Operational Performance Evaluations of Consecutive Conventional Signalized Intersections in Cairo, Egypt

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This article aims to evaluate the operational performance of a coordinated corridor Signalized Intersections. It focusses on exploring the interaction between of a set of four consecutive conventional signalized intersections located on an urban arterial corridor in Cairo, Egypt. The impacts of operational performance of each intersection on the adjacent intersections were investigated. To achieve the research objectives, on-site video observations were recorded. The microsimulation, PTV-VISSIM, was used to analyze and estimate the efficiency and the level of service (LOS) of the studied intersections. The results indicated the poor performance of the studied intersections under heavy traffic conditions during peak hours. It also showed that, under heavy traffic conditions, the intersections affect each other adversely. The intersections capacities, delays and the total travel time was impacted. This study recommends the necessity of deployments new innovative schemes, in which the operational performance of the existed conventional intersections could be enhanced. Unconventional intersection designs as a viable interstation treatment could be proposed to alleviate congestions.

Keywords: *Operational performance, Signalized Intersections, Egypt.*

1. INTRODUCTION

The Greater Cairo Metropolitan Region (GCMR), the 1st largest metropolitan city in all Africa, has experienced a significant growth of rapid motorization during the last fifty years [1]. In its report, the Central Agency for Public Mobilization and Statistics (CAPMAS), the official statistical agency of Egypt, that the total number of vehicles has been dramatically increased. It reported the total vehicles 3.5 million vehicles with 44.4% of the total nation's vehicles population in 2014.

Thus, a significant increase in the total daily trips, travel distances, increased travel times was observed. However, the limited existing road networks, could not accommodate this huge traffic demand. Therefore, a chronic traffic congestion problem has occurred. It was reported a lack of intersection management in Egypt, according to the World Bank (WB) reports [3][4]. As a result, the average speeds were reduced by at least half (15 to 40km/hr) of the normally expected speeds (60 to 80 km/hr) in central Cairo, according the (WB) published report [3].

Moreover, the existed conventional intersections, were dramatically deteriorated. The intersections operational performance, capacities and average delay were significantly impacted. The Saturation flow rates of the existed intersections was obviously impacted [2].

As adverse impacts on the safety aspect, in its published report, the WHO emphasized that Egypt loses about 12,000 lives annually from road traffic accidents, and more than 154,000 injures occurred because of road accidents [5] [6] [7]. For the economic side influences, the traffic problem in Egypt

Figure 1: A Google map showing the study area

directly and indirectly affects the nation's economic productivity. The WB reports indicated that Egypt loses up to 4% of its Gross Domestic Product (GDP) (8 billion USD/year) as a yearly economic cost of traffic. Moreover, it has emphasized that Cairo's costs from traffic congestion have been excessive [8].

The objective of this study is to assess the potential performance level of a series of four consecutive conventional existing intersections. For this purpose, video observations were conducted for the studied corridor. Later, a microsimulation package software, PTV-VISSIM, was used to estimate the (LOS) as operational performance indicator. The total travel time, the average delay, the queue lengths and the number of stops per vehicle were estimated for each of the studied intersections.

2. LITERATURE REVIEW

Various pioneering studies have provided general guidelines relevant to this study. El Azzony et al. (2010) studied the effectiveness of using U-turn intersection treatments at the same corridor of the studied area of this research. The authors investigated the potential of using a microscopic traffic simulation model, Quadstone Paramics, for testing and evaluating the operational impacts of different intersection treatments including different U-turn solutions with high traffic volumes. The results revealed that the U-turn solution is not the best solution for adopted case study [10].

El Esawey and Sayed (2011), used VISSIM as a microsimulation approach to analyze the operational performance of the unconventional median U-turn (MUT) intersection design in Cairo, Egypt. Under a wide range of balanced and unbalanced volumes scenarios the operational performance of the unconventional median U-turn was compared to conventional four-leg and conventional MUT intersections. They reported that unconventional MUT capacity was shown to be poor in comparison to other two designs [11].

As an attempt to find basic guidelines to regulate the use of restricted lefts/through U-turns instead of signal control in Egypt urban intersection, El Azzony et al. (2011) investigated the effectiveness of using restricted lefts/through U-turns in comparison with the signal control option. Based on simulation experimental analysis as well as two regression models, basic guidelines could be deduced which able to rationalized the use of U-turns as intersections treatment.

3. STUDY AREA

The adopted case study is a series of four consecutive conventional signalized intersections along Mostafa Elnahas Street; a major urban corridor in Cairo, Egypt (Fig 1). The corridor is an arterial one located on the central business district (CBD). It connects the CBD with the new urban residential communities located to the east of the city down town. In addition, the adjacent area is a residential and entertainment facilities. Thus, this corridor experienced daily heavy traffic volumes. Both of the major corridor and the intersected streets are three lanes per approach. However, an exclusive connector is provided for the left turning traffic in each intersection. Also, an exclusive free flow right-turn lane is provided for the right-turning flows. The four intersections, namely, Makram Ebid (ME), Abbas Alakad (AA), and Al Tayran (AT) are four legs intersections. Whereas Yossef Abbas (YA), is three leg intersection. The four legs intersections are operated within a fixed four signal phases. However, the three leg intersection, (YA), has a three phase fixed signal. The speed limit on the arterial corridor is 60 km/hr, while in all minor streets the speed limit is 30 km/hr.

4. DATA COLLECTION

Two data categories were required for the simulation model, network geometry and traffic volumes. The network geometry data considered, intersections configurations, numbers of lane for each major corridor as well as the minor intersected streets, lanes alignment, lanes widths and U-turn locations. Google maps was used to collect the geometric data.

For efficient traffic data collection, video observations for the studied intersections were recorded. Traffic counts of 2002 and corrected using link volumes of 2015 were used in this study. Growth factors were used while maintaining turning ratios.

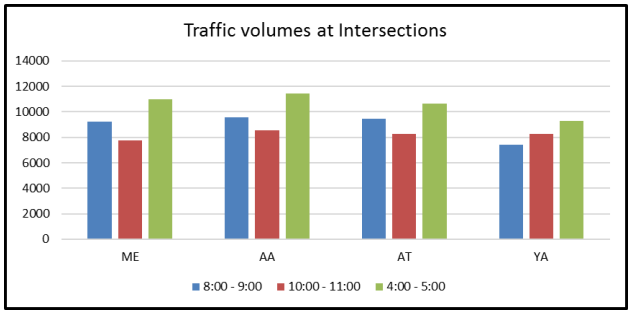

Figure 2: Traffic volumes of the studied intersections during different periods

The data recorded included the traffic flow, capacity, and operational ratio for each approach. The traffic composition of each turning flow from the different approaches was obtained.

For a sufficient amount of unbiased data, the observational periods were both daytime and night. The video sequences were recorded during three different periods, including peak and off-peak periods. The first period was during morning peak hours (8:00 to 9:00) and afternoon peak (16:00 to 17:00), whereas the off-peak morning period (10:00 to 11:00). The recorded videos were divided into 15 minutes' interval for efficient data obtaining.

5. DATA ANALYSIS

Based on video recoded, a comprehensive analysis was carried out. Several traffic parameters for each intersections and approach such as traffic volumes, headway discharges, traffic compositions and directional flow ratios could be observed. In addition, the Origin/Destination (OD) could be determined.

In terms of the traffic volumes, it was observed that the afternoon peak period is the most congested one among the three recorded periods. Also, AA intersections recorded the high traffic volumes among the studied intersections with 11444 veh/hr as shown in (Fig 2).

For the traffic composition side, it was found that the existed traffic volumes were a mixed traffic situation, included 75% of normal vehicles in, 10% heavy vehicles (including buses, mini buses and small trucks) and 15% motorcycles.

Regarding to the traffic directional ratios perspective, it was found the through traffic volumes was the majority with a range (49% to 79%), the left turn volumes were observed (13% to 65%) and the right-turn free flow traffic was found (2.5% to 45%).

6. SIMULATION MODELING

To accomplish this study objective, traffic simulation modelling was used. Microsimulation is considered a safe, cost and time effective and crucial analytical tool, which enables analysts to pre-deployment test-bed evaluation [9]. Replications of the traffic system physical components such as road network and traffic control systems as well as the driving behavior modelling as those in the real-world traffic conditions are provided within the microsimulation. In addition, different traffic scenarios, control strategies and design configuration could be evaluated effectively [13].

In this study, VISSIM, was used to model and analyze the studied intersections. Several measures such as total travel time, intersections average delay, queue length and the number of stops of each vehicle could be estimated.

7. RESULTS

The present study analyzes the operational performance of a set of consecutive conventional signalized intersections. The simulation results showed that the operational performances were dramatically affected, especially, during the peak periods under heavy traffic conditions. It was observed that the storage bays could not accommodate the left-turn volumes during the peak hours. The long cycle length of four phase intervals, which was necessary for discharging the traffic volumes, resulted in long queues at the intersections. Thus, spillbacks of adjacent intersections could affect the other intersections along the corridor.

As a result, the LOS of intersections was experienced significant reduction.

8. CONCLUSION

Drawing up the study conclusion, the overall attained results are presented. This research focused on evaluating the operational performance of a set of four consecutive conventional signalized intersections located on an arterial corridor in Cairo, Egypt.

To achieve the research aim, traffic data was collected via video recordings. Based on the data collected, traffic parameters such as traffic volumes, headway discharges, traffic compositions and directional flow ratios could be estimated for each of the existed intersections.

Microsimulation, VISSIM, was used to model and analyze the existed studied intersections. The LOS of each intersection could be evaluated using the out-

comes of the simulation models. The total travel time, the average delay, the average delay, queue length and the number of stops of each vehicle could be obtained.

The results emphasized that under heavy traffic conditions during the peak periods with the limited geometric designs, the studied intersections could not accommodate the high traffic volumes. In addition, the long cycle length of four phase intervals, resulted in long queues at the intersections. The spillback of adjacent intersections could affect the other intersections performance along the corridor. As a result, the LOS of intersections was significantly decreased.

It is highly recommended the urgent necessity of deployments new control techniques in which the operational performance of the existed conventional intersections could be improved. Unconventional intersection designs such as displaced left turn crossover could be studied as a treatment for high left-turn traffic volumes.

9.FUTURE WORK

A future extension of the current study will investigate the applicability of new control schemes to improve the performance of the existed conventional intersections. Alternative unconventional intersection designs will be proposed. The mixed traffic conditions as well as limited geometric designs, as common traffic conditions in the developing countries, have to be studied specifically.

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