

Performance Evaluation Of Diverging Diamond Interchange For Heterogeneous Traffic Condition

Mujammel.Z.Shaikh, Sujesh.D.Ghodmare, Akshay Gulghane

Abstract: Purpose: Diverging Diamond interchange is competent to handle huge traffic in a smooth and efficient manner which makes it a popular choice in many developed countries. It is the best option to improve junction safety and performance, Reduces conflict point, vehicle Delay, number of stops, fuel consumption, and emission of pollutants. This paper aims/ to study the change in traffic and environmental parameter after proposing Diverging Diamond interchange at Mahalunge Junction and Baner junction in Pune city. These two junctions are closely spaced having tremendous traffic from all directions due to which level of service (LOS) of existing Intersections falls to the worst range and there is an increase in fuel consumption and emission. Method: PTV Vissim is used to analyze the Existing condition of intersection and Proposed Diverging Diamond Interchange modeling is carried out in Vissim. Result: The change in scenario is studied and it is identified that there is a drastic change in the traffic and Environmental parameter after proposing Diverging Diamond interchange, a further result obtained are summarized for the purpose of recommendation. Conclusion: research clarifies that implementation of Diverging Diamond interchange reduces traffic Q-length, delay, number of stops up to ninety percent, and curtail fuel consumption up to fourteen percent ultimately reduction in emission of pollutants.

Index Terms: Diverging Diamond Interchange (DDI), Modal simulation on Vissim, sustainable transportation system, Traffic analysis, Urban planning.

1. INTRODUCTION

Interchange is widely used due to their enormous Advantage, Selection of interchange depend on the capacity and performance required at a particular intersection. Every interchange has there a limitation that's the reason it is transforming from conventional diamond interchange to Super Diverging Diamond interchange and definitely, this will go on. In an urban area when traffic capacity increases rapidly at an intersection due to which more Saturation at junction occurs which ultimately increases delay, fuel consumption, and Emission. This problem is categorized as related to Traffic and Environmental. The major traffic problem such as the number of Stops, Delay, Queuing Length, and Problem Associated with Environmental is the Emission of CO, NOX, VOC, and Fuel Consumption. It is stated that Fuel consumption of the vehicle and emissions at the city transfer is a growing concern in both traffic and the environment [11]. Proper Traffic organization is greatly helpful to decrease fuel consumption [16]. The innovative way is to introduce interchange to tackle this problem considering Future Traffic Demand. Diverging Diamond Interchange can be described as it is a type of interchange having on ramp and off ramp and there is a free left-turning movement and widely use where there is a high volume of left-turning traffic. Diamond interchange is an important means of controlling the demand for transportation in urban areas DDI consist of Freeway segment, Speed change lane, Ramp Terminals, Ramp segment. Different author and researcher have defined as Diverging Diamond Interchange is a typical type of interchange used when the freeway is crossing the arterial road but limit left-turning movement. A comparison between these different types of interchange has been studied by various research [8] [7] [2]. It has been concluded that compare with a different type of interchange Diverging Diamond interchange is a well-recognized type of Interchange in Developed Counties. Performance evaluation between two

different type interchange like Double Cross Interchange and DDI using Vissim has Simulation tool is carried out and it is stated that DDI reduces 50% of Delay in high Volume traffic [8]. Which Handle Heavy left-turning traffic, Reduce Conflict Point, More Safety. Some researcher has derived a planning model for the primary stage of planning which is based on critical lane volume [1]. Introduction of DDI reduce the number of traffic conflict and provide safety [16][19]. Mostly it is also used to transfer Diamond Interchange to Diverging Diamond interchange, This Conversion is beneficial considering Financial Aspect Comparison. DDI aims to optimize the left-hand movement and increase the green phase movement [8]. In this paper, an attempt was made to study the change in traffic scenario by using a simulation tool and comparison between states of the result after implementation. The Year-wise growth of traffic is considered having a Five-year interval for Thirty-Year simultaneous simulation is carried out with Implementation of DDI and without Implementation of DDI, results are summarized Considering Traffic and Environmental Parameter.

• Objective

- i. To improve the road Condition by Proposing Diverging Diamond Interchange
- ii. To study unexpected changes in Traffic conditions, Emission, and Fuel Consumption after Implementation of Diverging Diamond Interchange.

2.1 Research Background

Research Background is assembled in such a fashion that gives readers a brief idea about the work carried out related to the Implementation of DDI in the field of Transportation engineering .which is mainly summaries as follows. Comparison between Different Types of Interchange: From Recent Decades interchange has derived wide attention. Due to their innovative design and operation. The selection of a particular type of Interchange is base on Geometry Design, Signal Control, and Safety consideration. Comparison of Geometric Characteristics of Diamond Interchange with One intersection, two intersections between China and America is studied considering Spacing between adjacent intersections, Ramp width, Width of approaching Lane [7]. Considering the Safety point of view Different Model and Regression equation are use To predict Crash Frequency example Poisson

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distribution, Binomial Distribution, safety Performance model (SPF), Crash Prediction Model, Wilcoxon Signed rank, Naïve, Empirical Bayes by the different researcher [3][7][8]. Crashes are predominant on Conflict Point when there is a comparison between Crash of Single Point and Tight Diamond interchange there is no Major Different (Joe Bared et al 2016). Another research is carried out which Concludes that Diamond Interchange with one intersection has less Conflict Point compare with two intersections [7]. Diverging Diamond Interchange is Best Implementation Has per Crash are Concern Studies stated that DDI is found to be safer than Conventional Diamond Interchange (Boris Claros et al 2014). DDI design can efficiently reduce the number of conflict points and enhance safety and Cost-effectiveness. DDI has to Clarify traffic in two-phase signal loss time is used has green time. Models for Optimization and synchronizing of Signal offset with Crossover spacing is derived It is Conclude that an Extensive increase in crossover spacing is not beneficial [16],[17].

Performance Evaluation:

Different Authors have considered different Parameter for Evaluation Example delay, Stop time, Number of stops, Avg Queue, Max Queue, and Capacity [9][1][8]. The comparison between Different Interchange is put forward. It has been commented that Double Cross Interchange Compare to Conventional Intersection performs well. Also, Diverging Diamond interchange Compare with Crossover Diamond Interchange and there is a huge improvement in traffic Parameter [8]. Many Researcher has proposed a Model has Planning Tool which Introduces Critical Lane Volume and Lane Utility Factor to Calculate intersection LOS which is used in the primary Planning Stage [1]. A similar kind of research is carried out using a Surrogate Safety assessment model for Vehicle and Pedestrian Safety [2]. Microscopic simulation is carried to Analyze Operation Performance of DDI this investigation comment that the design of DDI can improve the efficiency of the interchange [9]. Comparing with different types of Interchange, Diverging Diamond interchange is Extensively Good Performer. DDI can reduce about sixty percent of Delay and stops [16]. DDI is Easy to construct and Cost-saving when there is a Limitation of land. DDI occupies less Right of way has compared to CDI [8].

Environmental Impact Assessment:

An increase in delay time at the Intersection increase emission of pollutants and Fuel consumption, Where Adequate spacing and Suitable Selection of Interchange on the corridor will have a negative impact on Pollutant Emission. The study state that the simple implementation of roundabout yield emission by 16 to 17 % and delay and queue length by 44to 64 % compared to a signalized intersection [11][20][21].

Model Simulation Tool:

Vissim is one of the most used Simulation Tool used by many researchers. For Evaluation of change in Traffic scenario, Optimise Cycle Length, Calibration of Model Results, Crash Comparison. In some Case studies, Synchro is also used as a Simulation tool for Comparison between two different types of intersection [5]. Synchro is mostly used for Signal Optimization. For Analysis of different Scenarios, Vissim is an effective Simulation Tool [8]. To Study, Delay, Stoppage, and Cycle length Different software Tools such as Corsim, Sim traffic, Synchro have been used and it is declared that results

obtained from Simtraffic are more precise [3]. In Summary, the above research Background gives an Idea about research carried out on Diverging Diamond Interchange. It has been noticed that performance evaluation on DDI base on environmental Constraints is not seen in any of the research papers' major investigation focus on Traffic Constraints.

2.2 Study Area

Pune is the seventh-most populous city in India and the second largest in the state of Maharashtra. It is situated 560 meters (1,837 feet) above sea level on the Deccan Plateau, on the right bank of the Mutha River. Pune is considered as the cultural capital of Maharashtra and is also popularly known as the 'Queen of the Deccan. Mhalunge- Nande Junction and Baner Road Junction are selected for the Study area. This Two intersection are four Legged Signalized Intersections and National Highway 48 is passing has Grade separated as shown in fig 1. Intersection as Latitude of 18°33'47" N and longitude 73°46'37" E, at the elevation of 1866 feet. Two intersections are 203 meters apart from each other. This Intersection is surrounded by corporate companies, IT Park, Hotels, and Society.



Figure.1. Site Location

2.3 Methodology

Data Collection:

Traffic survey is carried out by videography method, Peak Hour Traffic and Composition of a vehicle is extracted from a preliminary traffic survey. Med Block Section is taken near Intersection and inflow and outflow traffic is calculated shown in Table 1 below to be noted traffic account is taken at Peak Hour. In Illustrated Table the empty block indicates one-way traffic. The Traffic is converted in PCU according to guidelines provided by IRC 68-1998.

Table 1 Direction Traffic Flow

Junction	Direction	Traffic Flow From Med Block Section				Traffic Flow Toward Med Block Section			
		TT	LT	RT	Total	TT	LT	RT	Total
A	Mahunge Baner Road	2424	595	-	3019	2621	148	-	2769
	Pasahan Highway Side Road	402	148	281	831	-	-	-	0
	Baner Road	2621	-	733	3354	2821	-	281	3102
	Shivaji Maharaj Chowk	-	-	-	0	402	595	733	1730
	Total				7204				7601
B	Baner Road	2268	241	310	2819	1520	-	210	1730
	Baner Highway Side	478	754	120	1352	-	241	584	1066
	Balewadi Road	1520	445	584	2549	2268	754	-	3022
	Pasahan Highway Side Road	-	-	-	0	478	445	310	1233
	Total				6720				7051

Note: Junction 'A' is Named has Mahahunge chowk and Junction 'B' is Named has Baner Chowk (TT: Through Traffic, LT: Left turning Traffic, RT: Right Turning Traffic).

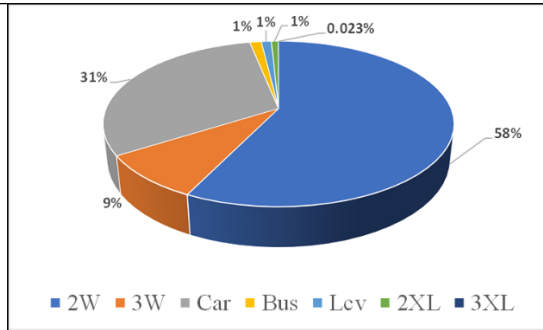


Figure 1.2 Model Split (Morning PHF)

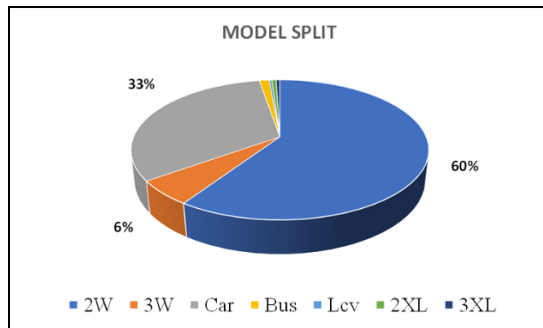


Figure 1.3 Model Split (Evening PHF)

Analysis of Intersection:

Intersection analysis includes finding of Level of Service (LOS), Model Split, Direction wise traffic Distribution. It has been observed that Model split in peak hour is 30% of Car, 9% 3Wheeler Commuters, 55% 2wheelers Commuters, (2%) Light Commercial vehicle and (4%) of Bus It is reported that Maximum Occupancy on road is of a private vehicle ref fig 1.2 and fig 1.3. Currently, the existing Level of Service of Roads is fallen to E, and considering Future growth of Traffic it will reach the worst Range.

Modeling in Vissim:

Vissim is one of the approved simulation tools, it is developed by PTV which is based on the car-following model. Vissim creates the best circumstance for testing different traffic scenarios. Flow chart summarizes different steps adopted in simulation ref fig 1.3. AutoCAD 2018 is used to draft the Diverging Diamond interchange considering the Geometric aspect and it is imported to Vissim (11.00-10.00) than Modelling is carried out in Vissim by using Links. Once modeling is done realistic vehicle input is given and Routes are assigned to the network with Desire Speed, Class of

Vehicle, Reflow, Rate of Acceleration and deceleration, priority rules. Signal programs are set and Six Signal head is set in the network. Hereafter Simulation is run and results are obtained by Node evaluation.

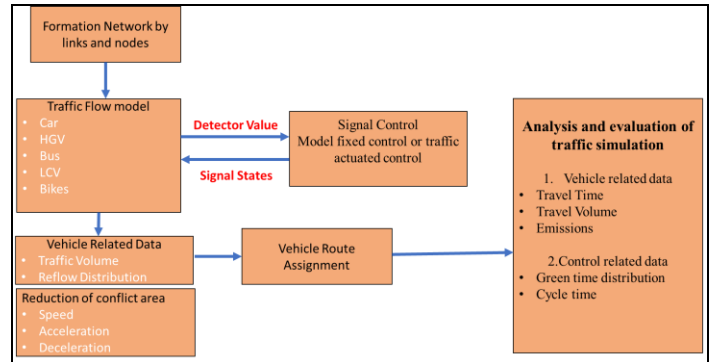


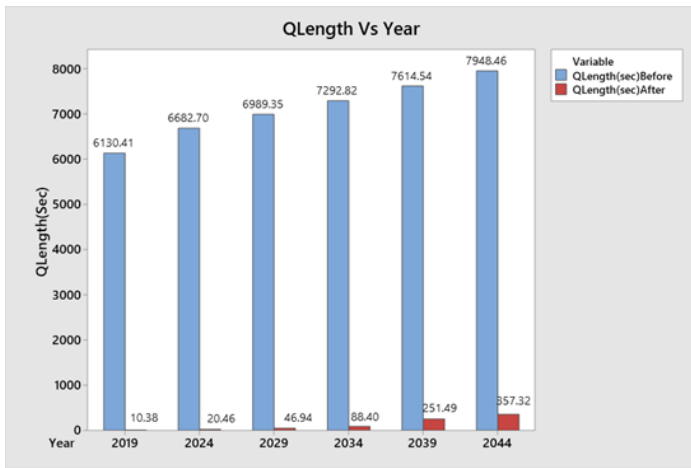
Figure 1.3 Traffic flow simulation on PTV Vissim

• **Comparative Study: Change in traffic scenario after proposing Diverging Diamond interchange is studied for the upcoming Thirty-year base on the Following parameter.**

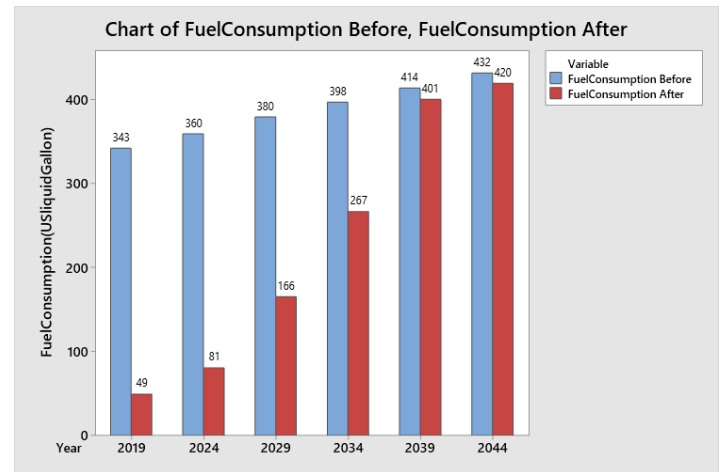
- I. Queuing length
- II. Vehicle delay
- III. Stop delay
- IV. Fuel Consumption
- V. Emission of Nitrogen oxide (NOX)
- VI. Emission of Carbon mono oxide (CO)
- VII. Emission of Volatile organic compound (VOC)

3. RESULTS AND DISCUSSION:

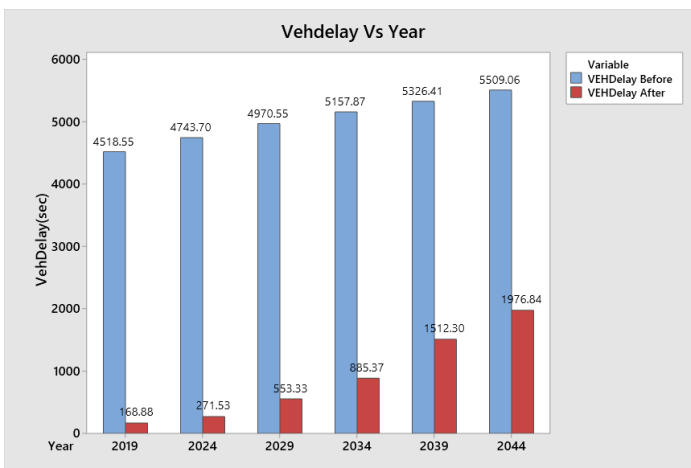
Results are obtained by simulation in VISSIM (11.0-10.0) which are represented in graphical format by using the Minitab Statically Software tool. Simulation result states that after proposing DDI there is a noticeable change in traffic and Environmental parameter if we talk about the formation of Queuing length, from simulation result it is proven that the queuing length is curtailed by ninety-five percent by considering forecasted traffic for thirty-year refer to graph 1 for better clarification. The noticeable change in Stop Delay and Vehicle Delay (up to Thirty-Five percentage reduction) is observed Corresponding for the upcoming thirty years shown in graph 2, 3. Referring to the obtained Simulation Result it is stated that the performance of DDI Network assists change in traffic scenarios. Evaluation concerning the environmental parameter DDI performs well, It reduces up to fourteen percentage fuel consumption shown in the graph (4) This Decrement in fuel consumption ultimately reduces the emission of CO, NOX, VOC which has been proven by the simulation results refer graph (5 to 7). So overall drawn inference DDI performs good in both aspect traffic and environmental even after considering the anticipation of future traffic for thirty years assuming a five percent increment each year. The finding encourages the implementation of DDI at metro cities where the intersection is closely spaced and Congestion is detected. Also, Results gives a profound view for transportation planner and infrastructure developer to propose DDI at Indian traffic Scenario no be noted obtained result is truly based on the output of simulation software.



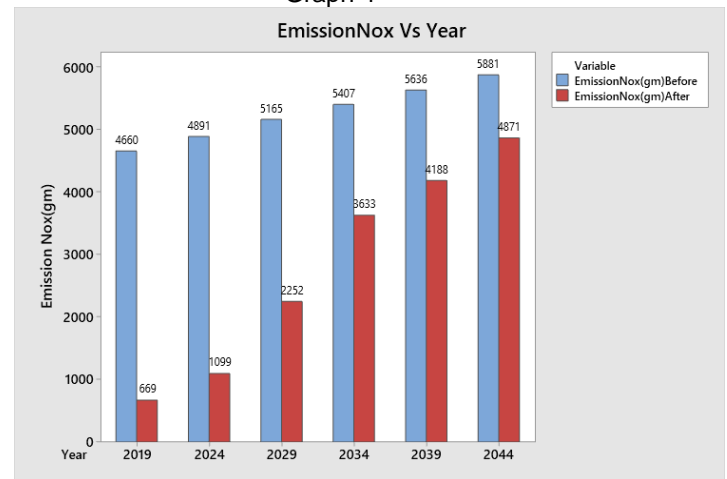
Graph 1



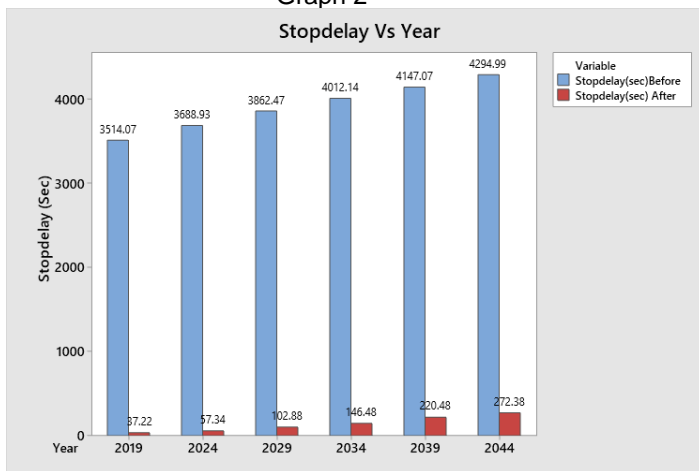
Graph 4



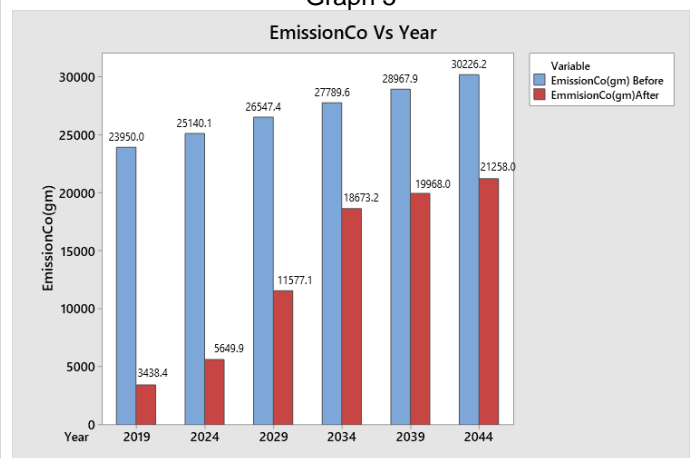
Graph 2



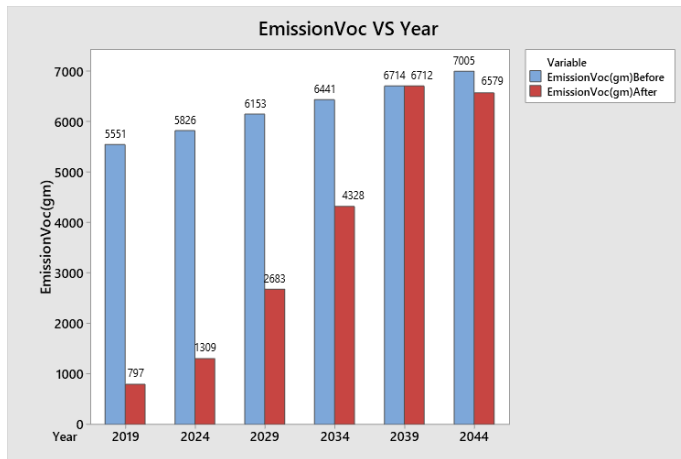
Graph 5



Graph 3



Graph 6



Graph 7

4. CONCLUSION

It can be concluded that Diverging Diamond interchange is proven to be the best solution to overcome the problem of traffic and emission at the congested junction. The above research clarifies that implementation of Diverging Diamond interchange reduces traffic Queuing length, delay, and several stops up to ninety percent and curtail fuel consumption up to fourteen percent and emission of pollutants by twenty percent. DDI construction is a prominent way to improve junction performance when there is no limitation of land. Implementation of DDI increases mobility and reduces the formation of queuing and enhance air quality by making less emission. Considering future viewpoint study needs to be carried out by EnViVer emission analysis software by taking the output from Vissim and pedestrian, cyclist movement shall be considered in the simulation for further study.

5. ABBREVIATION

Diverging Diamond Interchange (DDI), Crash Prediction Model (CMF), Carbon Monoxide (CO), Nitrogen Monoxide (NOX), Volatile Organic Compound (VOC).

5.1 AVAILABILITY OF DATA AND MATERIAL

Not Applicable

5.2 SOFTWARE TOOL

VISSIM (11.0-10.0)

5.3 DISCLOSURE STATEMENT

The author declares no conflict of interest.

5.4 FUNDING

The work was supported by the Research and Development Department of GHRCE Nagpur.

6. ACKNOWLEDGMENT

We thank GMD Consultant for Making Available Traffic Data and Special thanks to the Managing Director of GMD for this Valuable Suggestion.

REFERENCES

- [1] Avijit Maji, Sabyasachee Mishra, & Manoj.K. Jha (2013). Diverging Diamond Interchange Analysis: Planning Tool. *Journal of Transportation Engineering*, 139: 1201-1210.
- [2] Amirarsalan Mehrara Molan, Joseph E.Hummer (2019). Modeling safety performance of new super DDI design in terms of vehicular traffic and pedestrian Accident Analysis and prevention 198-209.
- [3] Boris Claros, Praveen Edara (2017). When driving on the left side is safe: Safety of the diverging diamond interchange ramp terminals Accident Analysis and Prevention 133-142
- [4] Eric J. Nelson, Darcy Bullock, & Tom Urbanik (2000). Implementing Actuated Control of Diamond Interchanges. *Journal of Transportation Engineering*, 126(5): 390-395.
- [5] Gilbert Chlewicki,(2011) Should Diverging Diamond interchange is consider has Diamond Interchange. *Transportation Research Board (2223):88-95.*
- [6] Hongyun Chen, (2009) Evaluating the safety impact of the number and arrangement of lanes on freeway exit ramps. *Accident Analysis and Prevention*, 543-551
- [7] Hongqiao Songa (2006). Comparison of Operation Performance of Diamond Interchanges between China and U.S.A *Journal of Transportation Engineering*
- [8] Joe Bared (2005). Crash Comparison of Single Point and Tight Diamond Interchange *Journal of Transportation Engineering* 131(5):379-381
- [9] Mohommed Balley Madhi (2015). Microscopic Simulation on the Design and Operational Performance of Diverging Diamond Interchange *Journal of Transportation Engineering*
- [10] Michael .S.Griffin (2014) "US Department of Transportation Federal Promethean Highway Administration"
- [11] Mujammel.Z.Shaikh et al, (2020) "Diverging Diamond Interchange: A Comprehensive Review "Journal of Emerging Technologies and Innovative Research, Volume 7, Issue 5
- [12] Lina Wu, Yusheng Ci (2020).Fuel Consumption at the oversaturated signalized intersection considering queue effect: A case study in Harbin, China *Energy* 192(2020) 116654.
- [13] Sangsoo Lee, Carroll J. Messer, Youngtae Oh, & Choulki Lee (2004). Assessments of Three Simulation Models for Diamond Interchange Analysis. *Journal of Transportation Engineering*, 130(3): 304-312.
- [14] Siddharth Sharma (2011). Performance Evaluation and Diverging Diamond Interchange in Comparison with Conventional Diamond *Journal of Transportation Engineering*
- [15] Stewen Wengler, & Thomas Urbanik (1995). Real-time Optimization at Diamond Interchanges. *IEEE*.
- [16] Sergey Sannikon, Vera Timonovetz (2018). A Procedure for an individual design of an interchange. *Transportation Research Procedia* 682-688
- [17] Sujesh D. Ghodmare, et al, (2019) "Application of the multi attribute utility technique with it's for sustainability evaluation of emerging metropolitan city of Nagpur", *International Journal of Civil Engineering and Technology* (2019), EID: 2-s2.0-85060924119.
- [18] Sujesh D. Ghodmare, et al, (2019) ""Sustainable Transportation System With Intelligent Transportation System: A Framework For Assessment And Application

For Emerging Metropolitan City” © JETIR February 2019, Volume 6, Issue 2.

- [19] Xian Feng Yang 1, GanLenChang (2014) Development of a Signal Optimization Model for DivergingDiamond Interchange Journal of Transportation Engineering 04011010-1
- [20] Yao Cheng & Xianfeng Yang (2018). Concurrent Optimization of Signal Progression and Crossover Spacing for Diverging Diamond Interchange Journal of Transportation Engineering 144(3).
- [21] IRC 92(2007) “Manual of Specification and Standards”, Indian Road Congress.