

### 1- Introduction

Owing to the high level of car ownership and high net residential density in Abu Dhabi central area, there is a noticeable shortfall in parking supply if compared to the required parking demand. This is more pronounced in most of the capital's C.B.D sectors. These conditions certainly have negative impact on the traffic operation and the level of service[1] of the main sector roads and this will persist unless some measures are applied.

Two of the most congested sectors in Abu Dhabi City centre were chosen for this study, namely W-4 and E-9. These two sectors were selected because they often experience considerable delays and long queues at their entries and exits to/ from the surrounding main arterials especially during peak periods.

Data collection regarding the traffic volume and parking demand and supply have been collected for these two sectors and then analyzed.

Some appropriate traffic management measures (TMS) were suggested in order to seek a good relief for both heavy traffic and high parking demand problems. Based on the before and after collected data and its analysis, the resulted impacts on the internal road network were assessed in terms of level of services (L.O.S) and average speed[2].

In addition, different options were suggested for both sectors and evaluation of their advantages and disadvantages bearing in mind the extra parking spaces added and cost implication was performed. These options were generated applying some suggested low cost traffic management measures[3] and other alterations to the existing layout of the road network and parking facilities of these sectors.

Finally, conclusions and relevant recommendations drawn from applying these measures and its impact on the traffic operation or/and improvements of parking conditions were presented.

### 2-Data Collection on Traffic Volume and Parking

Prior to data collection procedures, several field visits have been carried out in order to know where and when the oversaturation conditions of these selected sectors occur. Two sector W-4 and E-9 were chosen for traffic volume and parking data collection since they have most acute problems in the C.B.D area. The key In / Out access points as well as number of congested internal roads in both sector W-4 and E-9 was chosen for high level of traffic volumes. Also, the parking demand and supply surveys were performed in these two sectors.

#### 2.1 Study Area Description

The two sectors selected for this research lie in the central area of the Adu-Dhabi. Each sector is surrounded by number of main arterials which have fixed time signal controlled intersection at their crossroads. Each sector has number of In/Out access points for traffic entering or/and leaving the sector to/from the surrounding main arterials. All internal roads are 7.5 single carriageway two-way roads. The type of the sector roads network is often gridiron system. Therefore, all internal intersections are priority type ones giving preference to main flow to the less important ones.

Figure (1) and Figure (2) show the geometrical plan of these two sectors road network as well as the parking areas inside.

#### 2-2 Traffic Count Survey and Analysis

It was found from the field visits that for sector W-4, there are some Entries /Exits access points and internal roads which are experiencing considerable delay and relatively low average speed during the peak periods. Therefore, it was decided to carry out simultaneously classified traffic counts on these points and the busiest internal roads. Three Entries/ Exits points and three main internal roads were selected for data collection procedures. So,

number of well trained personnel has been assigned to carry out this task during peak periods. The location of these counting stations either on Entries /Exits access points or the internal roads are shown in Figure (1).

In addition, using moving observer car technique, average speed measurements along these main internal roads I, II, and III in W-4 sector were carried out.

For analysis purpose convenient P.C.E's values (Passenger Car Equivalents) conversion factors have then been used in order to convert the different vehicle types (Pick-up& Buses, Minibuses Bicycles,...etc) into passenger car equivalent. The typical values found in Abu-Dhabi Roadway Design Manual [4] were used in this study. It is worthy mentioning that, these data collection procedures have been executed during peak periods on one of the typical working days.

Table (1) and (2) present the results of the existing traffic volumes expressed in P.C.E,s values as observed at three main In/Out points and three internal roads of W-4.

Generally speaking, changing the direction into one-way system instead of two ways will improve traffic condition in terms of traffic directional segregation as well as reducing the conflict points. Also, the road capacity will increase and saved width could often be used for additional parking spaces. Thus the net traveled one-way road width could occasionally be 5 meters instead of 7.5 meters two way road and it can be as minimum as 4.5 meters in width in some cases of one-way aisle in off street parking areas.

Also, number of maneuvers per hour to/from parking stall or curbside parking areas would seriously affect the discharging capacity the Entry/Exit access points as well as the whole road capacity [2].

Regarding sector E-9, also three Entry/Exit points were selected on basis of heavy flows and maximum traffic counts were found occurring often during the evening peak period (19.30-20.30). Only one main sector road along junction No. 1 was found quite busy during evening peak periods due to the heavy shoppers at that time.

Although, the traffic volume were found low on the other two-way roads but, the main Entry/Exit points were very busy mainly due the acute parking problems. This is can be ascribed to the frequent interruptions from curbside parked vehicles and traffic maneuvers of drivers when getting into or coming out of any parking stalls. Therefore, it has been suggested to re-circulate the traffic in these congested roads and change traffic direction into one-way system.

The three main internal roads traffic volumes for sector W-4 and associated average speed and (V/C) (volume to capacity ratio) as a representative measure of the existing level of service were presented in Table (3). The capacity of these roads were calculated using relevant values found in ref[4].

Regarding sector E-9, the existing traffic peak flows expressed in terms of P.E.C,s values were obtained and presented in Figure(2).

As observed junction (1) was found to encounter high level of traffic flows, delays and long queues that could sometimes cause spillover. This eventually affects the operation of the preceding traffic signal in peak periods. Figure(2) shows the obtained peak hour traffic flows on the main In/Out access points as well as the main sector road parallel to Hamdan Street ( Main Arterail). Other sector roads are quite low traffic, however, they experience some delay mainly due to parking problems. Since the new suggested layout of sector E-9 has not been implemented, only the after situation conditions as shown in Figure(4) of sector W-4 in which (V/C) ratios and average speed of traffic are obtained and given in Table(4).

### 2.3 Parking Supply & Demand Surveys

The parking supply and demand surveys for both sectors W-4 and E-9 were also carried out during the periods of heavy demand.

Firstly, parking supply survey was conducted, simply by counting the marked parking spaces within the whole sector. Both existing parking supply for on street



parking (curb parking) and off street parking (parking lots) in these two sectors were determined. It was found that the total supply in Sector W-4 and E-9 are equal to 3600, and 1850 spaces respectively.

Secondly, the parking demand should be obtained for W-4 and E-9 sectors in order to know to how extent there is an insisting need for additional parking spaces in that sectors. Obviously this parking demand will vary with hours of day and days of week. Therefore parking demand survey was conducted during the heavily congested period which was found to occur in the evening period (20.30-22.30) due to high concentration of heavy shopping traffic to these sectors and residents high parking demand at that time.

Three surveyors were chosen for parking demand survey for each sector. Each surveyor was assigned a definite beat and instructed to start from an identifiable point in the area assigned to him, and then walk around noting down the number of the legal and illegal parked cars. Then each surveyor returns back to the starting point and repeats the same process following exactly the same route and approximately will take the same time to cover the same route.

Each surveyor was instructed to carry out as much runs as possible. Total number of parked cars were averaged and recoded during each survey period. Average number of on street parking either legal or illegal was recorded for each stretch of street. The same procedures were followed also in order to obtain the actual demand for each parking lot in sector W-4.

The results showed that the illegal parking percentage out of the actual capacity of each area varies considerably from time to time and from area to another. These percentages depend upon the time of survey, parking and area type under consideration. Data given in Table (5) shows that percentage of illegal parking varies from 22-70 % of the exiting capacity for the different parking area types. Table (5) gives average parking volumes obtained for different parking areas in W-4. It was found that as maximum as 276 and 185 parking spaces can be added to

the existing number of parking spaces in W-4 and E-9 respectively without utility relocation which has very prohibitive cost. Figure (3) and (4) show the proposed traffic and new parking configuration plan for sector W-4 and E-9 respectively as after situation conditions.

### 3-Data Analysis and Results Discussion of Traffic Volume and Parking

Analysis of obtained traffic flows of W-4 and E-9 for main sector roads showed that it is not a problem of congested sectors roads rather than insufficient parking spaces available for visitors and residents. So, the traffic flow result obtained can not be discussed in isolation of the parking condition in each sector[5]. Although the (V/C) ratios for sector W-4 roads vary from 0.40 to 0.96, as found in Table (3), this does not mean that some roads are operating near full capacity condition but there is only traffic impedance due bad parking conditions and considerable drop in capacity due parking factor[1]. Also, the capacity of the internal roads is dramatically fallen due to frequent misbehavior of drivers.

As regard to In & Out traffic count in sector W-4, it should be mentioned that there are some discrepancies between total numbers of IN & OUT vehicles in both morning and afternoon peak hour's flows as clear in Table (1) whilst the discrepancy is minimum in the evening peak In and Out flows (total IN=1477 & OUT = 1486 vehicles). This is mainly due to directional distribution imbalance for both morning and afternoon periods, since most vehicular trips occur during these period are either work or educational trips (i.e., home based trip) while most trips that take place during the evening period are mostly for entertainment or shopping purposes (i.e., non home based trip). Since the (V/C) values for such two ways two lane roads are below one, this is simply because the capacity of a lane of such area and facility type can be estimated from ref. [6].

As for the average speed on these two way sector roads during the peak periods, it is as expected whenever the (V/C) is approaching 1.0 the speed decrease and vice versa.

Changing the main roads into one-way system will definitely increase capacity as well as decrease of potential conflict points. Thus, the (V/C) ratios will decrease and the current traffic conditions will improve significantly. Also, on street parking causes much interruption to the moving vehicles, in particular, when two-way road system is used as typically found in most main sectors roads. Moreover, when using spacious parking stall dimensions, parkers attempt to occupy any unused spaces in case of necessity[7]. Hence, in order to prevent such practice and maximize total number of parking spaces available for parkers, changing the traffic system from two way into one-way system as well as relaxation of parking standards in regard to parking stall and aisle widths dimensions would be beneficial. However, due to limited spaces available not much gain of spaces can be achieved when angle of parking is changed.

It is worth noting that parking shortfall has its adverse impact on the traffic condition of many sectors in the C.B.D of Abu Dhabi city. Certainly, the unbalance between supply and parking demand will have its impact on the traffic flows along these main sector roads [4]. The interference from those drivers trying park or impark their vehicles as well as those searching for a parking spaces are seriously affect traffic conditions of these roads.

Analysis of parking surveys results showed also that the illegal parking percentages are representing a considerable amount of the actual capacity (parking supply) of each area in the C.B.D sectors. This depends upon the time of survey and the parking area type in the area under consideration, as clear in Table (5). The percentages of illegal parking vary from 22% to 37% of the existing capacity for on street parking areas. On the other hand, the illegal percentages vary from 23%-46% of the existing capacity for existing off street parking facility. In the mixed parking areas in sector W-4, it was found to be more than 70% in some times

during the evening peak periods. Another study carried out lately has suggested that 25% reduction in the number of illegally parked cars at curbside could lead to average speeds increasing by around 10% [8].

Generally speaking, the average percentage for illegal parking was found to exceed 30% of supplied spaces in most sectors of the C.B.D area of Abu-Dhabi. This necessitates a parking policy to be followed in order to restore the balance between the parking supply and demand requirements since major changes to the intensity of residential density has been occurred in the last five years.

It should be mentioned that two different policies were adopted in order to cope with both parking and traffic congestion problems encountered in this study.

Firstly, is to segregate to some extent the parking from moving traffic especially those of perpendicular type or angled on street parking. Since on street parking type causes much interruption to the moving vehicles, especially when imparking maneuverings occur this is will be minimal when using one-way road system without curbside parking. Therefore, the one-way system was adopted for congested main roads whenever this will considerably improve the traffic operation conditions in any sector of the C.B.D area.

Secondly, trial has been made in order to maximize total surface parking supply in each sector either by using 70 degree parking angle instead of 45 degree or by parking stall standard dimension relaxation. This is apparent in the proposed plans given in Figures (2) and (4).

It should be borne in mind that, operation, traffic circulation, and sector accessibility of each sector were thoroughly studied after application of the above mentioned measures.

Figure (2) and (4) show these proposed options for the suggested traffic plan and parking configuration of sector W-4 and sector E-9 respectively.



#### 4-Conclusion & Recommendations

The aim of this paper is to describe the impact of some proposed traffic and parking measures towards relieving congestion and improving traffic operation conditions in the C.B.D sectors in Abu Dhabi city.

Each sector has its unique traffic condition and parking problems. Therefore specific traffic arrangements and parking measures were proposed for each sector based on its site specific situation. It was concluded that the following measures will benefit all categories of road users either directly or indirectly.

1) One-way system was found more appropriate in most congested main sector roads hence it improves both capacity and traffic conditions and save road width for parking usage in some cases. Strict enforcement in observing traffic laws and regulations should be applied and these will eventually help in solving most of the traffic problems

2) The level of service represented by (V/C) and average speed on two-way main roads has significantly improved when converted into one-way as clear from results obtained.

3) Mixed land use of residential and commercial in most C.B.D sectors has resulted in coincident of peak periods for both usages especially for parking evening peaks. Also, loading and unloading controls need to be strictly enforced by Traffic Police man presence on such sectors.

4) Appropriate controlled parking zone should be setup in the C.B.D area in order to restrict unnecessary vehicular trips in peak periods. It is of great importance to establish parking policy in the C.B.D area with metered zones and parking fare structures.

5) Since only small percentages of parking supply can be attained by rearrangement of on street or off street parking, it is highly recommended to construct multi-storey garages or/and underground parking structures where highly needed in congested sectors.

6) In addition, permissions should not be issued to any new high rise building unless adequate parking spaces are provided in its basement.

Also, it is recommended to carry out prior T.I.A (Traffic Impact Assessment) as prerequisite for issuing building permission especially for large developments. Using such measures would improve the traffic condition as well as increase the parking supply in heavy congested sectors in Abu Dhabi.

#### 5-References :

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**Table (1) Observed IN/OUT Traffic Counts of Main Entry/Exit Points of Sector W-4**

IN/OUT Point No.	Morning Period		Afternoon Period		Evening Period	
	7.00-8.00	8.00-9.00	14.30-15.30	15.30-16.30	19.30-20.30	20.30-21.30
IN 1	179	217	397	201	261	229
OUT	509	390	364	354	531	522
IN 2	451	541	589	463	765	835
OUT	449	306	277	231	403	473
IN 3	126	202	189	158	451	406
OUT	478	512	453	369	552	563

**Table (2) Observed Traffic Volumes During Peak Periods on Sector W-4 Main Roads**

Road No.	Direction of Traffic	Morning Period		Afternoon Period		Evening Period	
		7.00- 8.00	8.00 - 9.00	14.30- 15.30	15.30- 16.30	19.30- 20.30	20.30- 21.30
I	From Sheikh zayed 1 <sup>st</sup> Mosque to Chiothram Supermarket	123	191	202	142	309	314
	Vice Versa	192	205	224	194	344	444
II	From ETISALAT To Chiothram Supermarket	204	410	346	310	420	509
	Vice Versa	233	362	245	217	281	332
III	From Road No.2 To road No. 1	153	168	204	138	266	268
	Vice Versa	94	146	132	112	211	216

**Table (3) Peak Hour Traffic Flows & (V/C) for Sector W-4 Main Roads (Before Situation)**

Rd. No	Direction of Traffic.	Morning Period			Afternoon Period			Evening Period		
		7.00- 8.00	Av. Speed Km/h	(V/C)	14.30 - 15.30	Av. Speed Km/h	(V/C)	20.30 - 21.30	Av. Speed Km/h	(V/C)
I	From Sheikh zayed 1 <sup>st</sup> Mosque to Chiothram Supermarket	191	43	0.50	202	44	0.53	314	35	0.95
	Vice Versa	205	45		224	48		444	30	
II	From ETISALAT To Chiothram Supermarket	410	32	0.96	346	37	0.74	209	37	0.68
	Vice Versa	362	34		245	39		332	32	
III	From Road No.2 To Road No. 1	168	44	0.40	204	45	0.42	268	38	0.61
	Vice Versa	146	47		135	47		216	42	

**Table (4) Peak Hour Traffic Volumes & (V/C) for Main Roads of Sector W-4 (After Situation)**

Road No	Direction of Traffic	Morning Period (7.00-8.00)		Afternoon Period (14.30-15.30)		Evening Period (20.30-21.30)	
		Volume & (V/C)	Average Speed Km/hr	Volume & (V/C)	Average speed Km/hr	Volume & (V/C)	Average speed Km/hr
I	From Sheikh Zayed 1 <sup>st</sup> Mosque to Chiothram Supermarket	630 (0.52)	45	586 (0.48)	45	555 (0.46)	44
II	From Chiothram Supermarket To ETISALAT	592 (0.49)	44	495 (0.41)	45	792 (0.66)	42
III	From Road No.2 To Road No. 1	356 (0.29)	48	412 (0.34)	47	584 (0.48)	43

**Table (5) Average Number of Parked Cars in Different Parking Area Types**

Day & Time of Survey	Tuesday (Evening) (9.30-11.00)				Wednesday(Afternoon) (12.00-14.00)				Thursday(Morning) (7.00-9.00)			
	Legal	Illegal	Total Demand	Illegal %	Legal	Illegal	Total Demand	Illegal %	Legal	Illegal	Total Demand	Illegal %
On street Beat (a)	167	51	218	31	121	12	133	37	140	19	159	22
Full Capacity (No of stalls supplied)	164											
On street Beat (b)	117	58	175	46	80	29	109	23	114	62	176	30
Full Capacity (No of stalls supplied)	126											
Mixed Parking Beat (c)	116	46	162	47	97	26	123	25	110	61	171	53
Full Capacity (No. of stalls supplied)	105											

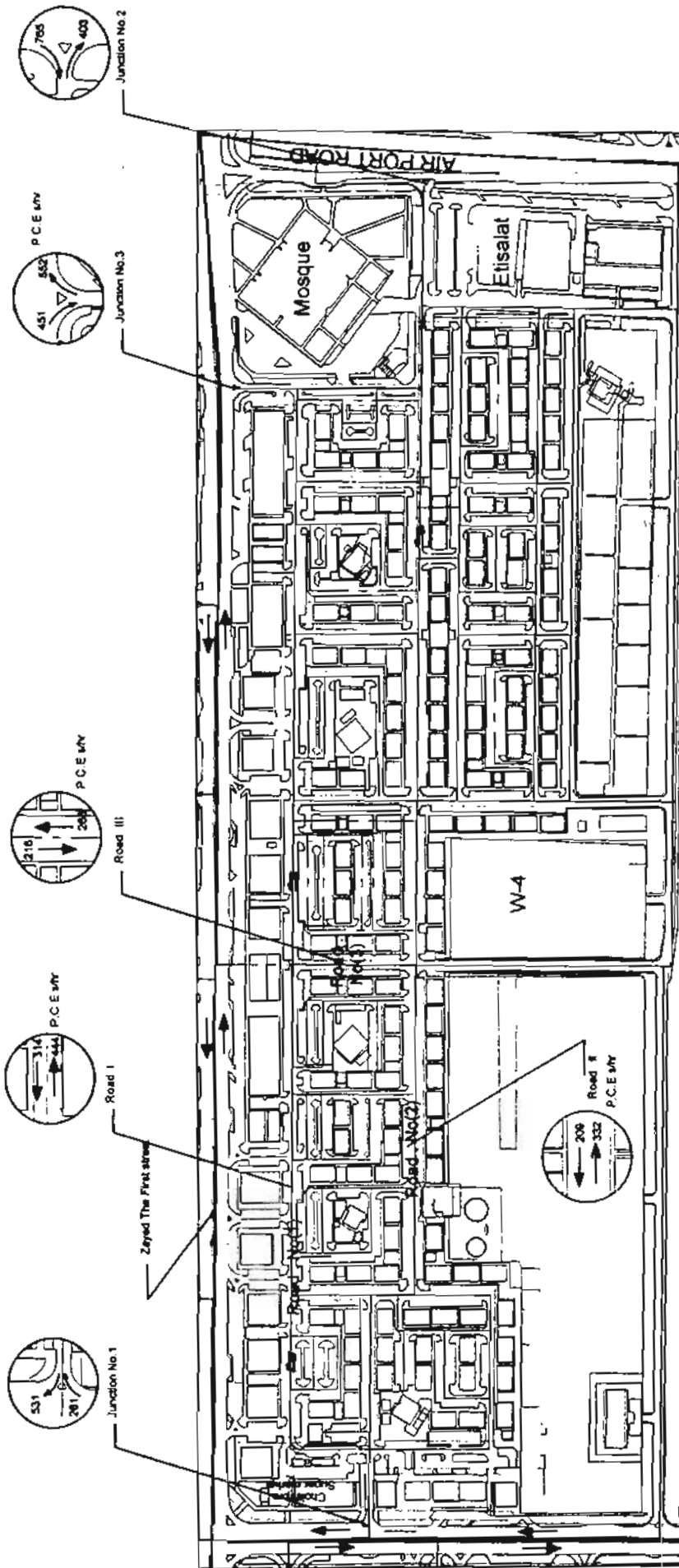


Figure (1) Existing Geometrical Plan Of Sector W-4 Showing the Main Sector Road and Exit / Entry Junctions (before situation)



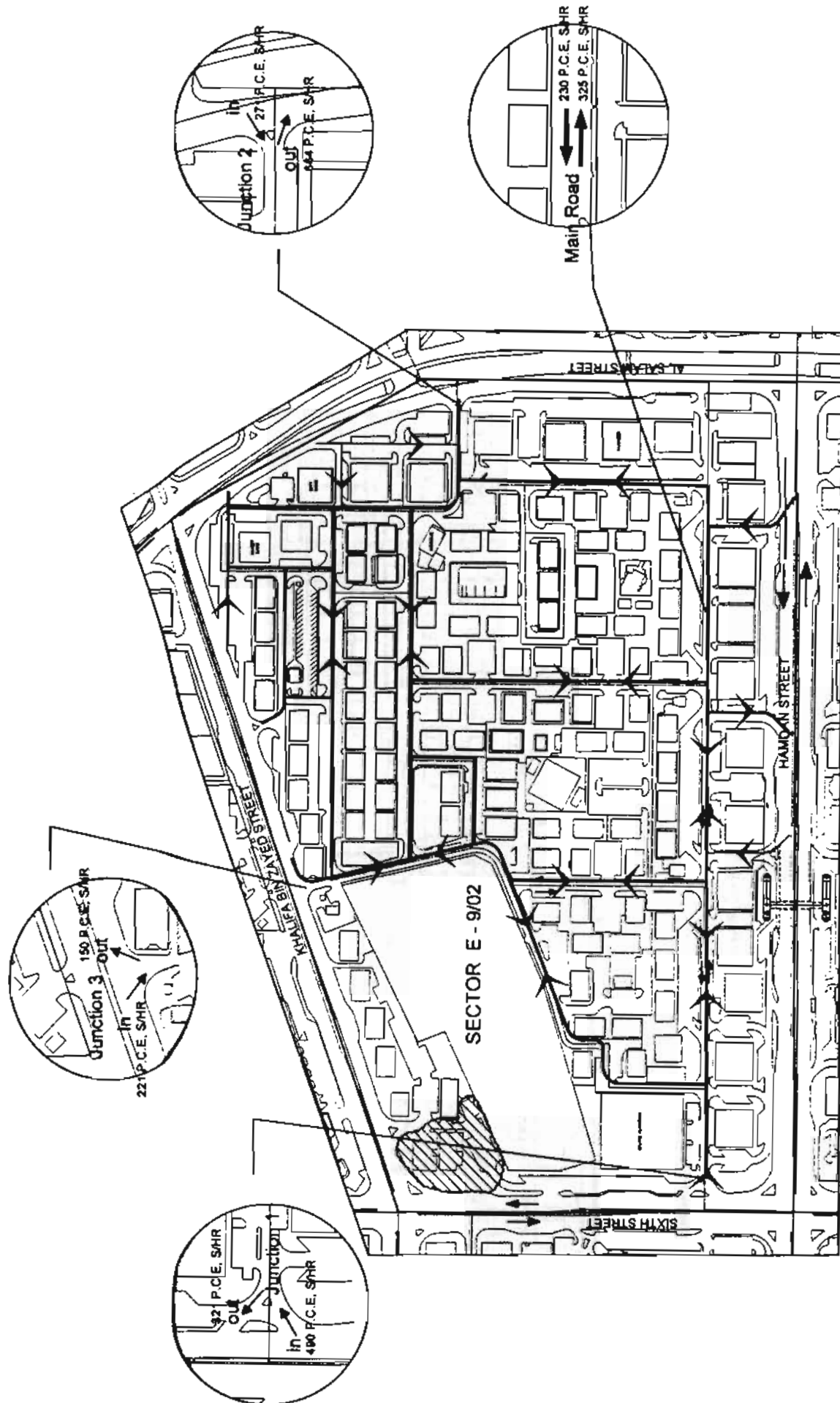


Figure (2) Existing Geometrical Plan Of Sector E-9/02  
Showing the Main Sector Roads and Junction (after situation)

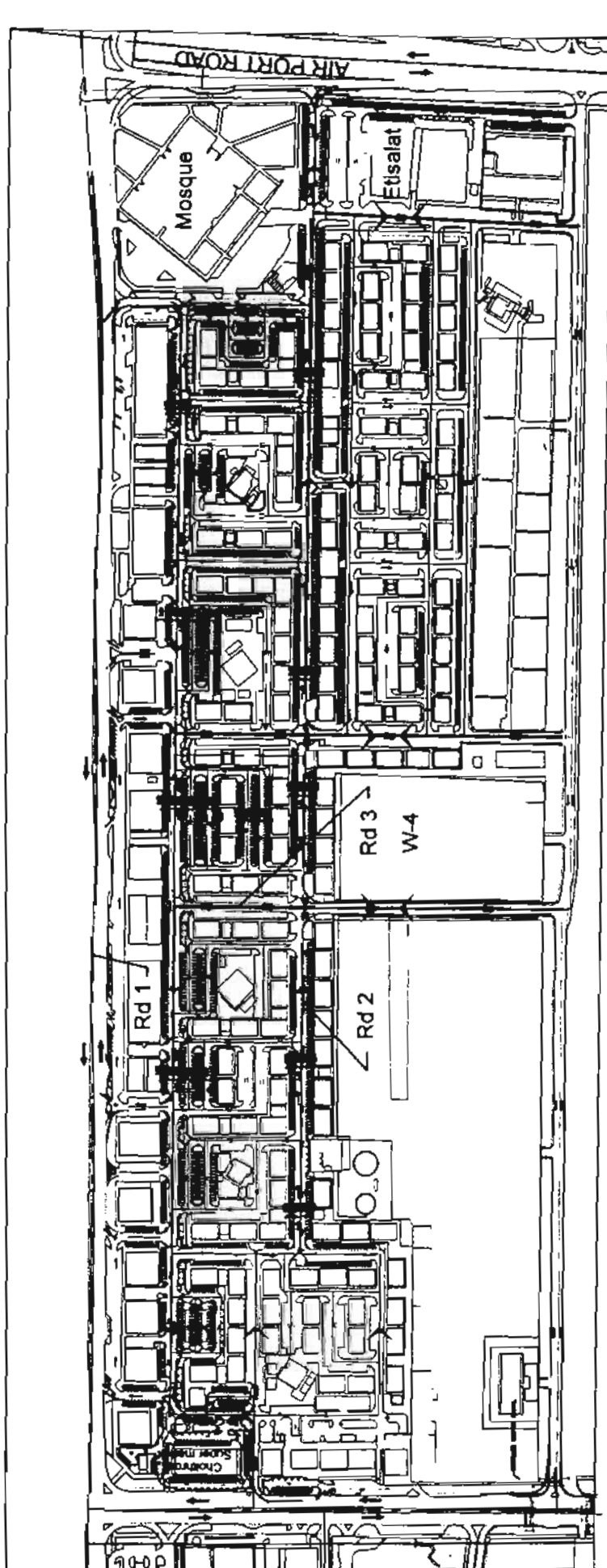


Figure (3) Proposed Traffic & Parking Configuration Plan For Sector w-4 (before situation)

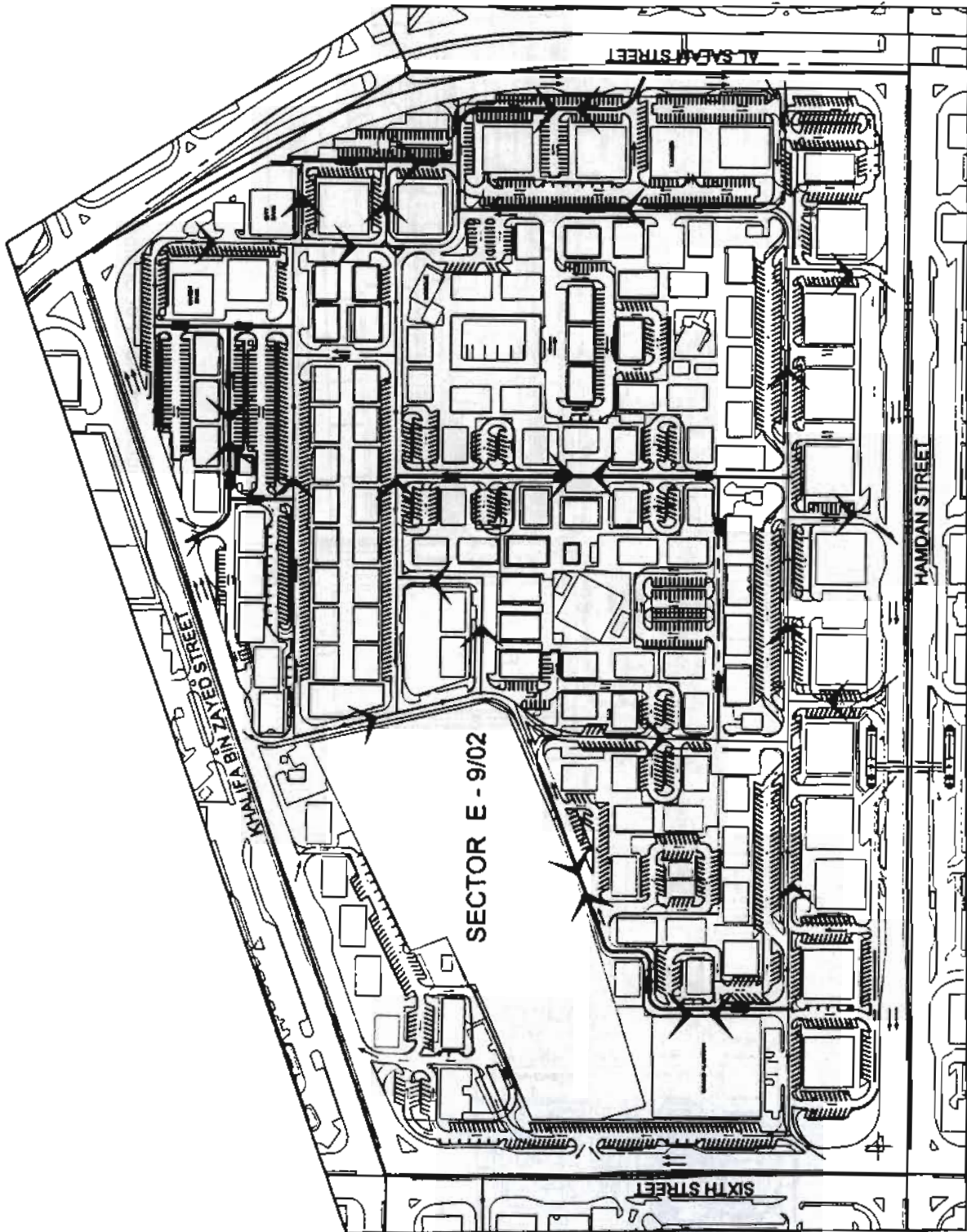


Figure (4) Proposed Traffic and Parking Configuration For Sector E-9/02 (after situation)