Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (39) No. (3) july, 2017

Modeling of Pedestrian Crossing at Unconventional Median U-turn Intersection

Nasser M. Abdallah[1], Mahmoud H. Ali[2], Ahmed S. El Hakim[3] and Abdallah H. Wahdan[4]

[1] Lecturer of Transportation Planning & Traffic Engineering, Faculty of Engineering, Al Azhar University.

[2] Demonstrator, Dept. of Civil Engineering, Faculty of Engineering, Al-Azhar University.

[3] Professor of Transportation Planning & Traffic Engineering, Faculty of Engineering, Al Azhar University.

[4] Professor of Transportation Planning & Traffic Engineering, Faculty of Engineering, Al Azhar University.

الملخص

فى السنوات الاخيرة تم استخدام نظام الدوران للخلف (UMUT) فى التشغيل والتحكم لمعظم تقاطعات مدينة القاهرة . وقد تم تقييم أداء نظام الدوران للخلف من خلال المحاكاة باستخدام برنامج PTV VISSIM 9.00-06 مع أحجام مشاه متعددة وقد أجريت عملية جمع البيانات لغرض المعايره والتحقق من فاعلية المحاكاه وفحص الاخطاء فى بناء النموذج وتصحيحها. وقد اجريت المعايرة بإستخدام المعادلة الاحصائية (GEH) واشارت النتائج الى ان النموذج مقبول. فى حين تم اختيار مقدار متوسط الخطأ التربيعى المعيارى للتحقق من فاعلية نموذج المحاكاه. وقد تم عمل سيناريوهين بالاضافة الى نظام التشغيل الحالى (عبور المشاه العشوائى عند UMUT بعد المعايرة والتحقق من فاعلية النموذج) . وقد تبين انه يوجد زيادة مؤثرة لقيمة التأخيرات عند هذا النوع من التقاطعات مع زيادة أحجام المشاه. واستنادا الى نتائج المحاكاه باستخدام الاحجام المختلفة للمشاه تبين انه لا توجد تأخيرات مؤثرة مع احجام المشاه المنخفضة. وتبين ايضا انه عند احجام المشاه المتوسطة من المفضل عمل اشارة ضوئية للمشاه فى نظام تشغيل التقاطعات بالدوران للخلف UMUT لتقليل التأخيرات وكذلك الحد من وقوع حوادث للمشاه . وقد تبين ايضا انه مع احجام المشاه المرتفعة فإن عمل اشارة ضوئية للمشاه أو تحويل نظام التحكم فى التقاطع الى الاشارة الضوئية الكاملة سوف يقلل التأخيرات بنسبة 19.92 % و 75 % على الترتيب عن تشغيل التقاطع بنظام الدوران للخلف. ومن المفضل إنشاء حواجز بين نهر الطريق وارصفة المشاه لإجبار المشاه على العبور فى أماكن محددة وتوفيرمعابر مطوره للمشاه ومجهزه لتجنب الحوادث وتقليل أزمنة التأخيرات للمشاه وبالتالى توفير استهلاك الوقود الذى له تأثيرات بيئية سيئة مثل تلوث الهواء وكذلك الضوضاء

Abstract

The unconventional median U-turn (UMUT) design has been put in operation in Cairo, Egypt from several years ago as shown in Figure 1.

This research simulated the operational performance scenarios of the UMUT intersection under a wide range of pedestrian volumes by using PTV VISSM 9.00-06 micro-simulation program. Data collection was conducted at selected UMUT intersection in Cairo, Egypt for calibration and validation purposes. Prior to calibration and validation procedures, the code error checking was conducted to eliminate any coding error. Calibration of Model has been conducted by using the Geoffrey E. Havers (GEH) Statistic formula. While, to validate model the Root Mean Squared Normalized Error (RMSNE) has been chosen. Two different scenarios were developed for model

---

Key words: unconventional intersections, median U-turn, micro-simulation.

in addition to base case scenario (Random pedestrian crossing at UMUT) after calibration and validation. Intersection delays are significantly increased with increased pedestrian volumes. Based on the results of this analysis, it was shown that, there is no noticeable impact on the intersection delays with low pedestrian volume. Under moderate pedestrian volumes it is recommended using pedestrian signal at UMUT to reduce delay and potential of accidents for pedestrians. At high pedestrian volume, UMUT intersection delays will decrease about 75 % when convert control type to signalized intersection and 19.92 % when convert random pedestrian crossing to signalized pedestrian crossing. It is better to install safety barriers between carriageways and sidewalks to enforce pedestrian to crossing at certain location and provide pedestrians more facilities and equipment to eliminate crashes, saving time, fuel consumption, and environmental bad effect such as noise and air pollution.

1 Introduction

Most of the intersections in Cairo, Egypt suffer from congestion/delay. Improvements of intersections has been the main concern of traffic management authorities. Therefore, some of signalized intersections along arterial corridors were replaced by UMUT with no considerations for design criteria and intersection conditions. The number of intersections in Cairo has increased significantly with the construction of new roads, and at some point, the numbers of the traffic police force are insufficient to operate all intersections. Moreover, drivers' incompliance to traffic regulations continued even with the existence of traffic policemen. Transportation authorities in Cairo found no other solution rather than forcing certain routes at the intersection using physical barriers. From one side, this helped "saving" the traffic police force to other traffic-related tasks and at the same time compelled drivers to follow traffic rules. Consequently, the UMUT design was put into service as a solution to some policy-related problems rather than operational problems.

In most Egyptian cities UMUT has been installed to improve performance of intersections without any study of this action to both geometrical and operational characteristics and the suitability of this control type for each intersection or not. Lack of sufficient information on operational performance of UMUT and the role they play in access management have boosted researchers to conduct more studies in this regard lately.

The World Bank study titled traffic congestion in Cairo, 2012 reveals that:-

- Cairo's infamous traffic costs Egypt (USD 6.5 billion) annually.
- Is expected to reach (USD 14.6 billion) by 2030.
- This study concluded that poor traffic management was the main cause of congestion such as: limited parking capacity, few traffic signals and expansion in using UMUT, random stops by cars and minivans and no proper pedestrian crossings.
- Cairo's traffic not only poses dangers to the economy, but also poses dangers to pedestrians and inhabitants of the GCMA. Egypt's roads lead to almost 10,000 deaths per year; while, almost 1,000 deaths in Cairo occur due to traffic related accidents, of which more than half are pedestrians. An average of (USD 1 billion) is spent every year on health issues related to traffic.

So, studying this type intersection control was adapted in this research to illustrate the delay at intersections, especially the pedestrian delay which is considered a large proportion of the total delay at intersections.

1.1 Unconventional Median U-Turn Definition

The UMUT design utilizes an on-traversable median to prohibit minor street traffic from crossing the primary intersection. Both of the through and left-turning traffic coming from the minor street are rerouted through right turns followed by U-Turns at a median opening located on the major street downstream the primary intersection. Left-turn traffic of the main street also has to make a U-turn followed by a right-turn on the cross-street. The conflict between merging traffic from the cross-street and main street through traffic can be handled by a 'STOP' or 'YIELD' sign that gives priority to through traffic of Main Street. The same control level is applied at the MUT opening. The UMUT, as shown in Figure 1, has been a common treatment for signalized intersections from about 15 years ago in Cairo, Egypt (Esawey and Sayed 2011). The same design was put into service from a years ago in Iran (Shahi and Choupani 2009).

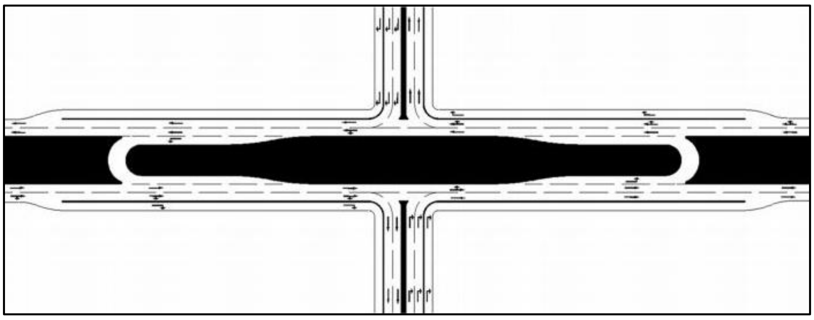


Figure 1 Unconventional Median U-Turn (UMUT)

1.2 Problem Statement

In most of the proposed designs, planners of transportation and traffic in Egypt, often do not give the same priority to the pedestrian traffic at intersections, where traffic signal control are usually designed to increase the capacity of the intersections and/or reduce the delay of the vehicles regardless pedestrian requirements. So, the pedestrians cross the street in any place and at any time, which leads to an increase of delay, especially at intersections controlled by UMUT. The comfort of vehicles and their occupants is considered the main objective of traffic system improvement, while, pedestrians crossing requirements are not considered, then the pedestrian intend to cross the road randomly, leading to considerable delays and long queues lengths.

Also, intersection levels of service will be decreased at this type of intersections, as well as traffic accidents will be increased, between both vehicles to vehicles or to pedestrians. Often, the inequality in the facilities offered for these two groups of road users, result in significant pedestrian delays compare to vehicle delays at the same intersection. This situation contrasts with current policies to encourage using of public transit and walking.

1.3 Research Objectives and Scope

This research aims to study the delays due to increasing pedestrian crossing at UMUT intersection by using micro simulation modeling. The developed models after calibration and validation can reflect the suggested scenarios efficiency to enable planners, designers and decision-makers to choose the ideal scenario to control pedestrian movement at UMUT intersection.

2 Literature Review

Reid and Hummer, 2001 used a microscopic traffic simulation software (TSIS-CORSIM) package developed by McTrans Center, University of Florida to compare the travel times of seven isolated UMUT and a similar conventional intersection. The comparison results supported the superiority of the quadrant and the MUT intersections for most volume scenarios.

Bared and Kaisar, 2002 showed that conventional intersection designs are frequently not capable of alleviating congestion without incurring significant improvement costs and increased conflicts. A few states are considering and applying nonconventional treatments for high traffic-volume intersections, especially those with high left-turn traffic volumes. Nonconventional intersections provide unique channelization of particular turning and indirect traffic movements. Moreover, safety benefits are possible with separation and reductions of potential conflicts. This article study the traffic-operational benefits of signalized median U-turns for left-turning vehicles making indirect maneuvers. A discussion of possible safety benefits was also provided.

Zhou et al., 2002 study the operational performance of RTUT as an alternative to DLT from driveways to multi-lane highways. About 300 h of field video data were collected and used to develop regression models that compute the delay and travel time of DLT and RTUT as a function of major and minor road traffic flow rates. A binary model was developed to estimate the ratio of drivers who prefer to make a RTUT rather than a DLT.

Rodegerdts, 2004 discuss five types of unconventional intersections as “indirect left-turn treatments” for signalized intersections. These designs include jughandle, MUT, CFI or XDL, quadrant intersection, and super-street. A large body of literature exists on the performance of different types of unconventional intersections (Federal Highway Administration).

Shahi and Choupani, 2009 evaluate the traffic operation at the unconventional MUT design. Field video data were collected from five intersections in Iran and used to analyze the design. Regression models were developed to estimate the travel time of left-turn traffic, Minor Street through travel time, weaving time and speed of U-turn vehicles, and speed of non-weaving flows. In addition, some models were developed to describe the operations of weaving sections. There are some concerns about the impacts of the unconventional U-turns on the safety of pedestrians and vehicles. It is recommended to carry out separate studies on safety performance of the U-turns. Despite being developed for a different roadway facility (i.e., the UMUT), the accuracy of the developed models was compared against the models developed by FDOT for RTUT. The latter were shown to always overestimate the travel times for all volume ranges. A comparison of the performance to a conventional four-leg intersection or a conventional MUT design was not carried out.

Esawey and Sayed, 2010 evaluated the potential implementation of an (USC) intersection in Doha, Qatar. The objective was to investigate if there will be any improvements associated with the implementation of this unconventional intersection. The results indicated that corridor travel times of the USC configuration were less than those of the conventional configuration by 14.7 and 12.2% for the AM peak period, 13.5 and 10.6% for the PM peak period for the westbound and the eastbound directions, respectively. While for the Midday peak period, the corridor travel time of the westbound direction experienced a delay reduction of 6.2% and the eastbound direction experienced a slight delay increase of 0.4% higher delay in the USC configuration.

Esawey and Sayed, 2011 analyzed and compared to baseline conventional four-leg and conventional MUT intersections in Cairo, Egypt. VISSIM was used to model the three designs under a wide range of balanced and unbalanced volume scenarios. The performance of the unconventional MUT intersection was shown to be poor in comparison to the other two designs. The overall capacity of the unconventional MUT intersection was lower than that of a conventional four-leg intersection by about 27%. Meanwhile, the capacity of conventional MUT intersections with signalized and un-signalized crossovers was about 10% and 8% higher than that of the conventional intersection, respectively. Despite the poor performance, the unconventional MUT is increasing in popularity among city officials in Cairo. Traffic regulations enforcement and policemen’s safety gains might be the main incentives behind the implementation of the design in Cairo. Kamran, 2011 evaluates low cost “Indirect Right Turn Treatment” to reduce conflicts and congestion at signalized intersections in urban areas. Volume and travel time studies were conducted at three signalized intersections in Islamabad (Capital city of Pakistan), where indirect right turn treatments were applied. Travel time study was done using GPS device. It should be noted that traffic operates on left hand side in Pakistan i.e. right turn movements are signalized. To monitor the traffic flow and driver behavior video recordings were also done on each intersection during the peak hours. Microscopic simulation model (VISSIM) and field travel time runs were used to evaluate before and after scenarios. It found that at, some locations, application of indirect right turn reduce travel time and increase the vehicle output. However, at one intersection the implementation of indirect right turn treatment resulted in increased travel times and reduced vehicle output. This is because of the number of vehicles affected by the closure of intersection are higher and also the movement of vehicles at the U-turns was effected by on-street parking. It was also observed that U-turns provided at all locations are not properly designed, which elevates the safety issues.

Al-Jameel, 2014 found that left turn flow from U-turn leads to high congestion on both origin and destination roads. Therefore, field improvements have been done by the traffic policemen who create a temporary barrier from traffic plastic signs in order to protect left turn vehicles from through traffic in opposing direction. This study introduces new design for U-turn in order to protect both turning and through traffic to increase the level of performance. This design has been tested by using the simulation model.

The developed model (Paramics) has been calibrated using field data collected from Al Najaf city. Then, the validation for the developed model has been implemented using another set of field data. Finally, the simulation model has been adopted to test the new design for the U-turn. It was found that the new design gives higher capacity than the current design.

Soliman, 2016 found that at some point, continuous increase in weaving length does not necessarily improve traffic operations and could reduce the capacity and level of service. It was also concluded that, 200 meters is the optimum length for maximum capacity. At high crossing demands, mainstream vehicles penetrate through the section with very low speeds and could be forced to queue with the U-turn vehicles until sufficient gap arises. Therefore, the design should be implemented at areas with low crossing demand conditions and cannot be used at major intersections.

The literature discussing the UMUT without traffic signals is relatively limited. This may be attributed to the fact that the design was only implemented in few developing countries and delay due to pedestrian movements were not considered

3 Methodology

In the UMUT design, pedestrian movements were not considered. The impact of this pedestrian crossing volume on the performance of the UMUT design was not analyzed in previous researches. So, this research will adapt the following methodology as shown in Figure 2 to achieve the main aim of this research. In order to achieve the aim and objective of this research, a comprehensive review of pedestrian crossings, types of intersections unconventional and conventional advantages, disadvantages, criteria of usage, pedestrian treatment, effect on delays and evaluation scenarios are carried out. Then, a model is developed using VISSIM micro simulation. Data collection was conducted at Abass Al-Akad-Autostrad intersection in Egypt for calibration and validation purposes. Prior to calibration and validation procedures, the code error checking was conducted to eliminate any coding error. After the model was successfully calibrated and validated, the model is ready to be used for scenarios applications. The calibrated and validated model was then developed further into two different scenarios: installed signal for pedestrian crossing and converting the intersection to signalized one. These two scenarios were evaluated, then conclusions and recommendations have been mentioned.

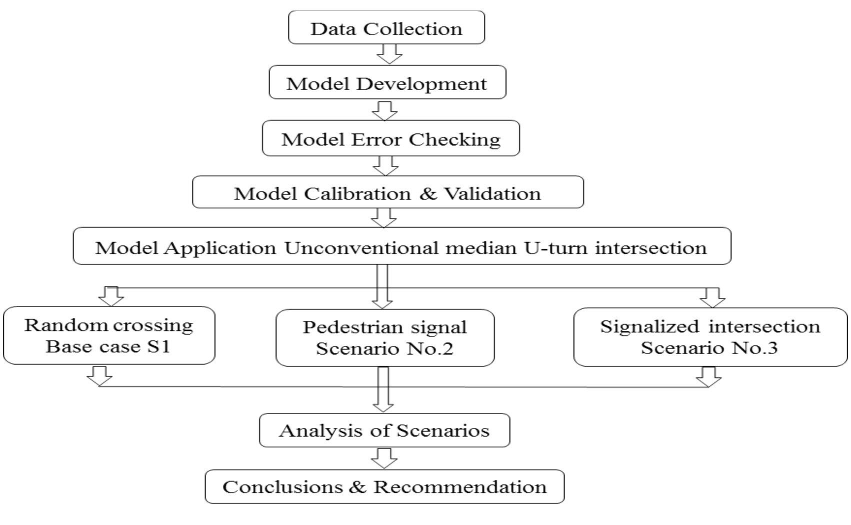


Figure 2 Research Methodology Flow Chart

4 Data Collection

Abass Al-Akad-Autostrad intersection has been chosen to achieve study methodology according to result of Urban Transport Infrastructure Development Project (UTIDP, 2016) where unconventional median U-turn. (UMUT) represented about 62 % from control types, located in mix land uses area and high pedestrian demand, high traffic volume where is located at major arterial corridor and Varity in pedestrian volumes.

Several data are required for the VISSIM model and are categorized into two types: Basic input data (road geometry, traffic data and pedestrian), Calibration and validation data.

The first type is the basic input data used for intersection coding after correction of manual count movement volumes according to video recording volumes of the simulation model.

The second type is the observation data employed for calibration of simulation parameters. Basic input data included data of road geometry, traffic volume data, turning movements, traffic composition, speed data and traffic pedestrian data prepared as input to VISSIM micro-simulation program, summary of collected data for this research is shown in Table 1.

Table 1 Summary of Collected Data

Category		Data Type
Input Data	Road geometry data	• Links with start and end point • Link length and width • Number of lanes • Connectors between links to model turning movements
	Traffic demand data	• Through and turning traffic volume counts • Vehicle composition • Pedestrian volumes and composition
	Speed data	• Travel speed
Data for Calibration	Vehicle and Driver Performance Data	• Car following behavior • Lane change behavior • Lateral behavior
	Performance data	• Travel speed
	Traffic Counts	• Vehicle and pedestrian volumes

The intersection under this research has only through movements, right turning and U-turning movements. Traffic volume, traffic speeds, travel times, pedestrians behavior, and drivers behavior were extracted over the 8 hour video recording (7:00 AM to 2:00 AM) for Abass Al-Akad-Autostrad intersection and manual count for working and off-day. These data were used for calibration and validation of a simulation model to represent pedestrian-vehicle interactions realistically, Figure 3 shows layout of the intersection under this research.

Figure 3 layout of the intersection under this research

The location of specific road features necessary for modelling, such as the location and width of pedestrian crossings, vehicle stop lines, width of road links and number of lanes per link were extracted from the video and google map. Some of the parameters were cross-checked with the site observation. The site observation confirmed that the parameters were followed and up-to-date.

4.1 Traffic and Pedestrian Volume

Traffic counts of both vehicles and pedestrians were conducted in order to introduce site representative flows in the micro simulation model. The video recordings were used to measure traffic flows and traffic composition on Abass Al-Akad-Autostrad intersection. Table 2 shows the vehicle volumes per hour and pedestrian flows per hour at intersection on each approach at AM Peak.

Table 2 Traffic and pedestrian volumes per hour

	Traffic volumes (veh/hr.)			
	Approach 1	Approach 2	Approach 3	Approach 4
Through movement	3243	2672	-	-
Right turning	1199	1882	1606	2722
U- turning	1683	1575	78	93
Total	6125	6129	1606	2722
	Pedestrian volumes (person/hr)			
	Approach 1	Approach 2	Approach 3	Approach 4
Total	1768	1119	1175	286

Source :(UTIDP, 2106). Urban Transport Infrastructure Development Project

The calibration procedure was conducted at AM peak which has high vehicle volumes and high pedestrian volumes. The validation procedure was conducted at different pedestrian volumes and traffic flow combination at PM peak of the intersection.

Eight vehicle classes are defined for modelling of this intersection as shown in Figure 4.

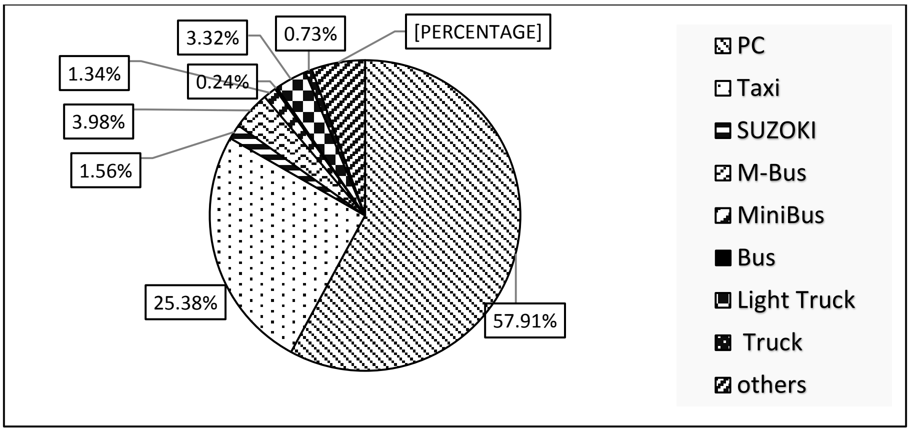


Figure 4 Traffic Composition at Abass Al-Akad-Autostrad intersection.

Source :(UTIDP, 2106). Urban Transport Infrastructure Development Project

From Figure 4 it can be noticed that private cars and taxi percentage is relatively high compared to other vehicle types since that this intersection is located at urban area on a major arterial road called Autostrad road.

5 Model Development

Simulation and modeling of the unconventional intersections were carried out using PTV VISSIM 9.00-06 where this program is one of the most widely used simulation software and is gaining increase interest among various parties in the transportation community. VISSIM is capable of simulating multi-modal traffic flows, including cars, trucks, buses, heavy rail, trams, LRT, bicycles, and pedestrians. It provides the flexibility to model any type of geometric configurations or unique driver behavior encountered within the transportation system.

VISSIM is versatile and provides the modeler with the ability to model a wide range of traffic operations in both the interrupted and uninterrupted traffic environment.

It has been used to analyze networks of varying sizes, ranging from individual intersections to entire metropolitan areas. It allows road networks or junctions to be developed lane by lane. This facilitates simulated of any unconventional intersection design exactly as the actual state.

5.1 Model Error Checking

Model error checking was conducted to determine the validity of the model. It was necessary to identify any model coding errors. Coding errors can distort the model calibration process by adopting incorrect values for calibration parameters. Such errors can be found at any time during the process of calibration. Accordingly, fixing model coding errors was an important task throughout the whole modeling process. The code checking was conducted to test the ability of the model to reflect the crossing operations, including gap acceptance and pedestrian behavior. A series of simulation runs were conducted to determine if the model was functioning as intended. Input data of the model such as traffic volumes, traffic composition was based on the data collected at Abass Al-Akad intersection. VISSIM allowed visual viewing of the simulation run.

5.2 Calibration of Model

The GEH Statistic is a formula used in traffic engineering, traffic forecasting, and traffic modelling to compare two sets of traffic volumes. The GEH formula gets its name from Geoffrey E. Havers, who invented it in the 1970s while working as a transport planner in London, England. Although it's mathematical form is similar to a test, but it is not a true statistical test. Rather, it is an empirical formula that has proven useful for a variety of traffic analysis purposes. The formula for the "GEH Statistic" is:

$$GEH = \sqrt{\frac{2(m-c)^2}{m+c}}$$

Where: m is the hourly traffic volume from the traffic model and c is the real-world hourly traffic count, their criteria are listed in Table 3.

The results indicate that the model is acceptable fit where GEH was 4.32.

Table 3 GEH Criteria

Value of Statistic	***Criteria***
GEH < 5.0	Acceptable fit
5.0 <= GEH <= 10.0	Caution: possible model error or bad data
GEH > 10.0	Unacceptable

(Source: WSDOT, Protocol for VISSIM Simulation, September 2014)

5.3 Validation of Model

To validate model the Root Mean Squared Normalized Error (RMSNE) has been chosen.

(RMSNE) measures the percentage deviation of the simulation output from observed data. This statistic measures the percentage of the typical relative error and it can be used to determine the width of the confidence intervals for the predictions. Mathematically, it can be expressed as:

$$RMSNE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{y\ sim - y\ obs}{y\ obs}\right)^2}$$

Where $\boldsymbol{y\ sim}$ and $\boldsymbol{y\ obs}$ are the simulated and observed measurements respectively, and **n** the number of measurements. A RMSNE of less than 0.15 is considered acceptable for traffic model calibration. (FDOT, 2014).

The results indicate that the model satisfies the criteria for validation with the $RMSNE$ was 0.089 and Figure 5 shows speed distribution of measure data and simulation.

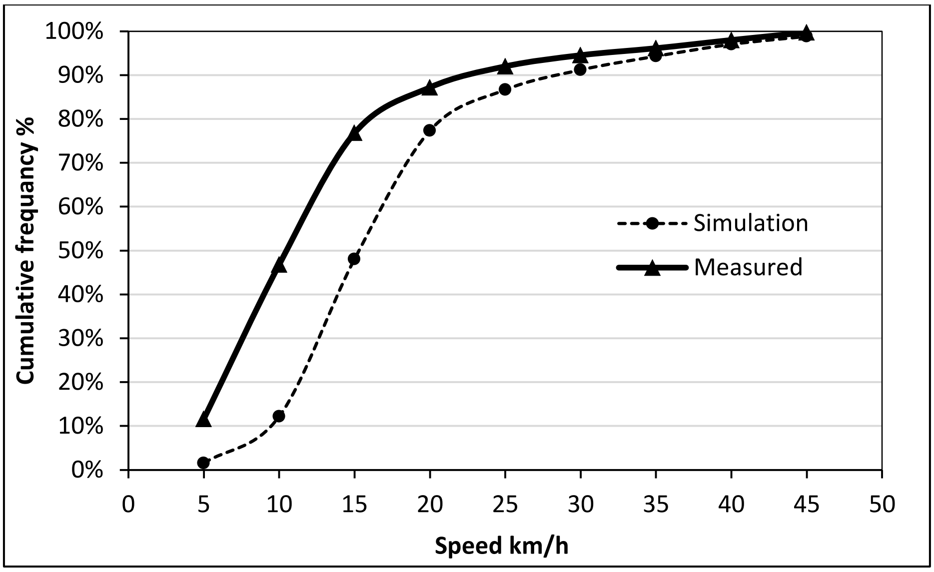


Figure 5 Speed distribution of measured data and simulation runs.

Table 4 show the descriptive statistics for measured and simulated speed with coefficient of correlation (R) is 0.91 .The correlation is statistically significant with $p < 0.05$ at the 95 percent confidence level.

Table 4: Descriptive Statistics for measured and simulated speed

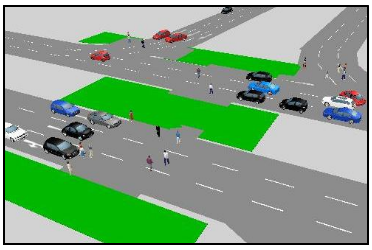
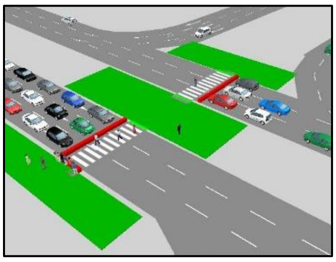
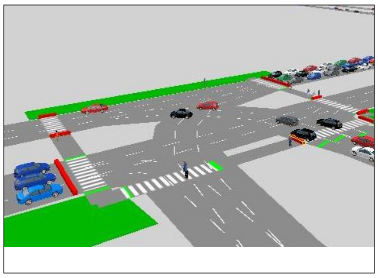
Statistics Measure	Mean	S.E	Mode	S.D	Skewness	Min.	Max.	Sum	Count
Simulated	21.91	0.30	16.40	8.37	1.40	1.1	51.7	16914.1	772.0
Measured	22.74	0.19	20.54	3.58	0.75	13.7	47.3	8185.2	360.0

6 Analysis of Scenarios

Two different scenarios were developed and analyzed for the model in addition to base case (Random crossing at UMUT) after calibration and validation as shown in Table 5 there are:

- **Random Pedestrian Crossing (base case):** in this case of operation drivers should yield to pedestrian crossing.
- **Pedestrian Signal (S1):** in this case pedestrians are protected by pedestrian signal (as mid-block signal) with appropriate green time for pedestrian volume (calculated from HCM formula) and pedestrians can cross through right turn by yield sign.
- **Signalized Intersection (S2):** in this case pedestrian crossing was through red time of vehicle movements at each signal phase.

Table 5: Scenarios definition

Base case	Scenario S1	Scenario S2
		
Random pedestrian crossing at UMUT (base case)	Pedestrian signal at UMUT	Signalized intersection

6.1 Result of Scenarios

Separating pedestrians and vehicles into two separated phase at UMUT should eliminate conflicts between pedestrians and vehicles, thereby pedestrian safety will be increased.

Dividing pedestrian volumes into three categories: Low < 400 ped. /hour, Medium >400 and <1200 ped. /hour, and High pedestrian volume >1200 ped. /hour. From Figure 6 it can be concluded that, at low pedestrian volumes there is no significant difference in delay per vehicle. While in medium pedestrian volumes there is a significant difference between the three scenarios, where S2 (Pedestrian signal) there the minimum delay compared to the other scenarios followed by base case (Random crossing at UMUT). Also, in high pedestrian volume there is a significant difference between these scenarios, where VISSM simulated for S1 (Pedestrian signal) confirmed decrease in average vehicle delay by 19.92 % compared to with base case (Random crossing at UMUT) and 75 % compared to S2 (Signalized intersection). Similarly, from Figure 7 it can be concluded that, the capacity of the intersection decrease with the increase of pedestrian volumes and S1 is the best one to increase the intersection capacity at the three pedestrian levels. Where, at high pedestrian volumes the capacity was 933 veh/hr. compared with 869 veh/hr for S2 and compared with 573 veh/hr with base case.

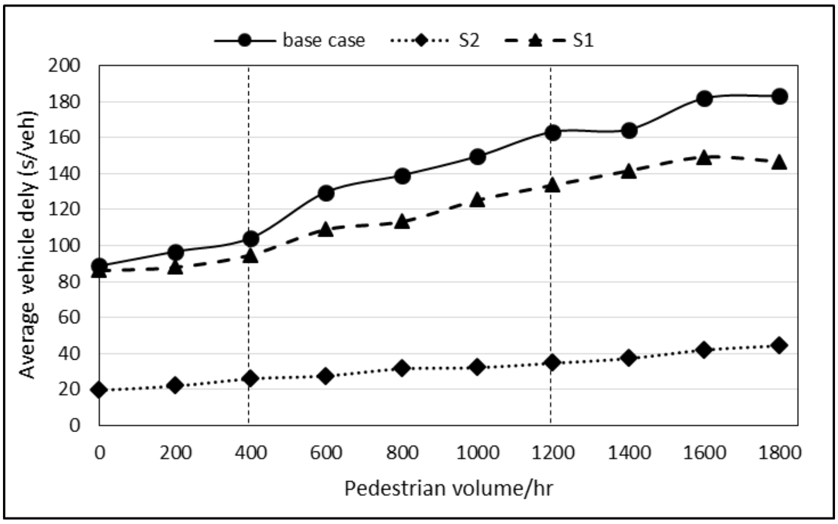


Figure 6 Relation between average vehicle delay & pedestrian volume

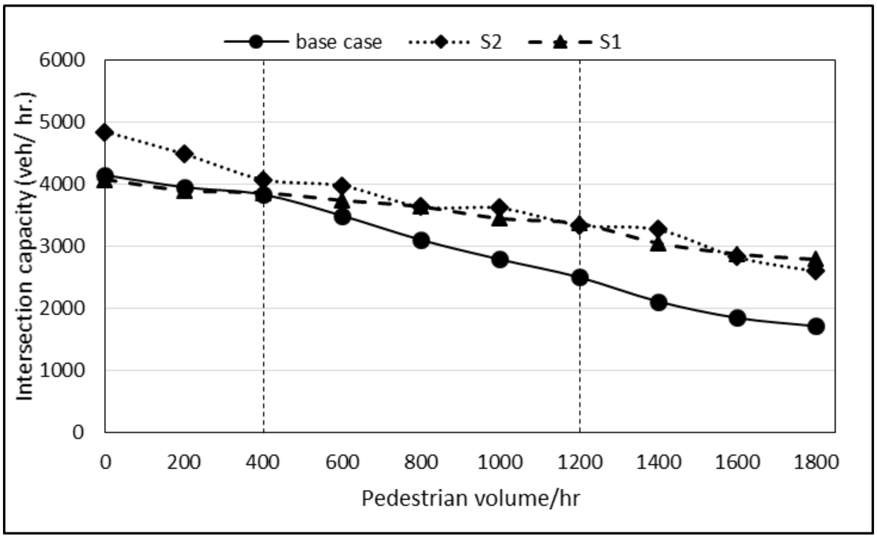


Figure 7 Relation between capacity & pedestrian volume

7 Conclusion and Discussion

The UMUT design has been put in operation in Cairo, Egypt for several years. This research simulated the operational performance of the UMUT intersection under a wide range of pedestrian volume scenarios by using PTV VISSIM 9.00-06 micro-simulation program. Data collection was conducted at Abass Al-Akad-Autostrad intersection in Cairo, Egypt for calibration and validation purposes. Prior to calibration and validation procedures, the code error checking was conducted to eliminate any coding error.

Calibration of Model has been conducted by using the GEH Statistic for traffic volumes.

The results indicate that the model acceptable fit where GEH was 4.32. While to validate the model the Root Mean Squared Normalized Error (RMSNE) has been chosen. The results indicate that the model satisfies the criteria for validation with $RMSNE$ was 0.089 for measured and simulation speed. Two different scenarios were developed for the model in addition to the base case (Random crossing at UMUT) after calibration and validation. The comparison criteria were the average vehicle delay and intersection level of service. In general, the UMUT design was shown to be used only at very low demand levels and was unable to accommodate high approach volumes and heavy left-turn traffic. Under high pedestrian volumes, it was shown that random pedestrian crossing at UMUT leads to huge delays, lower capacity, and major reduction in flow rate/hour due to enforcing drivers to yield to pedestrians. Intersection delays are significantly increased with increased pedestrian volumes. Based on the results of this analysis, it can be concluded that, there is no noticeable impact on the intersection delays with low pedestrian volume. Similarly with the capacity there is no problem from using UMUT. Under moderate pedestrian volumes it is preferred using pedestrian signal at UMUT to reduce delay and potential of accidents for pedestrians. At high pedestrian volumes, UMUT intersection delays will decrease about 75 % when converting control type to signalized intersection and 19.92 % when converting random pedestrian crossing to signalized pedestrian crossing. It is better to install barriers between carriageways and sidewalks to enforce pedestrian to cross at certain locations and provide pedestrians more facilities to eliminate crashes, saving time, fuel consumption and environmental bad impacts such as noise and air pollution. A future extension of the current research will include investigating the impact of the others pedestrians crossing scenarios as well as weaving length between the cross street and the U-turn crossovers, which is one of the main factors impacting the performance, that should be investigated. RTUT has been proposed as an access management strategy that improves the traffic operation at driveways intersecting with major arterials. In case of retaining this system, it is preferable to convert it from UMUT to MUT using traffic signal for through movement as well as the treatment of Pedestrian crossing.

List of Abbreviations

UMUT	-Unconventional Median U-turn
GEH	-Geoffrey E. Havers
RMSNE	-Root Mean Squared Normalized Error
USD	- United States Dollar
GCMA	-Greater Cairo Metropolitan Area
MUT	- Median U-turn
TSIS-CORSIM	-Traffic SImulation Software- CORridor SIMulation
RTUT	-Right Turn plus U-Turn
DLT	-Direct Left-Turn
CFI	-Continuous Flow Intersection
XDL	-Crossover Displaced Left-turn
FDOT	- Florida Department of Transportation
USC	-Upstream Signalized Crossover
GPS	- Global Positioning System
Paramics	-PARAllel MICroscopic Simulation
UTIDP	-Urban Transport Infrastructure Development Project
LRT	-Light Rail Transit
HCM	-Highway Capacity Manual

REFERENCES

A.K.Soliman. “Evaluation of weaving sections in urban areas a microsimulation- based approach.”
Master thesis, faculty of engineering, Fayoum, Egypt.2016

A.Kamran. “Evaluation of Low Cost Technique “Indirect Right Turn” to Reduce Congestion at Urbanized Signalized Intersection in Developing Countries”. 2011

Bared, J.G., and Kaisar, E.I. “Median U-turn design as an alternative treatment for left turns at signalized intersections.” ITE Journal, 2002. 72(2): 50–54.

Esawey and Sayed. “Unconventional USC intersection corridors: evaluation of potential implementation in Doha, Qatar” JOURNAL OF ADVANCED TRANSPORTATION J. Adv. Transp. 2010; 45:38–53.

Esawey and Sayed. “Operational performance analysis of the unconventional median U-turn intersection design”Published by NRC Research Press Can. J. Civ. Eng. Vol. 38, 2011.

Florida Department of Transportation “**T**raffic Analysis Handbook.”2014 (FDOT).

Hamid Athab Eedan Al-Jameel. “modelling the operational effects of unconventional U-turns at a highway intersection Kufa” Journal of Engineering (K.J.E) ISSN 2207-5528 printed in Iraq. Vol. 6, Issue 1, December, 2014.

J.D. Reid and Hummer, J.E. “Unconventional Left-Turn Alternatives for Urban and Suburban Arterials” An Update. In Transportation Research Circular E-C019: Urban Street Symposium Conference Proceedings, Dallas, and TX.2001

Jagannathan, R. “Synthesis of the median U-turn intersection treatment, safety, and operational benefits.” Presented at the 3rd Urban Street Symposium, Seattle, Washington.2007

Rodegerdts, L., Nevers, B., and Robinson, B.“Signalized intersections: informational guide. Publication FHWA-HRT-04- 091. FHWA, US Department of Transportation.2004

Sayed, T., P.Storer, and G. Wong. “Upstream Signalized Crossover Intersection: Optimization and Performance Issues.” In Transportation Research Record: Journal of the Transportation Research Board, No. 1961, Washington, D.C., 2006, pp. 44–54.

Shahi, J., and Choupani, A. “Modelling the operational effects of unconventional U-turns at a highway intersection.” Transportmetrica, 2009 5(3): 173–191.

World Bank. “TRAFFIC CONGESTION IN CAIRO “research Public Disclosure Authorized 2012 no. 71852.

Washington State Department of Transportation “**P**ROTOCOL FOR VISSIM SIMULATION”. September 2014. (WSDOT)

Zhou, H., Lu, J.J., Yang, X.K., Dissanayake, S., and Williams, K.M. “Operational effects of u-turns as alternatives to direct left turns from driveways.” In Transportation Research Record: Journal of the Transportation Research Board, No. 1796, Transportation Research Board of the National Academics, Washington, 2002 D.C., pp. 72–79.