A Traffic Control System for the City of Kuwait

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ABSTRACT

The background of the rapidly rising demand for transportation in Kuwait is described and the main features of a proposed area traffic control (ATC) system are discussed. This system will coordinate traffic signals throughout most of the urban area of the city of Kuwait. It will also monitor car park usage, control car park guide signs, and provide a variety of data for use in traffic engineering and planning studies. The ATC system will operate in parallel with closed-circuit television and motorway (freeway) surveillance and control systems. Factors affecting preparation of specifications for international bidding are discussed, including the needs to specify functional requirements and to minimize misunderstandings between contractor and purchaser at an early stage. Finally, the importance of an appropriate organization and staffing are stressed if the new systems of control are to achieve maximum benefits. The ATC system is expected to play a key role in this organization and is an important element in the municipality's overall plan for traffic control and management in the future.

The municipality of Kuwait has overall responsibility for planning urban transport and the roadway system. In this role, the municipality commissioned a feasibility study and functional design project for an area traffic control (ATC) system to control and coordinate traffic signals in the urban area of the city of Kuwait.

The scope of the study was broad in nature in recognition of the integrated nature of modern traffic management. In addition to ATC functions, attention was focused on monitoring of operations at key multistory car parks in the central business district (CBD), a closed-circuit television system, and potential interaction with a proposed motorway surveillance and control system.

The efficiency of the existing organization of departmental responsibilities for traffic-related functions was also examined, with a view to maximizing the municipality's capabilities for effective traffic management in the future--a capability that will assume increasing importance as increasing travel demand places greater strains on the CBD and urban area road networks.

Summarized in this paper are some of the major findings of this study and an outline is given of the principal features of the system, which will play a central role in traffic management in the city of Kuwait during the next 10 to 15 years.

DEVELOPMENT OF THE URBAN AREA OF KUWAIT

Before describing the feasibility study and the ATC system in detail, it is useful to consider how the urban transport system as a whole has developed to its current form and to indicate the intended role of the ATC system as an integral part.

Pre-1950 Development

Urban development in Kuwait before 1950 occurred in the old town, bounded by a wall approximately along the line of the existing Soor Street. The population of the country at that time was approximately 100,000, the majority of whom lived in the old town. The road system in town was extremely limited and most movement was by foot, camel, or horse. Although the statistics for the period are not very accurate, it appears that less than 10,000 motor vehicles existed in the entire country.

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Development in the 1950s and Early 1960s

The 1952 Kuwait master plan, shown in Figure 1, established a radial and ring system of roads extending from the boundary of the old town. This system included 1st Ring Road, 2nd Ring Road, and 3rd Ring Road, with radials converging on the town. The plan was based on a population of 1.25 million as a long-term growth target.

The radial and ring roads were all built to dual carriageway (four-lane divided roadway) standards with central reservations and generous rights-of-way, approximately 130 m (426 ft). A roundabout was constructed at almost all intersections on the Kuwait road system because it was the favored form of intersection in the United Kingdom at that time.

The decade from 1951 to 1961 was one of significant growth in population. By 1957 the population reached almost 200,000 and by 1961 had exceeded 300,000. Despite the rapid growth in population, the road network still provided a good level of service to traffic. This was primarily due to the very low rate of automobile ownership, that is, only 23,000 vehicles were registered in the country in 1960.

By 1965 the population had reached 475,000, and registered vehicles had almost quadrupled since 1960 to more than 80,000.

Transportation in the 1960s and 1970s

The development of the country had gone considerably beyond the limits foreseen in the original development plan. The municipality reacted to this development by extending the radial-ring development concept to include 4th Ring Road. However, it was clear that the original concept was out of scale with ac-

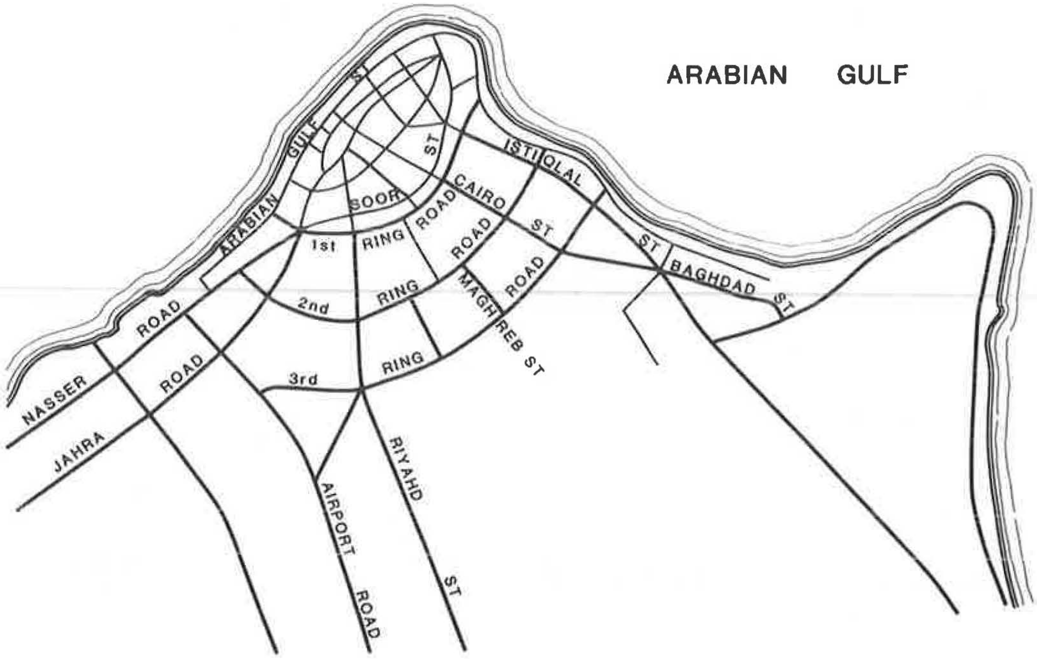

FIGURE 1 1952 Kuwait master plan.

tual and possible future developments. In 1968, the municipality initiated the development of a new master plan for Kuwait.

The new master plan predicted that a population level of 2 million would be reached between 1985 and 1997, along with corresponding increases in automobile ownership. Components of the 1971 master plan most relevant to the ATC project were as follows:

- The road system in the city of Kuwait Town should be restructured into a hierarchical system including new primary roads of motorway (freeway) standard at the highest level with secondary and tertiary roads to cater for shorter distance travel;
- A new (fifth) ring road should be built to motorway standard;
- Jahra Road from the city of Kuwait to Jahra in the west should be developed to motorway standard;
- Magreb Street should be upgraded to motorway standard and extended toward Ahmadi in the south to form the main connection to the proposed linear development down the eastern coast;
- Two other radials should be upgraded to motorway standard; and
- The population of the metropolitan area should be limited to 1.25 million, with additional development past this level being accommodated in new towns outside the metropolitan area.

The first comprehensive area traffic management plan for Kuwait was developed at the same time as the 1971 master plan. This traffic management plan introduced a system of one-way streets, related control of turning movements, improved parking layouts, replaced many roundabouts with signal-controlled intersections, and so forth. Although traffic signals had previously been applied at a few intersections in Kuwait, this plan clearly demonstrated their advantages of positive control in the urban area. Without doubt, this was the period during which the foundation of a system leading toward comprehensive ATC was set.

Design work began on the proposed motorway and expressway system during 1972 to 1973. Construction of the motorways and expressways began soon after the design effort. Consequently, much of the system is now open to traffic.

Effects of Population Growth

The problems of management and control of traffic in Kuwait are made more difficult by the population composition and rates of change. Table 1 shows the increases in the numbers of Kuwaitis and non-Kuwaitis from 1957 to 1980. It can be seen that while the Kuwaiti population increased during this period from 109,000 to 572,000 (this includes naturalization), the non-Kuwaiti population increased from 84,000 to 794,000.

TABLE 1 Population Growth, 1957-1980

Year	Kuwaiti	Non-Kuwaiti	Total
Total Population (1000s)			
1957	109.5	84.1	193.6
1961	153.7	155.0	308.7
1965	225.3	250.6	475.9
1970	336.7	397.7	734.4
1975	475.8	524.3	1,000.1
1980	572.3	794.6	1,366.9
Population Change			
1957-1961	44.2	70.9	115.1
1961-1965	71.6	95.6	167.2
1965-1970	111.4	147.1	278.5
1970-1975	139.1	126.6	245.7
1975-1980	96.5	270.3	366.8
Average Annual Percentage Rate of Increase			
1957-1961	8.8	16.5	12.4
1961-1965	10.0	12.8	11.4
1965-1970	9.6	9.7	9.7
1970-1975	5.9	5.7	5.8
1975-1980	3.8	8.7	6.5

Since 1961, the majority of the population has been non-Kuwaiti, that is, persons who come from a wide variety of backgrounds, nationalities, and social groups. Furthermore, the non-Kuwaiti population is continually changing because of migration into and out of the country. The 1980 census indicated that almost 50 percent of non-Kuwaitis had resided in Kuwait for less than 4 years. In such a dynamic situation, it will be appreciated that the scale of traffic growth is only one aspect of the problems affecting traffic control.

Because of a variety of factors, the municipality was convinced that traffic levels were likely to exceed the estimates of the 1971 master plan. Therefore, the municipality decided that an ATC system, in parallel with the work on the new primary network of motorways, could provide an overall improvement to the secondary network. This led to the municipality's commissioning Wilbur Smith and Associates to conduct the ATC feasibility study in 1980.

SCOPE OF STUDY

In recognition of the important role that traffic management has to play in meeting the severe transportation demands in a city such as Kuwait, the scope of the study was defined to cover a broad range of topics. In addition to a feasibility study and the preparation of functional specifications and plans for a comprehensive traffic control system, the scope encompassed recommendations on the creation of a traffic engineering department. For purposes of describing the scope of the study, the work can be divided into the following four categories:

- Data collection
- Definition of required facilities
- Preparation of specifications and plans
- Organization of a traffic management department

Each of these categories is described in the following subsections.

Data Collection

As is to be expected with a study of this nature, a wide variety of data was collected, including the following types:

- Manual intersection turning movement counts
- Directional machine traffic counts
- Speed-and-delay studies
- Driver behavior observations
- Vehicle occupancy counts
- Pedestrian movement counts
- Equipment inventory and intersection photographs
- Emergency vehicle operations
- Platoon dispersion studies

Most of the data collection surveys were conducted in a fairly conventional manner and are therefore not elaborated on further. However, the inclusion of platoon dispersion studies is somewhat unusual in a project of this nature and therefore will be further discussed in the following subsection.

Platoon Dispersion Studies

The distance between signalized intersections in certain areas of the Kuwait road network exceeds that range normally associated with deriving benefits from coordination of signal timings. However, because of the high standards of road construction, typically six-lane divided roadways with limited access to neighboring residential areas, traffic was observed to remain in platoons for distances of up to 2 km (6,560 ft).

Because of these observations, measurements were made of the rate at which platoons disperse on the roads in Kuwait. The data collection techniques used and subsequent analysis of data are described in more detail elsewhere (1). As a result of these efforts, it was concluded that

1. Traffic remains in platoons on the ring and arterial roads of Kuwait sufficiently to derive benefits from coordination of signals that are typically 1,000 to 2,000 m (3,280 to 6,560 ft) apart;
2. The normal range of values for the platoon dispersion factor (K) used in the TRANSYT signal-timing optimization program (2,3) is applicable to the ring and arterial roads of Kuwait as well as to the CBD road network; and
3. The optimized timings resulting from TRANSYT are not unduly sensitive to the value of the dispersion factor used, and in the majority of networks use of the program's default value (K35) will be adequate.

Definition of Required Facilities

The need to improve traffic management capabilities in Kuwait in terms of staff, organization, and the facilities available to the traffic engineer led to a wide range of functions being considered for inclusion in the system. These functions included

- Signal control and timing
- Emergency vehicle facilities
- Car park monitoring
- Closed-circuit television
- Motorway surveillance and control
- Data collection and retrieval

The extent to which each of these functions was incorporated into the functional design of the ATC system is described in the following subsections.

Signal Control and Timing

The continuing development of the city of Kuwait necessitated a system design that would be flexible to both short- and long-term changes in traffic demand. Accordingly, many intersections were specified to be equipped for vehicle actuation, with the central system having the capability to control, at any particular time, the mode of operation of each controller (pretimed, semi-actuated, or fully actuated operation). The flexibility to reorganize from the central computer the groups of intersections operating on a common cycle time (changing subarea boundaries) was also required.

Significant stand-alone capabilities were also required of controllers, including time-based coordination (cableless linking) to protect against failures of the data transmission system.

Alternative timing-plan selection techniques (time-of-day, traffic-responsive plan selection, and on-line optimization) were considered. The well-proven time-of-day technique was chosen. Although some additional benefits may be provided by an on-line optimization technique in the Kuwait CBD, it was not considered appropriate to specify such a requirement in the initial system. The most well-proven and thoroughly tested technique of this nature is the SCOOT system, developed by the Transport and Road Research Laboratory in England and three British signal system companies (4). Because this technique is only available to British companies at the current time, it was not considered proper to specify it by name in a specification to be used for international bidding. To permit such facilities to be made available in the future, the specifications required that the system be capable of expansion to provide advanced traffic control techniques.

Emergency Vehicle Facilities

During discussions with fire service personnel, the desirability of preempting traffic signals was identified. Such preemption would assist emergency vehicles moving along predetermined routes, shown in Figure 2, by providing a green signal for these vehicles and by clearing traffic ahead of them. Accordingly, a preemption system was designed and specified in which the central computer directly controls each preempted controller via the normal communication lines. The fire preemption system is initiated by fire service personnel requesting 1 of up to 15 routes at a terminal located at the fire house. The terminal is connected to the central computer via the same type of communication lines as the controllers. In the initial system, two fire houses will be equipped with preemption terminals. The system will be capable of accommodating a total of at least six terminals.

A simpler, hard-wired form of preemption was required at two other fire houses. In these cases, a single intersection nearest the fire house is preempted when a button is pressed inside the fire station. Up to three exit plans will be provided for each fire house.

Car Park Monitoring

The construction and control of 23 multistory car parks in the CBD is a key element of the municipality's transport policy for the immediate and short-term future. Because these car parks will be widely distributed throughout the CBD, it was considered important to inform motorists of the location of car parks in which excess capacity exists at any point in time. Signs controlled by the ATC system will present information to the motorist sufficiently far in advance to direct him to an alternative car park if his first-choice car park is already full. Two types of signs will be used, which are shown in Figure 3. Providing this information should minimize the extent to which CBD congestion is exacerbated by motorists searching for a parking space.

The ATC system will receive data on the number of vehicles entering and leaving each car park and will control the informational signs. The ATC system will not, however, control the FULL signs immediately outside a car park or on each floor of the car park (if installed); these signs will continue to be controlled by the internal monitoring system of each car park.

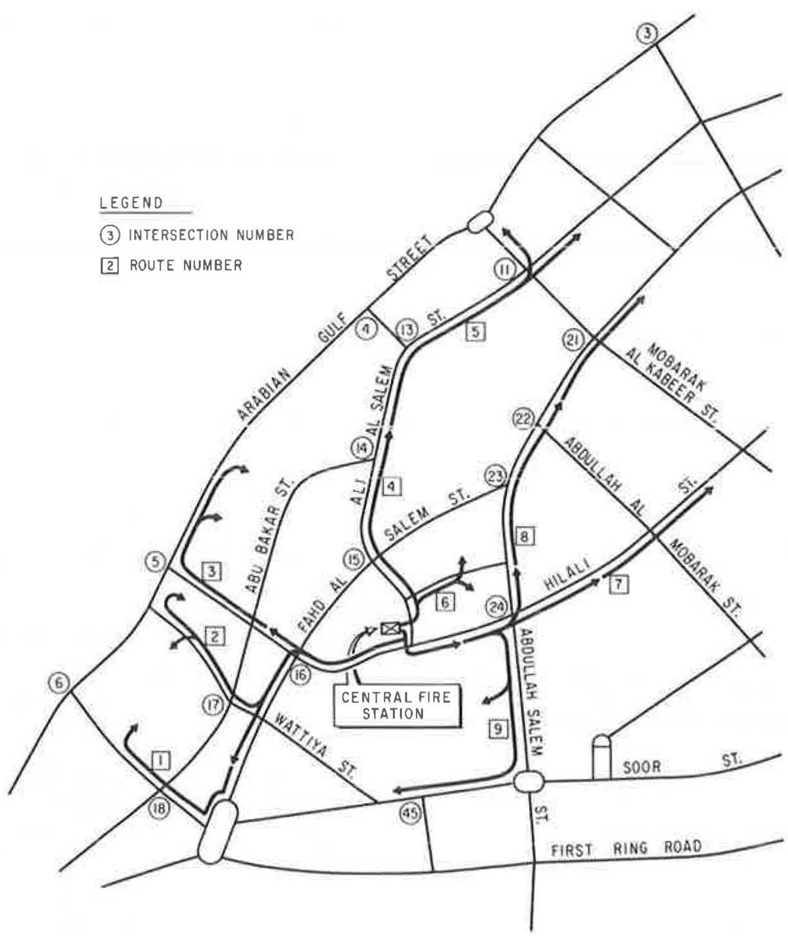

FIGURE 2 Proposed preemption routes for central fire station.

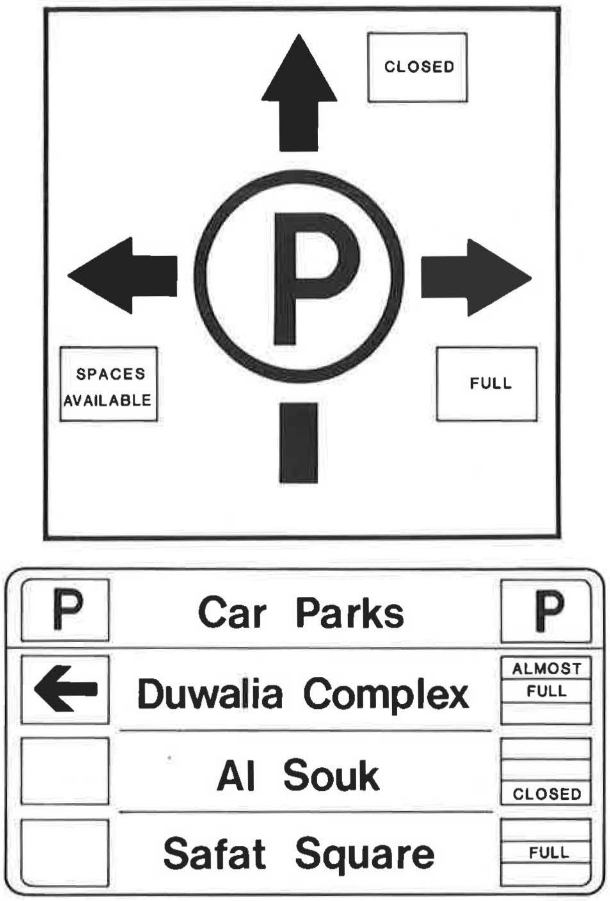

FIGURE 3 Car park information signs.

Monitoring of car parking performed by the ATC system is only one element of the municipality's car parking policy. If loss of roadway capacity caused by parked vehicles is to be minimized, several other points will also have a critical role to play: reduction of roadside parking, more rigorous enforcement of parking regulations, and control of car park fees.

Closed-Circuit Television

To enable system operators to monitor traffic conditions more effectively, a system of closed-circuit television (CCTV) cameras was designed to cover several key areas of the road network. A total of 12 cameras will be installed initially. These will be controlled by operators in the Traffic Control Center, who will view incoming pictures on any of the 12 wall-mounted television monitors and two desk-mounted monitors. The operator may also select that the output of any camera be recorded on a standard video cassette recorder for special studies, as necessary. A separate television monitor will be provided for use with the video cassette recorder. The CCTV system will be capable of expansion to incorporate up to 64 cameras and 16 wall-mounted monitors.

The CCTV system, while integrated into the traffic control system in an operational sense, will be provided by an entirely independent set of equipment. The CCTV system will be using its own transmission lines (coaxial cable), but may share some of the ducting used by the traffic control communication lines (25, 50, or 100 pairs of telephone-type cable).

As in most traffic systems of this nature, the use of CCTV will provide only one of a variety of means by which traffic problems will be brought to the attention of system operators. The ATC system has the capability of reporting when congestion is detected by unusually high occupancy at mid-block vehicle detectors. Direct communications will also be available from the ATC Center to the police and public transport agencies so that reports radioed in by police and bus drivers on the street can be relayed directly to traffic engineering staff. In addition, information from Kuwait's motorway surveillance and control (MSC) system will be readily available; this system is explained in the next subsection.

Motorway Surveillance and Control

At the time of the feasibility study in the early 1980s, Kuwait had already committed itself to a program of upgrading existing roads and constructing additional roads to provide a network of urban motorways. The principal features of this network were to be a new ring entirely surrounding the CBD, including both elevated and depressed roadway sections, together with a number of radial routes leading outward through the urban areas to neighboring towns and industrial complexes.

This motorway network will further improve the already high standard of roadway facilities in Kuwait and will eliminate a number of significant conflicting movements by grade separations. Nevertheless, the network will pose its own control problems, particularly regarding entry to and exit from the motorway system. The motorway's ability to rapidly move large volumes of traffic through the urban area is of little value if the street network in the vicinity of CBD exits is unable to absorb the demand without undue congestion. Design of the MSC system was not within the scope of the ATC feasibility study, and implementation of the motorway control system was expected to follow the ATC system at a later stage. However, the need for coordination of control activities between the two systems was recognized.

A number of possibilities concerning the integration of the MSC and ATC systems were reviewed. Coordination of control will be achieved principally at the operator level by the sharing of a common control room. The room will be of sufficient size to ensure that operators are not unduly distracted from their own duties. Nevertheless, this close proximity of operators controlling the two systems should enable the necessary feedback to be received concerning the impact on one system of action taken in the other. The central equipment of each system will operate independently of the other, although in due course some interchange of traffic count data may occur. In the street, the communication cables of the two systems will share ducting whenever practical.

Data Collection and Retrieval

Collection of a variety of traffic data and convenient presentation of such data to the end user were considered important requirements for achieving the overall objectives of providing an effective traffic management tool. Data to be collected range from short-term monitoring information on equipment failures, detector occupancy measurements, and car park status (full, almost full, or space available) to daily, weekly, and monthly reports and summaries of traffic volumes and car park usage.

Monitoring information will be presented by means of a wall map display operation, color graphics displays, and a combination of CRT and printed messages. The wall map display will provide a general overview of status. The color graphics displays will provide more detailed information and will be of particular value to operators and engineers because of the control available over the nature and level of detail of data presented. The optional weekly and monthly summaries of traffic flow and car park usage will be provided as printed reports; they are expected to be of use to planning and other departments, as well as to the traffic engineering department.

Preparation of Specifications and Plans

Specifications were prepared, to the extent possible, in a functional form to be suitable for international bidding. The specifications gave the contractor a certain degree of latitude in the final system design because detailing specific requirements could have inadvertently precluded some manufacturers from responding. In view of the functional nature of the specifications, the contractor will be fully responsible for designing, supplying, and installing a complete and operational ATC system, meeting the minimum requirements of the specifications.

Hardware Requirements

The functionality of the specifications applies to both hardware and software. In the case of hardware, certain minimum requirements were identified, together with specified performance characteristics such as the percentage of spare disk capacity, and CPU time and the maximum permitted response time to operator commands. Within these requirements, the contractor would then be responsible for designing and configuring a suitable hardware and software combination.

The computer configuration envisaged is shown in functional block diagram form in Figure 4. It features dual computer systems, one of which usually operates in a backup mode ready to take over if the primary computer fails. Peripherals essential for on-line operation are automatically switched to the on-line computer at all times. The primary storage medium is a disk, with magnetic-tape facilities being provided for archiving purposes.

Sufficient processing power and memory-disk capacity are required to enable the system to perform general engineering functions as background tasks, if necessary.

Software Requirements

The traffic engineering capabilities of a computerized signal system are defined by the system's software. To permit international bidding, no particular software package was specified by name, and requirements were defined in purely functional (although detailed) terms. The overall scope of the requirements is comparable to those included in systems in many other major cities around the world.

Using only time-of-day plan selection in Kuwait represents a simplification of software requirements, compared with other cities. On the other hand, the dual computer operation and car park monitoring requirements are less common.

Construction and Installation Standards

In addition to the functional plans and specifications for the ATC system hardware and software, the

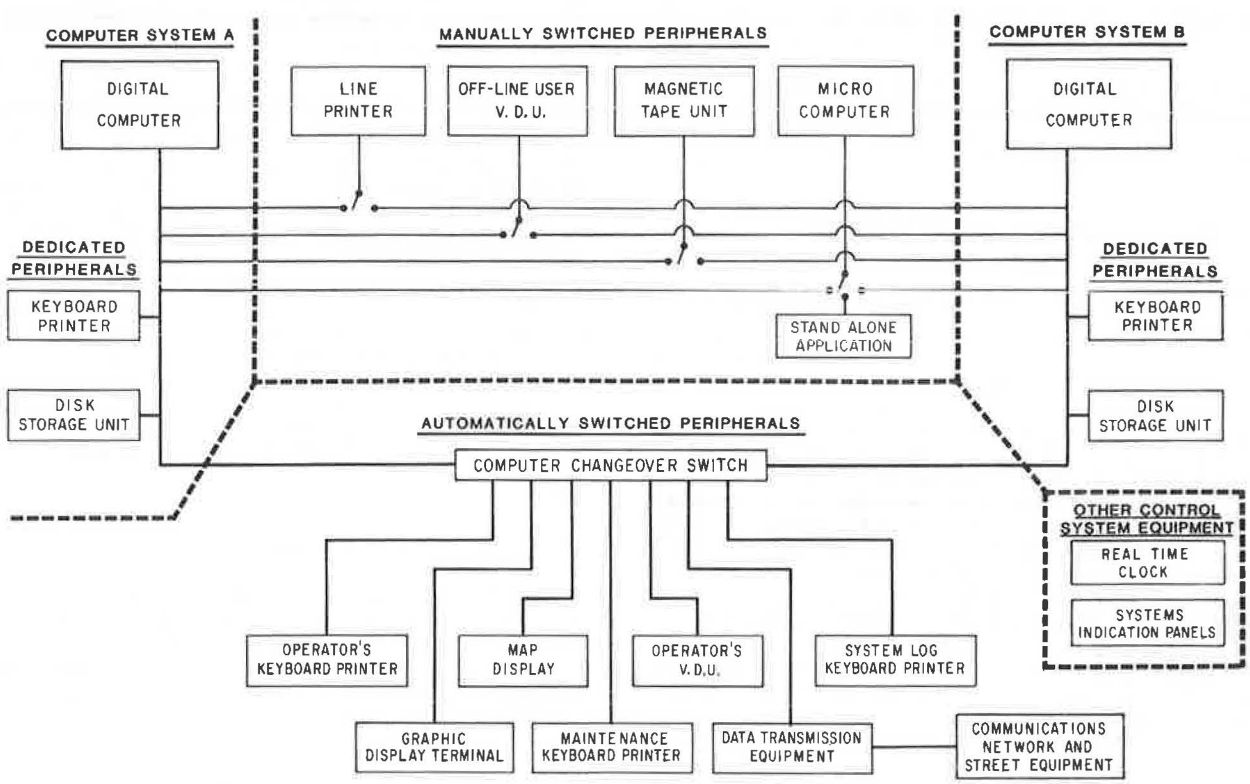

FIGURE 4 Functional block diagram form of central computer system.

practices and standards for construction of roadworks and installation of traffic signals and auxiliary equipment were defined in detail. To permit the contractor a measure of latitude, appropriate minimum standards and requirements for system implementation were developed. Detailed plans were prepared for roadway and intersection geometrics as well as for improvements to existing on-street signal hardware (signal heads, poles, conduit, detectors, etc.) and the construction of new signalized intersections.

Final System Proposal

As expected with a system of this nature, the specifications are necessarily detailed and lengthy, covering a wide range of equipment and services to be provided by the contractor, in addition to the computer hardware and software mentioned previously. Most sections of the specifications are along conventional lines, defining requirements for controllers, detectors, communications equipment, and so forth. However, one element of the specifications, while less common, is considered particularly important because of the international nature of the contract and the resulting problems of communications between the principal parties involved.

At the commencement of the contract, a 5-month-long final system proposal (FSP) period begins, during which the contractor is required to present a detailed proposal describing all aspects of the system to be provided. A preliminary submission is required after 2 months and a final submission after 5 months. Each submission is reviewed and discussed with the contractor in detail to ensure that the contractor fully understands and intends to comply with the specifications and to ensure that the purchaser fully understands the strengths and weaknesses of the proposed system.

The FSP period is typically one of intense discussion and brainstorming by all parties; this period is aimed at defining the final product in far more detail than can be placed in functional specifications or a bidder's technical proposal. The objective is to clearly define a system that both meets the requirements of the specifications and makes full use of the inherent strengths of the contractor's system philosophy.

Until the contractor's FSP is approved, no equipment may be ordered or manufactured. Although the FSP requirement may appear to result in the lack of any visible progress in system implementation for the first 5 months of the contract, this arrangement has proved most valuable on previous projects of this nature. Having an FSP period minimizes problems of system acceptance, both at the factory demonstration stage and on site following installation; it also should minimize wasted efforts on the contractor's behalf through avoidance of manufacturing of hardware or developing software for a system element that will ultimately not be accepted.

In a system as complex as a comprehensive computerized traffic signal system, it is inevitable that problems will arise during development, installation, and testing of the system. The requirement for an FSP period is based on the following premise: the earlier that problems, deficiencies, and misunderstandings are identified, the better for all concerned.

Organization of a Traffic Management Department

It is recognized that without appropriate staffing and organization of management, modern computerized systems for control of traffic signals and the motorway network will not in themselves provide the maximum benefits.

To date, management of many traffic-related functions in Kuwait has been somewhat fragmented between a number of ministries and the municipality. In some cases, the traffic function of a department has not been its primary area of responsibility and consequently may not always have received the attention it deserved. This has led to the situation in which traffic operations do not reflect the same level of management that is evident in the overall roadway network.

The impact of inefficient traffic operations has not been too severe to date because of the high standard and spare capacity of the roadway network. However, with increasing levels of vehicle ownership and travel demands, the need for more efficient usage of the road system is already apparent and will become increasingly apparent in the future.

To provide the necessary manpower and level of expertise required, the consultant recommended that (a) a single organization be responsible for dealing with future traffic problems, and (b) the wide-ranging goals of the nation's transportation and development plans, including the ATC system, be implemented. Overall responsibility for traffic management and control would be the primary concern and not merely a secondary activity of this proposed organization.

To facilitate the development of a strong traffic management organization, the ATC and MSC systems are to be housed in their own specially designed control center, with adequate office accommodations for management, engineering, and technical staff.

CONTINUING DEVELOPMENT IN KUWAIT

In 1983, the municipality commissioned the second overall review of the Kuwait master plan (the first review was conducted in 1977). Although these reviews resulted in modifications to the planned highway system, the overall principle of a hierarchical system was maintained, as shown in Figure 5. In the metropolitan area, the highway system has been extended to the west (5th Ring Road and 6th Ring Road), an outer bypass incorporated (running northwest from Shuaiba to Sulaibiya), and an intermediate connector added from this bypass, south of the airport, to Fintas (7th Ring Road).

According to the 1985 census, almost 1.7 million people currently reside in the metropolitan area, compared with the 1971 master plan projection of 1.25 million.

This review of the master plan, along with the data in the 1985 census, confirms the increasing importance of traffic control at all levels. As previously noted, an MSC system is already planned for the motorways and expressways. The ATC system, which will control signals within the CBD and on the main secondary roadway network, will interact with the MSC system and will form an integral part of Kuwait's overall traffic control and management program.

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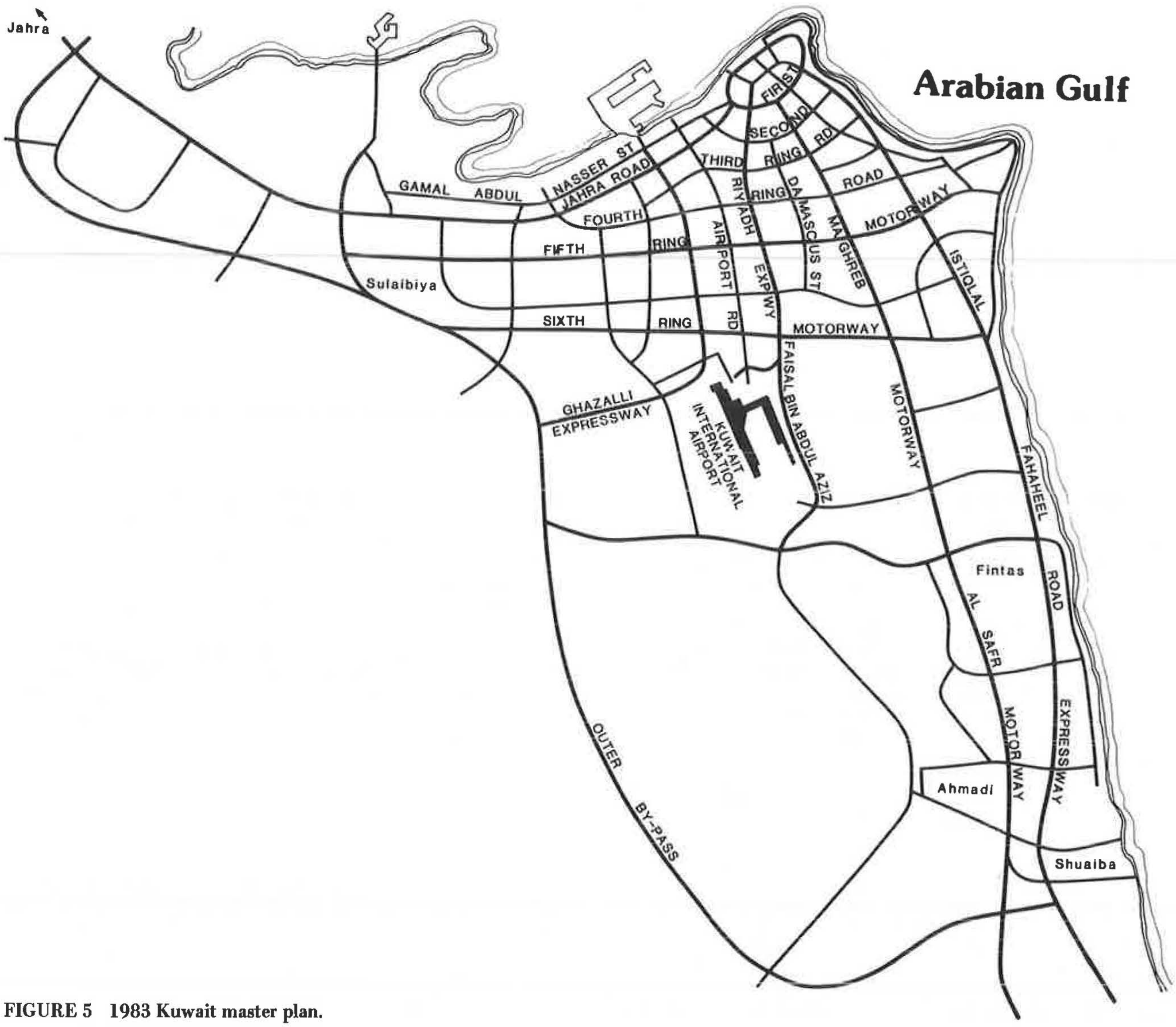

FIGURE 5 1983 Kuwait master plan.

REFERENCES

1. D.E. Castle and J.W. Bonniville. Platoon Dispersion Over Long Road Links. In Transportation Research Record 1021, TRB, National Research Council, Washington, D.C., 1985, pp. 36-43.
2. R.A. Vincent, A.I. Mitchell, and D.I. Robertson. User Guide to TRANSYT Version 8. LR 888. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1980.
3. TRANSYT-7F User's Manual, Release 3. Transportation Research Center, University of Florida, Gainesville, Feb. 1983.
4. P.B. Hunt, D.I. Robertson, R.D. Bretherton, and R.I. Winton. SCOOT--A Traffic Responsive Method of Coordinating Signals. LR 1014. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1981.