A REAL-TIME SIGNAL CONTROL ALGORITHM FOR DISPLACED LEFT-TURN INTERSECTIOS CORRIDOR UNDER HETEROGENEOUS TRAFFIC CONDITIONS

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To alleviate congestions at signalized intersections, Displaced Left-turn Crossovers (DLTs), also known as Continuous Flow Intersections (CFIs) are becoming prevalent over the last decade in some developed cities around the world. A novel solution is provided through DLTs by introducing a particular geometric layout as well as a special signalization control scheme. Within the geometric layout provided, left turn flows could cross opposing traffic lanes upstream of the main intersection. As a result, DLTs lead to higher capacity, lower delay and fewer crashes. Despite, the extensive preliminary studies focused on the operational performance of DLTs, little research has been conducted considering the coordination of DLTs. Hence, based on dynamic optimization principles, this paper presents a real-time algorithm considering the coordination of DLTs as a corridor. This context methodology is illustrated utilizing VISSIM as a simulator-based approach and MATLAB as a multi-paradigm numerical computing environment. Employing VISSIM COM interface and MATLAB an inter-process communication and dynamic object creation was provided. Although the academic in nature, the algorithm presented in this context could be evolved through real world practical application. As a realistic case of study, obtained data from three conventional signalized intersections located in an arterial corridor in Cairo, Egypt was used.

Keywords: *Displaced Left-turn crossovers, heterogeneous traffic conditions*

1. INTRODUCTION

As one of unconventional arterial intersection designs (UAIDs), DLTs intersections also known as Continuous Flow Intersections (CFIs) have been presented for the last decade as an innovative at-grade signalized intersection treatment to alleviate congestions at signalized intersections (El Esawey and Sayed 2013). A unique solution is provided through DLTs by introducing a particular geometric layout as well as a special signalization control scheme. DLTs' operational control scheme ensures a simultaneous flow of both through traffic as well as left-turn movements (Carroll and Lahusen 2013). Through the geometric layout provided, left turn flows could cross opposing traffic lanes upstream of the main intersection. By eliminating the left-turn conflicts through displacing the left-turn lane to the opposing direction (Hummer, 1998). Only a two-phase signal control is installed instead of four phases for the conventional signals, the through and left-turn traffic flows could operate at the main intersection simultaneously(Reid and Hummer 2001; FHWA, U.S. Department of Transportation 2014). Therefore, intersection capacity was significantly increased and delays were also decreased (Jagannathan and Bared 2004).

Despite, the extensive preliminary studies focused on the operational performance of DLTs, little research has been conducted considering the coordination of DLTs. Most of the previous considerable works on UAIDs dealt only with isolated UAIDs. However, few articles have been turned to placing a series of UAIDs on a coordinated corridor, no study has found to investigate the integration of the DLTs intersections applicability (Esawey and Sayed 2013).

On the other hand, although the early deployment of DLTs, they are mainly installed in the developed world where ideal traffic conditions. Therefore, almost all previous sparse studies focused on studying the operational performance of DLTs under ideal traffic operations. However, DLTs under the heterogeneous traffic conditions as a dominant operation in the developing countries has never been examined. The heterogeneous traffic conditions involve the complexities of mixed traffic compositions such as diverse dynamic and static properties of vehicles, aggressive drivers' behavior and the lack of lane discipline. As a result, complex operating systems were existing due to the wide variations in the operating performance characteristics of the heterogeneous traffic system compared to homogeneous one resulted in (Maini, 2000).

The objective of this research is directed to placing a series of DLTs on a coordinated corridor under dominant heterogeneous traffic conditions. The driving force of this study context is developing a real-time algorithm to optimize a series of DLTs traffic signals as a coordinated corridor in order to accommodate traffic demand variation.

2. LITERATURE REVIEW

Several valuable research work provided considerable in-depth literature review of existing analyzing DLTs operational performance methods relevant to this study. A valuable enhancement in the operational performance of three traditional intersections has been highlighted in a comparative study of three different DLT configurations to their similar conventional designs. Under low, moderate and high traffic volumes, a prominent savings in average control delays and average queue lengths. The DLTs outputs emphasized a reduction in the average control delay by 48% to 85%, 58% to 71% and 19% to 90% for low, moderate and high traffic volumes respectively. Consequently, the average number of stops reduction pointed to 15% to 30% for under saturated traffic flows and 85% to 95% for saturated traffic conditions. Accordingly, the analysis recorded a significant intersection capacity growth for the three studied DLTs over the conventional ones (El Esawey and Sayed 2007).

Utilizing VISSIM, as a powerful simulation-based assessment approach, Autey et al., evaluated and compared the operational performance of four unconventional intersections: upstream signalized intersection (USC), crossover displaced left-turn (DLT), median U-turn (MUT) and double crossover intersection (DXI) (i.e., half USC) under balanced and unbalanced volume scenarios. The DLT is always experienced superior to all other studied intersections in almost all volume conditions. The results showed while the USC and DXI capacities were about 50% higher than the conventional intersections, DLT exhibited a significant growth of capacity by 99% higher than the conventional counterpart, whereas. Also, DLT constantly recorded the lowest delay among the all compared counterparts (Autey, Sayed, and Esawey 2012).

Another comparative study was conducted for a fair travel time comparison of conventional intersection and seven unconventional designs: Quadrant Roadway (QR), Median U-Turn (MUT), Super Street Median (SSM), Bowtie, Jughandle, Split intersection and Continuous Flow Intersection (CFI). To achieve the study objective, CORSIM simulation software was used. Authors concluded that at least one unconventional scheme would outperform its conventional counterpart in at least one volume scenario. The conventional designs never produced the lowest average total time. The continuous flow intersection always had the highest move-to-time ratio for all designs. Additionally, DLTs design was also keeping traffic moving as its name implies, even if QR and MUT designs vied for the lowest average total time (Reid and Hummer 2001).

3. METHODOLOGY

Considering the novel nature of UAIDs, particularly DLTs, microsimulation platform has been broadly employed in several research works. As a cost and time effective and crucial analytical approach, VISSIM is utilized in this study (VISSIM 5.4 Manual 2012). Employing the given flexible VISSIM capability, especially, the psychophysical car-following model, construction of DLTs could be represented exactly like they would appear in the real life (El Esawey and Sayed, 2013). However, for accurate simulation of heterogeneous traffic conditions, model-specific parameters' adjustments were carried out. These adjustments include vehicles' static and dynamic properties as well as driving behavior representation (Khan and Maini 1999; Manjunatha, Vortisch, and Mathew 2013; Mathew and Radhakrishnan 2010, 2010; Kaur and Varmora 2015).

VISSIM COM interface and MATLAB was provided as an inter-process communication and dynamic object creation. VISSIM COM interface is used to manipulate the attributes of most of the internal objects dynamically. The generated data obtained via installed detectors in the simulated corridor as a real-time feeding data to MATLAB. Based on a real-time algorithm provided a proprietary program developed to optimize the coordinated DLTs signals based on VISSIM sent data.

4. TRAFFIC ENVIROMENT

The three intersections studied in this work are consecutive conventional signalized intersections in Mostafa El-Nahas Street; a major urban corridor in center Cairo, Egypt as shown in figure1. The studied corridor is one of the main arterial corridors located in the central business district (CBD). Therefore, the studied intersections, Makram Ebid (ME), Abbass Al-Akkad (AA) and Al Tayran (AT) intersections, practice daily heavy traffic volumes as shown in figure 2.

The analyzed intersections had the following geometric criteria:

1- All intersections were four-leg intersections;
2- Each Intersection had the same number of lanes per approach three lanes of 3.5m per direction

for both the major and minor approaches. However, as a result of the lane lines absence, non-lane based phenomena as a salient property of the heterogeneous traffic, has been observed. Therefore, under aggressive driving behavior, during the peak hour,

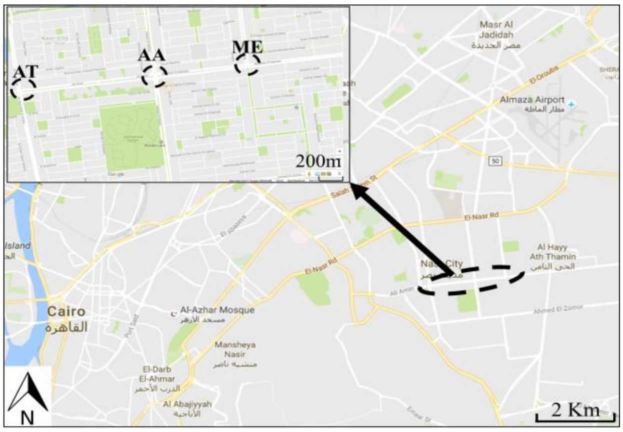

Fig.1 The case of study in Cairo, Egypt

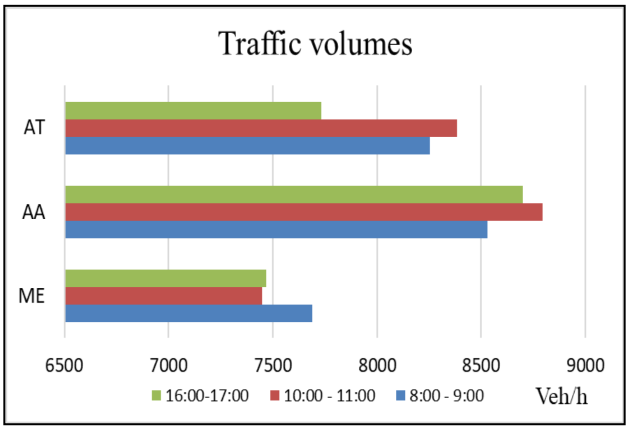

Fig.2 The studied intersections traffic volumes

vehicles could perform as four lanes per approach flow on the main studied corridor.

3- In addition, an exclusive bus lane of a 3.5 m width per was installed in the main corridor for the public buses. However, shuttle buses, private and school buses were not allowed to use those exclusive lanes;

4- For both major and minor free right-turning flows, a channelized right-turn lane was provided on all studied intersections;

5. DLTs REPRESENTATION

On the base of DLTs design principles and considering the earlier works, guide manuals as well as the pre-deployments of the scheme proposed, DLTs configuration could be simulated. This study context considers DLTs implementation of in both major and minor approaches. Based on the traffic volumes assigned for each intersection, different DLT geometric designs were configured. A typical geometric configuration was assigned for the minor approach for all studied intersections. For minor approach two exclusive lanes of 3.5m for through and other two lanes as crossover lanes with a channelized free right-turning lane. However, the geometric layout was different in the studied intersections for the major approach. For ME intersection, two exclusive lanes of 3.5m for each direction for through traffic flows were settled, while The other two lanes of 3.5m were installed as crossover lanes as shown in figure 3.

On the other hand, three lanes of 3.5m were employed for the through westbound flows of AT DLT because of the high traffic demand. Therefore, only one lane of 3.5m was left for left-turn crossover as shown in figure 4. The high traffic demand of major approach through flows resulted in assigning three lanes for both AA major approach through flows. Consequently, the right channeled lane of the westbound as well as the southbound was abolished and one lane was allocated for left-turn west and eastbound as shown in figure 5. Furthermore, the two existing bus exclusive lanes were kept on the main street for all DLTs.

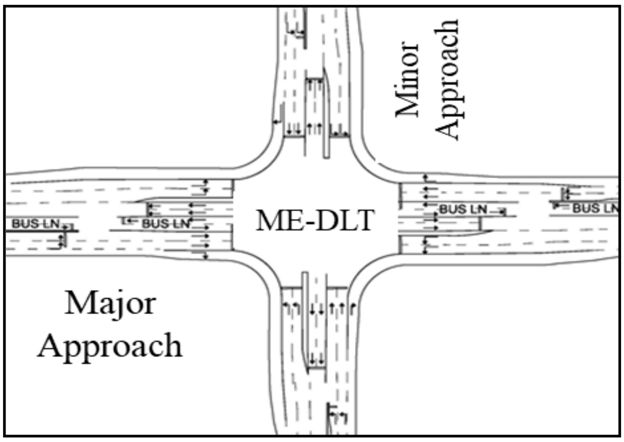

Fig.3 ME-DLT geometric design

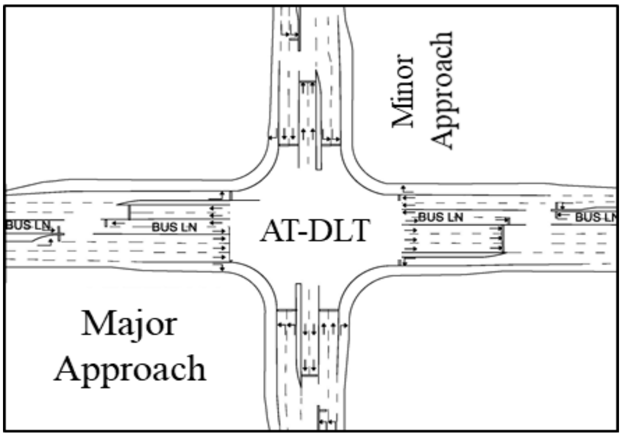

Fig.4 AT-DLT geometric design

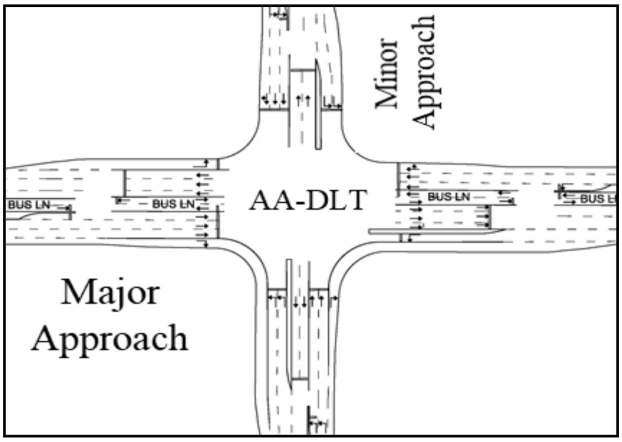

Fig.5 AA-DLT geometric design

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