Using Virtual Reality Simulation for Optimizing Traffic Modes Toward Service Level Enhancements.

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Abstract –

Traffic congestion and roads service level are major issue in many countries. Using technology such as simulation offers effective approach to better understanding the problem, and predict optimal solutions. This paper examines the application of Virtual reality (VR) for evaluating the roads service level of five different scenarios in UAE as new method to evaluate and enhance road service levels, as well as understanding the potential risks and costs for applying those scenarios into reality. The study will test the usefulness of VR simulation to enhance traffic service level, second creation of traffic objects to explore potential usage, third understand the interaction between users and digital objects. All hypothesis have significant impacts toward enhancing service level, and the overall findings are consistent and clear. The level of technological orientation was examined to the overall implementation. The results help understanding key issues and potential service level in development of future VR applications in roads construction.

Keywords –

Virtual realities; automation in Construction; roads service level; traffic objects enhancements.;

1 Introduction

Ministry of Infrastructure of Development in United Arab Emirates always strive to utilize the latest technology to enhance its service related to roads and infrastructure. Many scholars reviewed the use of technology to enhance construction modes and experience, construction has seen a significant increase in its productivity since using automation to analyze best practices [1]. The application of virtual reality in construction was described by Sampaio and Matins [2] to provide better understanding of how roads construction are being belt such as bridges with considering related to safety and level of service. Other scholars used virtual reality to study deeper usage of VR in maintaining complexed buildings, Grabowski and Jankowski [3] used this technology to study VR input methods using different HMD hardware setups. Roupé et al. [4] also studied the level of enhancement using VR and body movement, and stated that one of the main implications of VR body tracker is the cost of equipment’s and needs a specialized team to be able to utilize this technology, Roupé et al. proved that VR body postures is able to navigate through out city modeling. This paper will study the reflect of changes in optimizing traffic modes toward level of service based on the UAE government needs and reviews. Using Virtual Reality screening methods the system will predict the level of enactments and analyze the results of the interchange with the models update.

2 Literature Review

The Virtual Reality have been used rapidly for many industries recently, and the need of to apply this technology in the construction industry became a need from both government and private sector, and the positive impact of this technology has been demonstrated in many studies [5]. Goedert et al. [6] discussed the impact of VR simulation into construction education and to provide better understanding for different scenarios of building methodologies. The main feature of VR environment is to provide immediate real time results for its applications, especially in interactive activities [7]. VR also proven that it will be great addition for other technologies to enhance understanding and performance of construction sites in addition to analyzing the development of Building Information Modelling (BIM)[8-10]. Following the mixed realities technologies which combines both VR and AR, Russell el al.[11] demonstrated the usage of mixed realities technologies to train and improve understanding of 3D modelling techniques which can replace the traditional methods using computer – aided design (CAD). Hence, the Mixed realty technology became very acceptable by users and supports interactive visualization [12]. However, the studies related to VR actual application and its application in construction is very limited [13]. And many scholars found immersive technologies using head mounted display (HMD) can be cause errors and unpredictable results for many systematic applications [14]. Yet there are enormous need for studies to prove or to propose a successful usage technologies and to investigate or develop new methods of VR in training and analyzing results [15]. Most of construction drawings use 2D modeling, although using 2D modeling can assist specialists to determine necessary information in construction sites, it cannot interact with real time environment and more important it cannot provide enough information to build the required data. Jang [16] declared that using experimental methods using immersive technologies can enhance practical abilities to better understanding results. Additionally, virtual reality influenced by the way people do their work and provide new opportunities to better understand surrounding environment [17]. Arian and Burkle [18] virtual reality improves the understanding of real time issues in construction sites, and the successful collaboration of virtual reality with real construction sites will improve safety education through experiential learning.

3 Methodology

The analysis methodology that will be followed in evaluating the various roadway elements surveyed; interchanges, junctions, roundabouts and links. The basis of the analysis will be highway Capacity Manual (HCM) using VR scenario modeling. The Highway Capacity Manual (HCM) methodology specifies six levels of service to represent the operational characteristics of a given transportation facility. Roadway Level of service (LOS) describes the operating condition determined from the number of vehicles passing over a given segment of the roadway during a specified period of time. It is a qualitative measure of several factors which include: speed, travel time, traffic interruptions, freedom to maneuver, driver comfort, convenience, safety and vehicle operating costs. The study is based on Al Ittihad road in Sharjah – Sharjah bound.

The six levels of service which have been established as standards by which to gauge roadway performance are designated by the letters A through F and are defined as follows:

- LOS “A” – Free flow, individual users virtually unaffected by the presence of others;
- LOS “B” – Stable flow with a high degree of freedom to select operating conditions;
- LOS “C” – Flow remains stable, but with significant interactions with others;
- LOS “D” – Approaching unstable flow, freedom to maneuver is severely restricted;
- LOS “E” – Unstable flow, with volumes approaching capacity of the roadway; and
- LOS “F” – Forced flow in which the traffic exceeds the amount that can be serviced.

A Passenger Car Equivalent is essentially the impact that a mode of transport has on traffic variables (such as headway, speed, density) compared to a single car. The factors adopted in this analysis are as below:

Table 1. PCE factors

NO	Mode	PCE Factor
1	LGV	1.0
2	HGV	2.5

Signalized intersection LOS describes the operation of the intersection based on average delay per vehicle. To estimate the average vehicle delay for each intersection, average control delay per vehicle is calculated for each lane group and aggregated for each approach and for the intersection as a whole. The six levels of service are designated by the letters A through F. and are defined as follows:

- LOS “A” – Average vehicle delay 10 seconds or less;
- LOS “B” – Average vehicle delay between 11-20 seconds;
- LOS “C” – Average vehicle delay between 21-35 seconds;
- LOS “D” – Average vehicle delay between 36-55 seconds;
- LOS “E” – Average vehicle delay between 56-80 seconds; and
- LOS “F” – Average vehicle delay exceeds 80 seconds.

Unsignalized intersection LOS describes the operation of the individual movement. It is determined by the computed or measured control delay and is defined for each minor movement. LOS is not defined for the intersection as a whole. According to the HCM, six levels of service have been established, designated by the letters A through F. These levels of service levels are defined as follows:

- LOS “A” – Average vehicle delay 10 seconds or less;

- LOS "B" – Average vehicle delay between 11-15 seconds;
- LOS "C" – Average vehicle delay between 16-25 seconds;
- LOS "D" – Average vehicle delay between 26-35 seconds;
- LOS "E" – Average vehicle delay between 36-50 seconds; and
- LOS "F" – Average vehicle delay exceeds 50 seconds

This study proposes a comparison between the application of different models to study the level of enhancements to the same road for each prospective using HCM VR modelling.

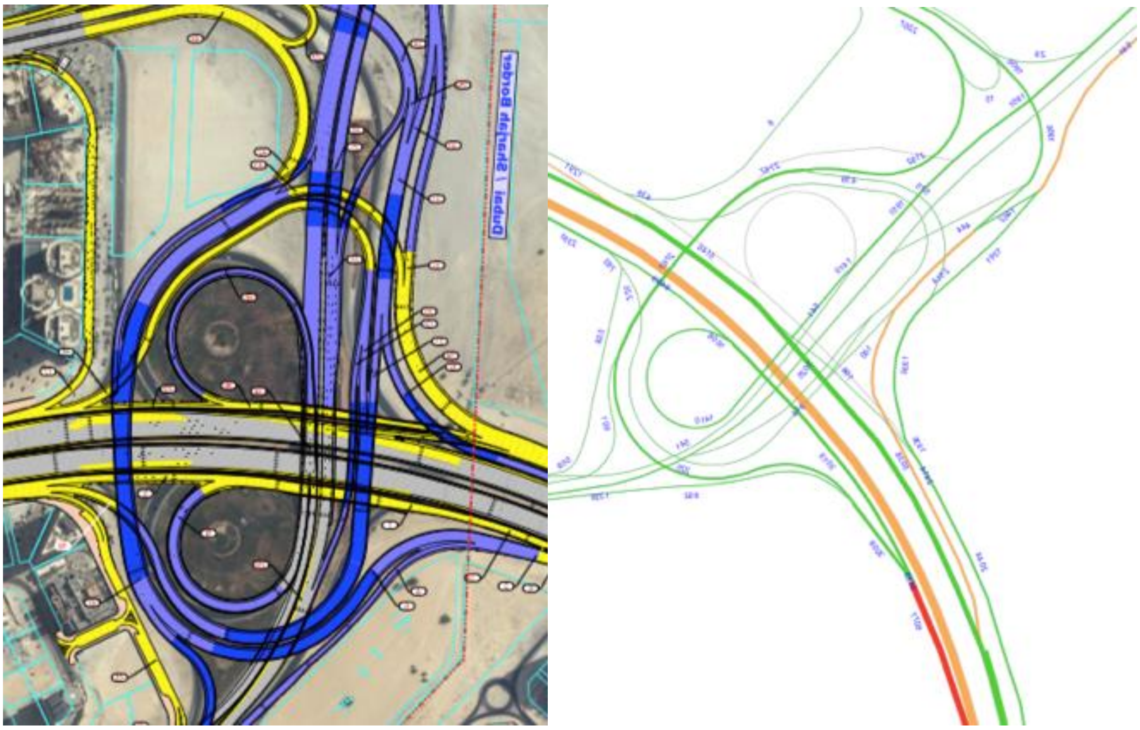

Figure 1. Screenshot for the system comparing between the Al Nahda intersection before and after utilizing VR technology

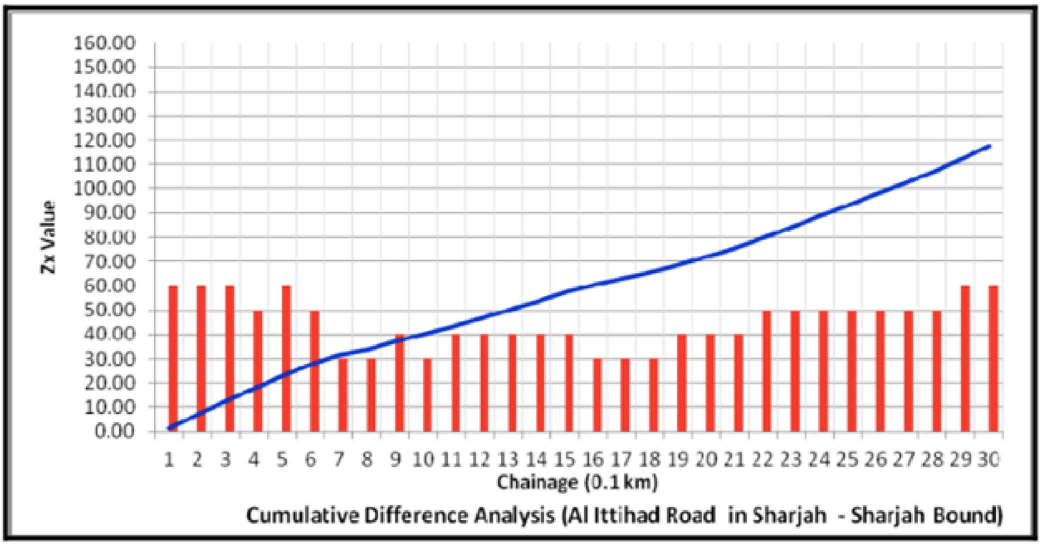

Figure 2. Cumulative difference analysis

The traffic count survey results and the analysis thereof for roadway elements surveyed. The methodology followed in the analysis is also mentioned along with the Level of Service (LOS) criteria.

4 Data analysis and discussion

Traffic count locations were discussed with the Ministry in the project early start as tabulated in the Table 2 - 3 below. The classification followed in the survey was Light Vehicles and Heavy Vehicles. Data were collected in 2018, junctions name were listed as per ministry of infrastructure development classifications.

Table 2. Existing traffic count

Junction No.	Junction type
J-1	Signalized
R/A-1	Roundabout
R/A-2	Roundabout
R/A-3	Roundabout
R/A-4	Roundabout
R/A-5	Roundabout
R/A-6	Roundabout
RIRO-1	Right In/ Right Out
RIRO-2	Right In/ Right Out
RIRO-3	Right In/ Right Out
RIRO-4	Right In/ Right Out
RIRO-5	Right In/ Right Out
I/C-1	Interchange

Table 3. Existing traffic count

Roundabout	AM		PM	
	LOS	Delay	LOS	Delay
R/A-1	E	42.8	F	70.8
R/A-2	F	236.3	F	248.2
R/A-3	C	19.6	D	31.2
R/A-4	F*	N/A	F*	N/A
R/A-5	F*	N/A	F*	N/A
R/A-6	F	296.3	F	166.5

Note: (*) Roundabout is failing due to upstream blockage

Data on vehicle classification were collected during the traffic count survey. Vehicles were classified into heavy vehicles and light vehicles. The percentages of LV and HV were calculated for two locations along Al Ittihad Road (Junction 1 and Roundabout 1), during the AM and PM peak periods. An overall summary of this vehicle classification is shown in tables (4) below.

Table 4. LV – HV percentage from traffic survey

Intersection	AM		PM	
	LV	HV	LV	HV
J-1	93.4%	6.6%	95.0%	5.0%
R/A-1	97.6%	2.4%	96.2%	3.8%
R/A-2	97.9%	2.1%	97.5%	2.5%
R/A-3	94.5%	5.5%	97.0%	3.0%
R/A-4	93.0%	7.0%	95.0%	5.0%
R/A-5	95.5%	4.5%	95.5%	4.5%
R/A-6	94.8%	5.2%	97.5%	2.5%
RIRO-1	93.8%	6.20%	95.6%	4.40%
RIRO-2	94.1%	5.90%	97.9%	2.10%
RIRO-3	92.0%	8.0%	97.2%	2.80%
RIRO-4	93.3%	6.70%	96.9%	3.10%
RIRO-5	97.7%	2.30%	95.2%	4.80%
I/C-1	95.60%	4.40%	97.10%	2.90%
I/C-2	92.0%	8.0%	93.0%	7.0%
I/C-3	95.0%	5.0%	94.7%	5.3%
L1	94.6%	5.4	97.4%	2.6%

In the experiments the above data were inserted into the VR prediction software and attributes were specified to study the level of enhancements and the influence of the proposed junctions' layouts in order to obtain future LOS based on average delay values according to the HCM methodology.

The proposed design includes upgrade of number of lanes, upgrade roundabouts to four legged and 3 legged signalized intersections, demolish flyover and replace it with four legged signalized intersection and underground tunnel, upgrade signalized intersections to flyover bridges and underground tunnels, and adding directional ramps to interchanges and eliminating key waving segments. The volumes obtained from the traffic model were used for the analysis. Table 5 tabulates the analysis results based on the recommended option and Figure 1 present the analysis summary. Based on the constructability and phasing of the project improvements two possible scenarios have been considered.

- Ultimate Scenario
- Reduced Configuration

Accordingly, for the reduced configuration scenario all tunnels in Junctions 1, 3 and 5 were removed and the traffic analysis for this option was carried out. Table 5-3 shows the analysis summary results of the reduced configuration scenario.

Table 5. LOS analysis for ultimate design scenarios

Junction #	Type of Junction	AM		PM	
		LOS	Delay	LOS	Delay
Junction 1	Signal + Tunnel	A	10	C	30.9
Junction 2	Signal	A	9.5	C	23.4
Junction 3	Signal + Tunnel	B	17.3	C	20.4
Junction 4	Signal	A	4.4	A	4.3
Junction 5	Signal + Tunnel + Bridge	C	20.9	C	25.7
Junction 6	Single point diamond Interchange	A	9.9	B	16.8
IC-1	Interchange	C	-	C	-
IC-2	Interchange	D	-	D	-
IC-3	Interchange	D	-	D	-

Table 6. LOS analysis for reduced configuration scenarios

Junction #	Type of Junction	AM		PM	
		LOS	Delay	LOS	Delay
Junction 1	Signal + Tunnel	C	23.3	F	87
Junction 2	Signal	B	14	C	30.8
Junction 3	Signal + Tunnel	B	13.4	D	40.6
Junction 4	Signal	B	13.7	A	8.4
Junction 5	Signal + Tunnel + Bridge	C	24.3	E	62.2
Junction 6	Single point diamond Interchange	B	16.4	C	21.9

It can be inferred from Table 6 that Junction 3 operates at an acceptable level of service with the reduced configuration. However, the removal of the tunnels in junctions 1 and 5 depict that the junctions do not operate at an acceptable level of service. Accordingly, the grade separations at junctions 1 and 5 are warranted.

Since Junction 3 was working at an acceptable LOS in previous experiment with the removal of the underground tunnel unlike Junctions 1 and 5, the reduced scenario comprised of the removal of the Junction 3 tunnel. Table 7 tabulates the analysis results based on the ultimate option.

Table 7. LOS analysis for ultimate design scenarios update

Junction #	Type of Junction	AM		PM	
		LOS	Delay	LOS	Delay
Junction 1	Signal + Tunnel	B	10.8	C	33.4
Junction 2	Signal	A	9.9	C	20.4
Junction 3	Signal + Tunnel	B	18.3	C	21.7
Junction 4	Signal	A	4.4	A	4.1
Junction 5	Signal + Tunnel + Bridge	C	23.5	D	42
Junction 6	Single point diamond	B	10.6	B	18.8
IC-1	Interchange	C	-	C	-
IC-3	Interchange	D	-	D	-

Table 8. LOS analysis for reduced configuration scenarios update

Junction #	Type of Junction	AM		PM	
		LOS	Delay	LOS	Delay
Junction 1	Signal + Tunnel	B	13.6	D	42.9
Junction 2	Signal	B	11.1	D	35.3
Junction 3	Signal	C	32.2	D	51.7
Junction 4	Signal	A	9.1	A	5.3
Junction 5	Signal + Tunnel + Bridge	C	26.4	D	37.7
Junction 6	Single point diamond	B	12.7	C	22.5

The analysis summary for the Ultimate Year update was carried out using the volumes obtained from the traffic model based on the proposed design is tabulated as Table 7 and 8

5 Conclusion

Many countries suffer because of traffic congestion problem. To handle it, many strategies have been followed to understand the potential risks and costs of this problem. Therefore, in this project; VR simulation has been used to evaluate the roads level of five different scenarios to obtain insights into alternate roads services to optimize roads service levels. Five different scenarios were proposed. Upgrade of number of lanes, upgrade roundabouts to four legged and 3 legged signalized intersections, demolish flyover and replace it with four legged signalized intersection and underground tunnel, upgrade signalized intersections to flyover bridges and underground tunnels, and adding directional ramps to interchanges and eliminating key waving segments.

As a result of the analysis using VR technology, two possible scenarios have been considered.

- Ultimate Scenario
- Reduced Configuration

The approach adopted in simulation is to understand and analyse service level and plan a better design in the targeted junctions. The resulting outputs can be visualized based on the attributes added into the simulations. The feedback obtained will have significant improve among the accessibility of roads optimizing.

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References

[1] E. Rojas, P. Aramvareekul, Is construction labor productivity really declining? J. Constr. Eng. Manag. 129 (1) (2003) 41–46.

[2] Sampaio, A. Z., & Martins, O. P. (2014). The application of virtual reality technology in the construction of bridge: The cantilever and incremental launching methods. Automation in Construction, 37, 58–67.

[3] Grabowski, A., & Jankowski, J. (2015). Virtual Reality-based pilot training for underground coal miners. Safety Science, 72, 310–314.

[4] Roupé, M., Bosch-Sijtsema, P., & Johansson, M. (2014). Interactive navigation interface for virtual reality using the human body. Computers, Environment and Urban Systems, 43, 42–50.

[5] Woksepp, S.; Olofsson, T. Credibility and applicability of virtual reality models in design and construction. Adv. Eng. Inform. 2008, 22, 520–528.

[6] Goedert, J.D.; Rokooei, S. Project-based construction education with simulations in a gaming environment. Int. J. Constr. Educ. Res. 2016, 12, 208–223.

[7] Park, C.S.; Le, Q.T.; Pedro, A.; Lim, C.R. Interactive building anatomy modeling for experiential building construction education. J. Prof. Issues Eng. Educ. Pract. 2015, 142, 04015019.

[8] Wang, X.; Truijens, M.; Hou, L.; Wang, Y.; Zhou, Y. Integrating Augmented Reality with Building Information Modeling: Onsite construction process controlling for liquefied natural gas industry. Autom. Constr. 2014, 40, 96–105.

[9] Li, X.; Wu, P.; Shen, G.Q.; Wang, X.; Teng, Y. Mapping the knowledge domains of Building

Information Modeling (BIM): A bibliometric approach. Autom. Constr. 2017, 84, 195–206.

[10] Russell, D.; Cho, Y.K.; Cylwik, E. Learning opportunities and career implications of experience with BIM/VDC. Pract. Period. Struct. Des. Constr. 2013, 19, 111–121.

[11] Russell, D.; Cho, Y.K.; Cylwik, E. Learning opportunities and career implications of experience with BIM/VDC. Pract. Period. Struct. Des. Constr. 2013, 19, 111–121.

[12] Wang, J.; Wang, X.; Shou, W.; Xu, B. Integrating BIM and augmented reality for interactive architectural visualisation. Constr. Innov. 2014, 14, 453–476

[13] Guo, H.; Li, H.; Chan, G.; Skitmore, M. Using game technologies to improve the safety of construction plant operations. Accid. Anal. Prev. 2012, 48, 204–213

[14] Kerawalla, L.; Luckin, R.; Seljeflot, S.; Woolard, A. “Making it real”: Exploring the potential of augmented reality for teaching primary school science. Virtual Real. 2006, 10,163–174

[15] Wu, H.-K.; Lee, S.W.-Y.; Chang, H.-Y.; Liang, J.-C. Current status, opportunities and challenges of augmented reality in education. 2013, 62, 41–49.

[16] Jang, S.J.: The effects of integrating technology, observation and writing into a teacher education method course. 50(3), 853–865 (2008).

[17] Cheong, D.: The effects of practice teaching sessions in second life on the change in pre-service teachers’ teaching efficacy. 55(2), 868–880 (2010)

[18] Arain, F.M., Burkle, M.: Learning construction project management in the virtual world: Leveraging on Second Life. J. Inf. Technol. Constr. (Special Issue: Use of gaming technology in architecture, engineering and construction) 16, 234–257 (2011)