector Maintenance											
° Intersection			10	11	12	13	14	15	16	17	108
° System			2	2	3	3	3	4	4	4	25
4. Communications Maintenance			5	5	5	6	6	6	6	6	45
5. Telephone Rental											
6. Operations Personnel	25	25	13	13	13	13	13	13	13	13	154
7. Interim Maintenance	24	24									48
TOTAL	49	49	54	56	61	64	66	71	73	76	619
TOTAL	507	805	107	130	135	138	126	145	130	147	2,370
Present Value Factor (7%)	1.0	0.9346	0.8734	0.8163	0.7629	0.7130	0.6663	0.6227	0.5820	0.5439	
Present Value	507	752.4	93.5	106.1	103.0	98.4	84.0	90.3	75.7	80.0	1990.4

TABLE B-3 CANDIDATE 2 - TEN YEAR COST ANALYSIS
(Thousands)

	Year 1	2	3	4	5	6	7	8	9	10	Total
CAPITAL COST											
1. Master Site Preparation	20										20
2. Master	34	70		5	5	6		6		6	132
3. System Integration	12	23									35
4. Timing and Data Base Development	8	17									25
5. Controller Equipment	113	228	31	31	31	31	31	31	32	32	591
6. Intersection Detection	56	115	22	22	22	22	22	22	17	17	337
7. System Detection	28	58		8	8	8		8		8	126
8. Communications	204	413	9	9	9	9	9	9	12	12	695
9. Test Equipment	12										12
10. Spares		14									14
11. Inspection and Supervision	17	34									51
12. PS&E	44										44
13. Implementation Assistance	23	47									70
14. Training	3	4									7
TOTAL	574	1,023	62	75	75	76	62	76	61	75	2,159
RECURRING COST											
1. Master Maintenance			13	13	14	14	14	15	15	15	113
2. Controller Maintenance			19	20	22	23	24	26	27	28	189
3. Detector Maintenance											
° Intersection			10	11	12	13	14	15	16	17	108
° System			4	5	5	5	5	6	6	6	42
4. Communications Maintenance			13	13	14	14	14	14	15	15	112
5. Telephone Rental											
6. Operations Personnel	30	30	22	22	22	22	22	22	22	22	236
7. Interim Maintenance	24	24									48
TOTAL	54	54	81	84	89	91	93	98	101	103	848
TOTAL	628	1,077	143	159	164	167	155	174	162	178	3,007
Present Value Factor (7%)	1.0	0.9346	0.8734	0.8163	0.7629	0.7130	0.6663	0.6227	0.5820	0.5439	
Present Value	628	1006.6	124.9	129.8	125.1	119.1	103.3	108.3	94.3	96.8	2536.2

TABLE B-6 CANDIDATE 5 - TEN YEAR COST ANALYSIS
(Thousands)

	Year 1	2	3	4	5	6	7	8	9	10	Total
CAPITAL COST											
1. Master Site Preparation	20										20
2. Master	53	109									162
3. System Integration	20	40									60
4. Timing and Data Base Development	14	28									42
5. Controller Equipment	78	157	24	24	24	24	24	24	27	27	433
6. Intersection Detection	56	115	22	22	22	22	22	22	17	17	337
7. System Detection	44	90		12	12	12		12		12	194
8. Communications	213	432	12	12	12	12	12	12	14	14	745
9. Test Equipment	12										12
10. Spares		17									17
11. Inspection and Supervision	18	37									55
12. PS&E	45										45
13. Implementation Assistance	33	67									100
14. Training	4	6									10
TOTAL	610	1,098	58	70	70	70	58	70	58	70	2,232
RECURRING COST											
1. Master Maintenance			14	14	14	14	14	14	14	14	112
2. Controller Maintenance			14	15	17	18	19	21	22	23	149
3. Detector Maintenance											
° Intersection			10	11	12	13	14	15	16	17	108
° System			6	7	8	9	9	9	9	10	67
4. Communications Maintenance			12	13	14	16	17	18	20	21	131
5. Telephone Rental		1	1	1	1	1	1	1	2	2	11
6. Operations Personnel	30	30	22	22	22	22	22	22	22	22	236
7. Interim Maintenance	24	24									48
TOTAL	54	55	79	83	88	93	96	100	105	109	862
TOTAL	664	1,153	137	153	158	163	154	170	163	179	3,094
Present Value Factor (7%)	1.0	0.9346	0.8734	0.8163	0.7629	0.7130	0.6663	0.6227	0.5820	0.5439	
Present Value	664	1077.6	119.7	124.9	120.5	116.2	102.6	105.9	94.9	97.4	2623.7

APPENDIX C
COMMUNICATIONS

As the communications facility necessary to interconnect signals to the computer is a relatively large component of the total system cost, an investigation of all alternatives was performed. This included the use of services provided by others, such as Northwestern Bell Telephone, and the joint use of telephone and power company facilities for the installation of city owned cable.

Sioux City is somewhat unique in that there does not currently exist an extensive city cable network or city owned facilities (conduit, pole lines, etc.) to install cable. Therefore, investigations were first made to determine whether it was feasible to install cable in or on facilities owned by Northwestern Bell or Iowa Public Service Co. This resulted in the following findings:

1. There are no requirements by these utilities to provide space in conduit or on pole lines for cable installation by the City.
2. Underground installation of city cable in Iowa Public Service Co. conduit, if available, is discouraged due to potential hazard and liability. The probability of joint use of underground facilities is very small.
3. Northwestern Bell has some conduit space available and would permit the City to install cable. However, a conduit rental cost of $.90 per foot per year would apply. Therefore, over the life of the system it would be less expensive for the City to build new underground facilities.
4. Joint use of pole lines is permitted by both utilities at a yearly rental cost of approximately $5.00 per pole per year.

Based on these findings a preliminary cable routing was developed using a city owned underground facility in the CBD and an aerial, joint use facility elsewhere. This was reviewed by the utilities, adjusted to minimize utility conflicts, and found to be a feasible approach.

The cost of the cable network was then estimated to permit a cost comparison of similar services provided by Northwestern Bell to