Assessment of Traffic Flow for the Central Area of Madinah

تقييم حركة مرور المركبات في المنطقة المركزية للمدينة المنورة

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Abstract

The central area of Madinah is a vital part of the city due to the fact that most services are located around it including hotels, restaurants, government offices, and at most Al-Masjid Al-Nabawi Al-Shareef. The traffic in this area has become cumbersome during peak times. This study intends to evaluate, analyze and assess the traffic conditions in the central area of Madinah, enclosed by King Faisel Rd. (First Ring Rd.), during peak times. This includes investigating the number of vehicles entering the area, the capacity of the roads, the arrangements of the roads, percentage of traffic entering versus exiting, etc. Finally, the analysis results in recommendations for better traffic management.

المستخلص:

المنطقة المركزية للمدينة المنورة تعتبر جزء حيوي من المدينة ويرجع ذلك حقيقة إلى وجود الحرم النبوي الشريف وأن معظم الخدمات موجودة حوله بما في ذلك الفنادق والمطاعم والمكاتب الحكومية. لذلك ، أصبحت حركة المرور ثقيلة ومرهقة في أوقات الذروة. هذه الدراسة تعتزم تقييم وتحليل ظروف حركة المرور خلال أوقات الذروة في المنطقة المركزية المحاطة بطريق الملك فيصل (الطريق الدائري الأول). وستتطرق تحليل الدراسة إلى تحديد عدد المركبات الداخلة الى المنطقة المركزية، السعة الإستيعابية للطرق، محاولة إعطاء بدائل لإعداة تخطيط الطرق، والنسبة المئوية لحركة دخول المركبات مقابل نسبة الخروج ،... إلخ. وستترتب نتائج التحليل لحركة مرور المركبات في توصيات لتحسين إدارة حركة المرور في المنطقة.

1- Introduction

The traffic in the central area of Madinah is the subject of this study. The central area of Madinah shown in Figure 1 encircled by the First Ring Road, occupies around 2.16 km^2. Al-Masjid Al-Nabawi Al-Shareef, located at the heart of Madinah, is the main target for most pilgrims and visitors from all over the world. The area is accessed by 12 roads which feed into the First Ring Rd. This area is very crowded especially during Umrah and Hajj seasons. According to the central department of statistics and information, the number of pilgrims during Hajj seasons from 1416 H – 1431 H (1995 – 2010) shown in Figure 2 has increased by approximately 50% [2]. Part of the Hajj trip of the pilgrims is to visit the mosque of the Prophet Mohammed (peace be upon him) in Madinah. Therefore, a large number of pilgrims visit Madinah from about a month before Hajj days until about a month after Hajj is over. In addition to this, people coming from abroad for Umrah also visit Madinah during the Umrah season. Thus, more traffic flows on the road network during Umrah and Hajj seasons. It is also noticed that the population of Madinah has increased significantly in the last decade to over one million and it is projected that the population may double in the next 10 – 20 years due to economic growth [2].

Figure 1: The area of study (enclosed by the First Ring Road) [1]

The traffic in the central area of Madinah has become a major concern for authorities especially during prayer times where heavy crowds start to form about an hour before and an hour after each prayer. Due to the problems of traffic congestion in major intersections in the central area the board of the municipality of Madinah in its meeting on May 10th, 2010 discussed the traffic congestion and noted the traffic jams in some important intersections which require immediate attention before the start of Ramadan and the Hajj season 1431H. In this meeting, a number of ideas were proposed to ease the traffic congestions which create bottlenecks in certain roads and

intersections feeding into the central area. The board supported the idea of reduction of traffic signals using a system of rotation (U-turns) before a traffic light, particularly in roads and intersections experiencing heavy traffic. The idea was implemented in several locations on the First Ring Rd. as well as on some other major intersections around the city. The board also discussed issues related to street naming and labeling [3].

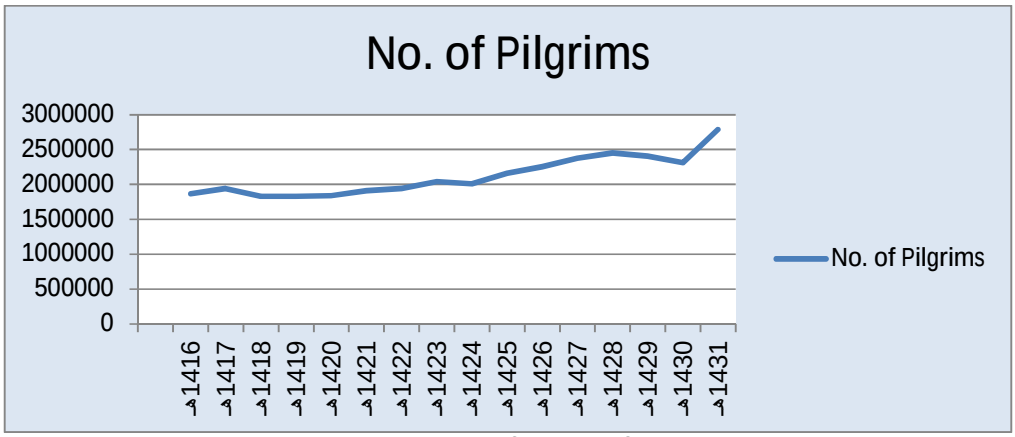

Figure 2: Number of pilgrims from 1416 H – 1431 H

Another concern in Madinah is the air quality and its effects on health. Given the fact that the peak temperatures in the summer exceed the 45^{o}C. Cars and buses during peak seasons on the roads of Madinah increase the exhaust gas emission which causes serious air pollution. Poor quality of air which in turn causes health problems. A study done in the U.S. on cities experiencing higher pollution rates found that mortality rates were 17-26% higher in cities with the dirtiest air compared to those with the cleanest air. Not surprisingly, the study also found correlations between bad air and lung cancer and cardiopulmonary disease. The risks translate roughly to a two-year shorter life span for residents of dirty-air cities. On a global basis, estimates of mortality due to outdoor air pollution range from about 0.4-1.1% of total annual deaths [4]. In the U.S., 30,000 people die every year from automobile emissions [5]. Also, a study conducted by the American Public Transit Association shows that using public transportation avoids the emission of more than 126 million pounds of hydrocarbons, a primary cause of smog and 156 million pounds of nitrogen oxides, which can cause respiratory disease [6][7].

This study was conducted during seasonal time (Hajj) to reflect the maximum vehicle flow into the central area of Madinah. The First Ring Road encircling Al-Masjid Al-Nabawi area works as a dead-end to most of the roads leading to the area. However, some of the traffic enters the central area. Therefore, percentage of the traffic dispersing from the main road to the area is calculated to count for the actual traffic on the ring road.

The paper is organized as follows: section 2 explains the data collection and methodology, section 3 provides the data analysis and discussion, section 4 presents the recommendations and finally section 5 concludes the paper.

2- Data Collection & Methodology

The vehicle count data collection is divided into 3 parts.

1- MetroCount traffic survey systems (automatic vehicle counts) placed on main roads feeding into the central area of Madinah were used to automatically count the number of vehicles going into and out of the First Ring Road of Madinah surrounding Al-Masjid Al-Nabawi.
2- Manual vehicle counts were carried out by subjects (students) using hand-held counters, on the secondary roads feeding into the central area.
3- Manual Vehicle counts at major 3-way and 4-way intersections conducted by subjects to count the number of vehicles in different directions of the 3-way and 4-way intersections. These intersections are junctions of: King AbdulAziz Rd, Omar Ibn AlQatab Rd, Quba'a Rd, Qurban Rd. and Sultana Rd with the First Ring Rd.

For the automatic vehicle counts the data collection was limited to five roads only due to the scarcity of metroCounters and the limited project budget. After surveying the area under study, the five busiest roads were identified then the metroCounters were placed on the following roads: King AbdulAziz Rd., Ali Ibn AbiTableb, Omar Ibn Al-Khattab, Sultana and King Fahd Rd. The manual count was used with the rest of the roads.

3- Data Analysis and Discussion

3.1 **Automatic Ingoing Vehicle Counts**

It is observed that the data obtained from the metroCounters for all roads surveyed throughout the day appear to have the same trend (behavior). Therefore, the average of the data collected from all days for all roads will be discussed. Figure 3 combines the hourly average number of vehicles travelling over different days in 24 hours on all roads measured using metroCounters. The graphs show a similar trend in traffic flow on all the roads feeding into the First Ring Road but with different traffic flow rates since this depends on the number of vehicles traveling from the different parts of the city into the central area.

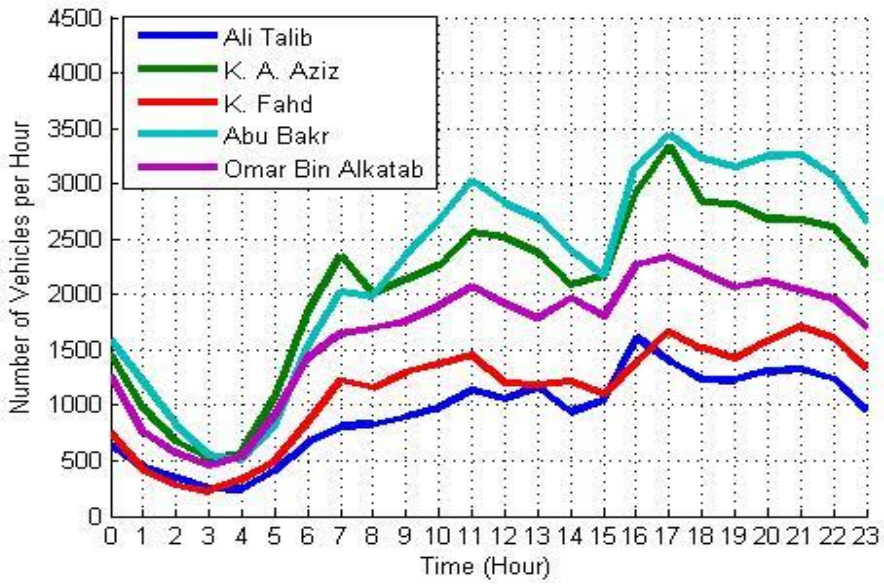

Figure 3: Average number of vehicles travelling over different days in 24 hrs. on all Roads

3.2 **Automatic out-going vehicle counts**

The roads surveyed for the ingoing vehicle flow into the central area of Madinah were also surveyed for the out-going vehicle flow except for Ali-Ibn Abi-Taleb Rd. which is a one-way street flowing into the First Ring Rd.

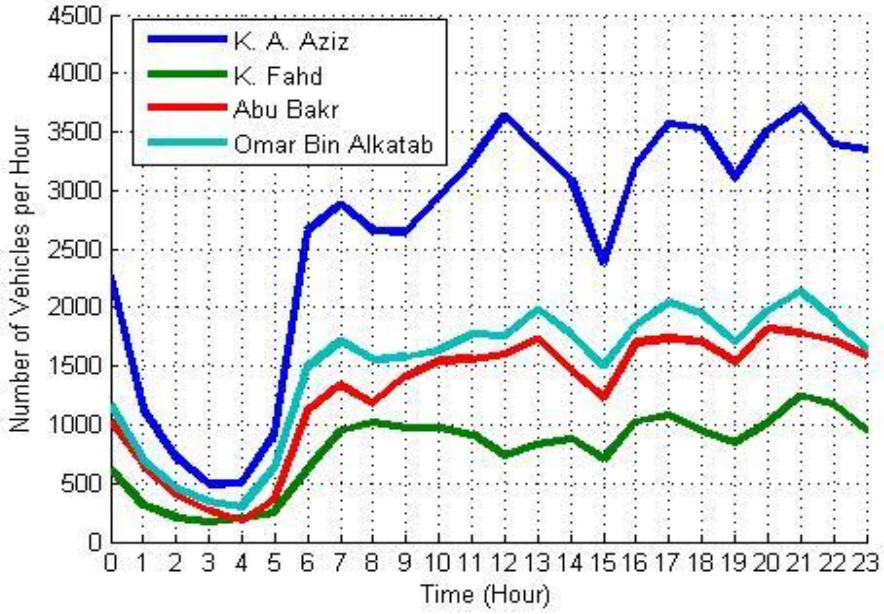

Figure 4: Average number of vehicles travelling over different days in 24 hrs on all roads.

The average vehicle flow traveling out of the central area of town during 24 hours of the day from the four roads measured using metroCounters is shown in Figure 4. It is very clear from the graphs that the trend for the outgoing traffic flow is similar for all the roads surveyed and this observation can be applied to all outgoing traffic for all other roads not surveyed. The figure also shows that the maximum out-flow is from King AbdulAziz Rd. followed by Omar Ibn Al-Khattab then Abu Bakr Al-Siddiq and finally King Fahd Rd with the lowest out-going traffic.

3.3 Manual vehicle counts

With the aid of a group of students from the college of computer science and engineering at Taibah University the number of vehicles from the secondary roads (not surveyed using metroCounters) flowing into the First Ring Road were counted using manual hand counters.

Table 1: Average hourly data for all roads feeding into the First Ring Rd. between 8:00 A.M. to 9:00 P.M.

	Alseeh	Al-Salam	Quba'a	Qurban	Ali Ibn Abi-Taleb	K. A. Aziz	Airport Rd.	K. Fahd	king Fahd exit - ramp	Abu Bakr Al-S	Omar Ibn Al-Khattab	Total
08:00	1875	1389	914	1762	819	2008	832	1149	155	1989	1736	14625
09:00	1723	1512	908	1469	879	2058	637	1269	228	2239	1758	14678
10:00	2011	1642	896	1223	953	2211	817	1347	319	2606	1856	15880
11:00	1822	1369	878	1349	1069	2450	710	1449	444	2952	2040	16532
12:00	2144	1951	886	1241	1121	2643	807	1274	320	2947	2035	17369
13:00	2414	1702	897	1165	1146	2408	786	1152	305	2718	1851	16545
14:00	2273	1789	853	1085	993	2179	742	1230	262	2468	1962	15834
15:00	2185	2008	837	1952	970	2142	657	1140	269	2193	1800	16152
16:00	2693	2022	1246	1788	1504	2657	852	1283	292	2841	2166	19344
17:00	2477	2151	1840	1594	1547	3315	948	1646	358	3522	2378	21776
18:00	2471	2219	1806	1306	1150	2853	808	1487	342	3126	2219	19789
19:00	2170	2063	1783	1594	1271	2995	751	1522	381	3323	2138	19990
20:00	2357	2096	1630	1306	1263	2619	684	1474	274	3113	2101	18915
Total average number of vehicles into the ring road from all roads between 8:00 A.M. and 9:00 P.M.												22,7428

The data was collected at different times and days during the Hajj season before and after the Hajj days. It was very difficult managing the data collection process at the same time for all the roads. Therefore, the average number of vehicles was calculated for all the secondary streets flowing into the First Ring Rd between 8:00 A.M. and 9:00 P.M. The manual count did not consider the times between 9:00 P.M. until 8:00A.M. and this could be a limitation in this study due to the fact that only 5 metroCounters were approved for this study and it was difficult to have the students

available all the time during the day and night hours. This part of data collection was combined with the metroCounters in order to determine the total number of vehicles using the First Ring Rd. between 8:00 A.M. and 9:00 P.M. Table 1 shows the data collected from all roads and streets surveyed between 8:00 A.M. and 9:00 P.M.

Figure 5 provides the graphs for the average vehicle count for all roads separately, from the data provided in Table 1. From this figure, the traffic flow is not uniform for all the roads and different behavior is noticed. Most roads show the same behavior of the average vehicle count of all streets shown in Figure 6, with the exception of Quba'a St. and K. Fahd exit ramp that flows into the First Ring Rd. Most of the roads show the PM peak between 4:00 and 5:00 P.M. which is confirmed from the average vehicle count for all roads shown in Figure 6. On the other hand, the AM peak time is around 12:00 noon. The peak average vehicle count is approximately 2000 vehicles and the average hourly vehicle flow is 17,495 vehicles/hour. The traffic flow is shown to increase from the middle of the morning rush hour at 8:00 A.M. until around noon time (Duhur time) then it slightly decreases. It starts to pick up around 3:00 P.M. (Asr time) after that it peaks around 5:00 P.M. after which the traffic decreases until probably the early morning hours where it starts increasing again around before Fajr time. The total amount of traffic flowing into the First Ring Rd. between 8:00 A.M. – 9:00 P.M. is 227,429 vehicles. This shows that the total number of vehicles flowing into the First Ring Rd. could exceed the 350,000 vehicles/day in a 24-hour period.

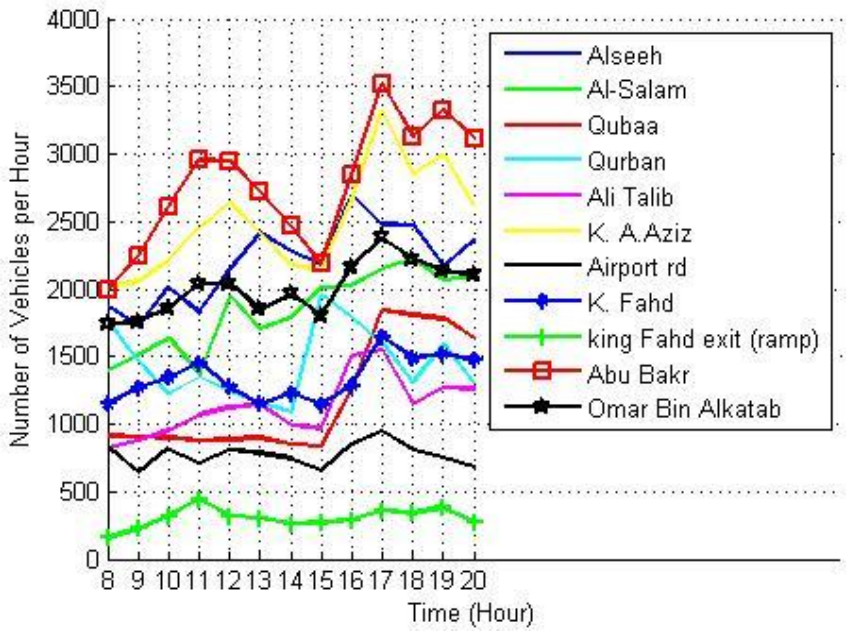

Figure 5: Hourly traffic behavior for all roads between 8:00 A.M. and 9:00 P.M.

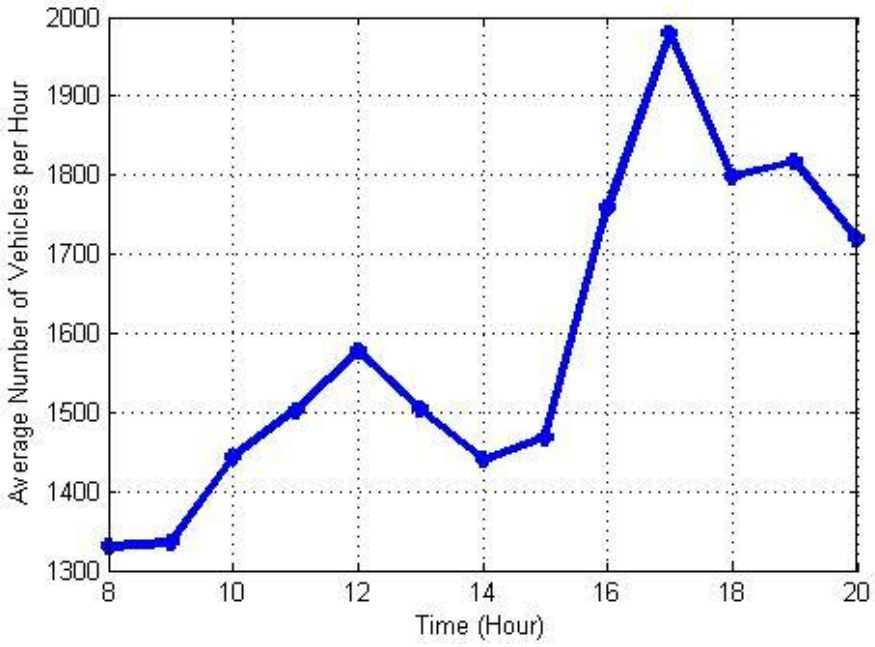

Figure 6: Average hourly traffic behavior for all Roads between 8:00 A.M. and 9:00 P.M.

Table 2: Percentage traffic flow during the peak average time using 15 minutes interval.

	K.A. Aziz	Ali Taleb	Qurban	Qubaa	Omar Ibn Al-Khattab	Al-Salam	Alseeh	Sultana	king Fahd-ramp	K. Fahd	Airport Rd.	Total
Peak	928	387	344	450	624	579	648	909	92	456	236	5653
%	16.4	6.8	6.1	8.0	11.0	10.2	11.5	16.1	1.6	8.1	4.2	100%

Table 2, shows the maximum average of vehicle count in an interval of 15 minutes happening between 7:30 – 7:45 P.M. The two main roads which contribute to a total highest percentage flow of 32% are King AbdulAziz Rd. and Sultana Rd., approximately 16% each. The other three roads contributing approximately 33% to the traffic flow, each approximately 11%, are Alseeh (Alemam Alshafai St.), Omar Ibn Al-Khattab Rd. and Al-Salam Rd. Therefore, four of these roads confirm to the choice of the busiest roads chosen for the automatic traffic count and the only road which did not confirm with the findings is Ali Ibn Abi-Taleb Rd.

The traffic flow between King AbdulAziz Rd. and Abu Bakr Al-Siddiq Rd. (Sultana Rd.) shows the busiest section of the First Ring Road, contributing approximately 46.4% of the traffic flow in the area, Table 3. However, this section of the First Ring Rd. is about 1/3 of the Ring Rd. However, it this section contributes to approximately 46.4%. The reasons for the highest traffic flow in this section of the First Ring Rd. are: it contains two major roads feeding into the First Ring Rd., heavily populated

area with many hotels, close to the Second Ring Road which can be accessed from many other streets in the area, contains some old residential parts of Madinah and contains many business and service areas such as a Alansar Hospital, SAPTCO bus terminal … etc. In addition to the above reason the inner area enclosed by King Fahd Rd., King AbdulAziz Rd. and Al-Masjid Al-Nabawi is considered the area having the highest number of hotels and it is also noticed that there are many hotels that are currently being built which will add to the traffic and pedestrian congestion problem in this section of the Fist Ring Rd.; therefore, the government of Madinah should pay more attention to the roads network of the central area due to the above findings.

Table 3: Percentage traffic flow according to different areas on the First Ring Rd.

Area	Location	% of Traffic Flow
1	King AbdulAziz Rd. + Airport Rd. + King Fahd Rd	28.7%
2	King Fahd (ramp) + Abu Bakr Al-Siddiq (Sultana Rd.)	17.7%
3	Al-Seeh + Al-Salam Rd.	21.7%
4	Omar Ibn Al-khattab Rd.	11.0%
5	Quba'a + Qurban + Ali Ibn Abi-Taleb	20.9%

The outgoing and ingoing traffic were compared by considering the total average traffic flow for all days surveyed from the four main roads using the metroCounters data collected during the 24-hour period. Table 4 below shows the comparison for the only four roads surveyed for both ingoing and outgoing traffic.

Table 4: Ingoing and outgoing traffic comparison

	K. AbdulAziz	K. Fahd Rd.	Sultana	Omar Ibn Al-Khattab	Total
Total average outgoing traffic flow (Out)	55532	18642	30697	35605	140476
Total average ingoing traffic flow (In)	49763	20833	54403	39337	164336
Ratio (Out/In)	111.593	89.483	56.4252	90.5127	85.481
$\frac{\text{(Out/Total In)}}{\text{Total Ratio(Out/In)}} * 100$	0.395313	0.132706	0.218521	0.25346	100

From table 4 it is very clear that King Abdul Aziz Rd. followed by Omar Ibn Al-Khattab Rd. take most of the traffic out of the central area of Madinah. Their proximity to the 2nd Ring Rd which provides an easy exit from the area can be a main reason for that. Another reason might be the fact that the traffic from Al-Masjid Al-Nabawi's underground parking lot is directed through them. Also, it is noticed that traffic is flowing smoothly on these two roads due to minimum number of traffic lights installed on them. However, Sultana Rd. has a moderate outgoing flow of traffic since it passes through a heavy business and residential area, thus, people

avoid using it to go to the 2nd Ring Rd. On the other hand, King Fahd Rd. has the lowest outgoing traffic since it does not directly meet the 2nd Ring Rd. as well as it does not have a direct connection with Al-Masjid Al-Nabawi parking lot, therefore this is why the ratio of (Out/In) is 56.4% which is the lowest among the other 3 roads.

3.2 Traffic diversion on Ring Road I.

The main roads in Madinah end at the First Ring Road. From the main road, vehicles can turn right, left to the ring road or straight in the central area. A pilot study was performed to determine how much percentage of the total traffic is diverted to either of these directions. The study revealed that majority of the traffic remains on the ring road rather than entering the area. It has also been noticed that majority of the traffic represents a counterclockwise traffic nature for the whole area as shown in Table 5.

Table 5 percentage of traffic diversion from main road

	K.A. Aziz	Ali Ibn Abi-Taleb	Qurban	Quba'a	Omar Ibn Al-Khattab	Al-Salam	Alseeh	Sultana	king Fahd - ramp	K. Fahd	Airport Rd.
Left	65	0	0	0	41	0	0	0	0	0	0
Right	21	100	30	40	49	100	10-0	55	100	100	100
straight	14	0	70	60	10	0	0	45	0	0	0

The majority of the traffic flow is counterclockwise on the ring road with the exception of some roads leading to the left direction. King AbdulAziz directs 65% of the traffic to the left, 21% to the right and, 14% straight. From Omar Ibn Al-khattab road, 49% of vehicles turn right, 41% left, and 10% move straight into Al-Masjid Al-Nabawi area. Quba'a road directs 60% of its traffic towards Al-Masjid Al-Nabawi area and 40% to the right on the ring road. 30% of Qurban road traffic is directed to the right while the rest flows straight towards the tunnel. 55% of traffic of Sultana road flow to the right on the First Ring Road and 45% is discharged through the tunnel.

Airport Rd, Abu Dhar Algefari Rd. (SAPTCO bus terminal) and King Fahd roads are all located close to each other (within about 600 m). Beside pedestrians crossing halting the vehicles, this portion of the Ring Road has become the busiest area causing high traffic congestion. Same phenomena is noticed at Alemam Alshafai St., Al-Salam Rd. and, Omar Ibn Al khattab Rd. which are located within a distance of 430 m.

4- Recommendations

Some steps and regulations if taken would help alleviate the traffic congestion problem faced at the first ring road. Among these steps, installation of pedestrian crossings (underground or overhead) in the busiest sections of the First Ring Rd., standardization of road design across the city which may include taxi/bus stop

locations, road bumps, U-turn locations, pedestrian crossing design and road crossings, and forcing one way traffic on some streets. Road labels and signage should be redesigned for better consistency and posted in a clear and organized fashion. It is very clear that information and communications technology can play a significant role in reducing the traffic congestion such as electronic boards, a local radio channel to broadcast traffic news, and sending SMS messages to mobile phones within the city and GPS systems. The area represents almost the only link between the city four directions; east, west, north, and south. Users of these roads are forced to go through the area if they were to cross from one direction to the opposite other direction. Although might be expensive, bridging over the area may solve most of the problem.

5- Conclusion

This paper presents a detailed study of traffic flow within the central area of Madinah during season time. The study entailed a comparison between streets leading to this area in terms of traffic flow nature, peak times, bottlenecks, and traffic distribution. Despite the fact that the study was performed during a short period of time that may not indicate the real behavior of the traffic over the whole year, it gives a clear insight of traffic flow behavior. The study revealed streets with high and low volume of traffic, area design deficiencies, and the need for some rearrangements to the area in order to ease the traffic congestion. Implementation of such measures should not be delayed since the number of vehicles is escalating annually. A general conclusion that was drawn from the study is that all streets follow the same pattern in terms of traffic behavior despite the difference in their traffic volume. The fact that some roads are located close to each other (within about 600 m and some 450m) and flowing in the same direction resulted in high volume of traffic within some portions of the ring road. When pedestrians' main crossing areas are added to the mentioned case, the problem becomes more noticeable.

Daily readings taken once per week cannot be relied on for solid conclusion. Therefore, we recommend that more data for the same time periods to be taken to consolidate the findings. Students' time was another shortcoming to this study; students were not able to cover all day traffic limiting the data collection to limited hours of the day compared to other data that was taken automatically.

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