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Microsimulation Modeling of Traffic Congestion at Signal Intersection of Thirumangalam Chennai Metrocity

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Abstract

Background: Generally, Chennai is a hub of traffic congestion, where the major roads of the city are filled with vehicle. It gives the challenging situation to the road and traffic management officials to control and regulate the existing traffic with the existing facilities. **Objectives:** This paper deals with the microscopic simulation of existing road network model which helps in evaluating the performance of the Thirumangalam road intersection such as delay, queue length and also to evaluate and understand the pedestrian vehicle interaction at the intersection and to propose the improvements of signalized intersection in Thirumangalam at Chennai which is without basic facilities like pedestrian crossing time and it causes heavy congestion during peak hour which makes the management to operate the signals manually. **Methods/Findings:** PTV VISSIM software is used for evaluation and validation of the road network in order to choose the best alternative and optimization measures before implementation. This study helps to improve the existing junction by suggesting the improvement proposals by referring Indian road congress codes (IRC 106, 86, 103) and it also gives the new optimized signal design which is automated to regulate the traffic.

Keywords: Signalized Intersections; Signal Design; Microscopic Simulation; Junction Improvements

1 Introduction

Microsimulation is a process of modelling individual movement of vehicles in a particular computer software which is done to evaluate the traffic, pedestrian performance of a Junction or road. The softwares used for traffic simulation are PTV VISSIM, TSIS-CORSIM, Cube dynasim, LISA+, AIMSUN and MATSIM etc. Microsimulation of traffic in a software includes feeding inputs regarding traffic & pedestrian volumes, system evaluation and validation is done to judge the performance of road [1,2]. In the present study PTV VISSIM software package is used for analyzing Thirumangalam junction and appropriate improvement facilities are suggested.

The objectives of the study are,

1) To evaluate the performance of the thirumangalam road intersection such as delay, queue length.

2) To evaluate and understand the pedestrian vehicle interaction at the intersection.

3) To simulate the existing traffic condition in the Intersection using the microsimulation software 'PTV- Vissim'.

4) To propose suitable improvements at the intersection in par with the IRC standards.

2 Methodology

This study includes Primary surveys, Pedestrian-vehicle interaction analysis, New signal design, Vissim modelling and finally Suggestions for Improvement.

2.1 Study Area Description

Based on the statement of traffic officials in Chennai the thirumangalam junction is operated by manual signal control timer and lacks in providing sufficient pedestrian crossing time. So that particular signalized intersection is considered for the study.

The study area description involves the following.

Location:

13°05'14.1"N 80°11'54.1" E

13.087260, 80.198371

Thirumangalam Junction

Bharathi Colony, Natarajan Nagar, Thirumangalam Chennai,

Tamil Nadu 600040

Junction Importance:

The Thirumangalam is the major junction which regulates a traffic of 1.58 lakh PCU (Passenger Car Units) in all directions. As it is a border of Anna Nagar it connects the roads from Padi, Mogappair, CMBT and causes lot of vehicle delay and major pedestrian fatalities.

For Road layout refer [Figure 1 (a) & (b)].

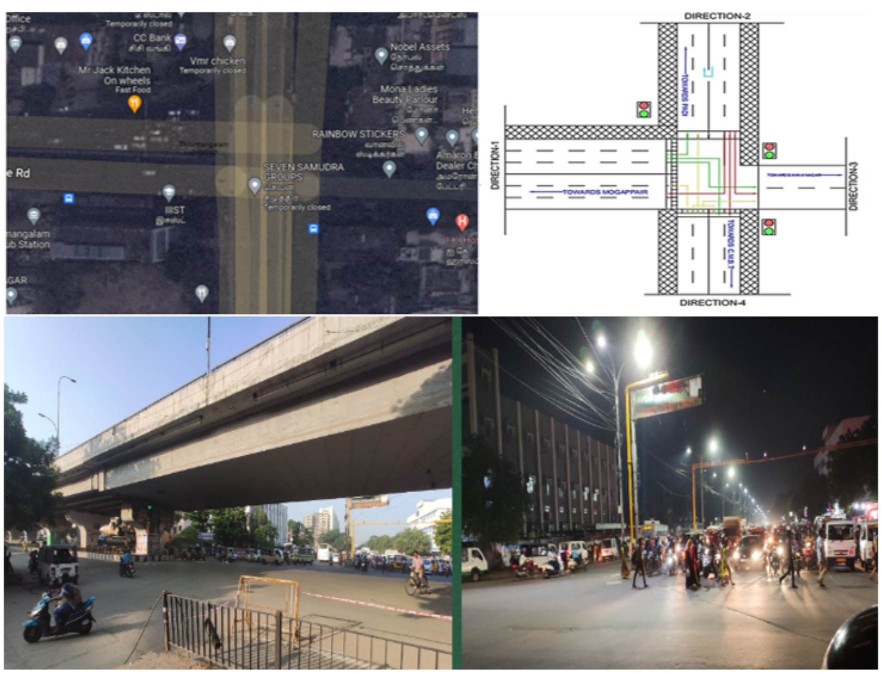
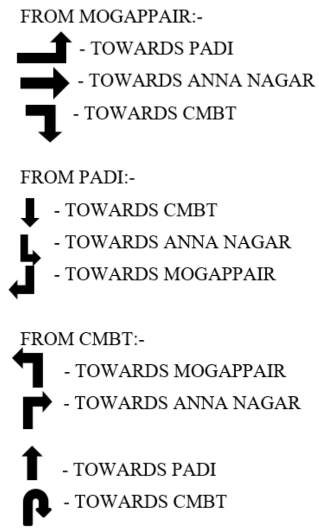


Fig 1. (a) Road Layout (b) Photos Taken at the time of Traffic Survey

Possible turnings from the supply arms



2.2 Primary Surveys

These are the basic surveys which are performed to obtain essential details of the study. The primary surveys are classified in to the following

2.2.1 Road Inventory Survey

The road inventory survey is carried out as per rural road inventory[3]. It is the survey used for studying the road parameters.

The details of road inventory survey are given in the Table 1.

Table 1. Road Inventory Details

Directions	Type of Pavement	No. of Lanes & Type	Width of the Pavement	Length of Road to the Nearest Signal Head (M)
Direction 1- Mogappair	Bituminous	6 Lanes Divided	26 m	650m
Direction 2 - Padi	Bituminous	4 Lanes Divided	14 m	800m
Direction 3 -Anna Nagar	Bituminous	2 Lanes Undivided	7 m	No Signal
Direction 4 - CMBT	Bituminous	4 Lanes Divided	14 m	490m

The intersection consists of 4 directions as shown in the [Figure 1 (a)], and in that there are 3 supply arms
Direction-1: Towards Mogappair (Three lane Two-way, supply)
Direction-2: Towards Padi (Two lane Two-way, supply)
Direction-3: Towards Anna Nagar (Two lane One way)
Direction-4: Towards CMBT (Two lane Two-way, supply)

2.2.2 Traffic Survey

These are counts of vehicles turning left, right from the supply arm. The traffic survey is done by turning movement counts which are noted to estimate the traffic volume in the intersection[4]

The intersection consists of three supply arms
ARM 1: Mogappair - three possible turns (green in road layout)
ARM 2: Padi - three possible turns (red in road layout)
ARM 3: CMBT - four possible turns (yellow in road layout)

The traffic survey has been done for peak hours during Morning [8:00 AM TO 9:00 AM] and Evening [6:00 PM TO 7:00 PM] including buffer time of 15 minutes.

The vehicle turning movements are counted and recorded for the identified peak hours. Since the evening traffic volume is peak, it is considered for simulation & further study.

2.2.3 Pedestrian Survey

These are counts of pedestrians crossing across arms which are noted to estimate the pedestrian volume in the intersection. The pedestrian survey is carried out as[5]. In the existing intersection only two arms are provided with zebra crossings. In this study pedestrians walking across all the arms are counted.

There are four arms, namely

1). Mogappair arm.
2). Padi arm.
3). Anna Nagar arm.
4). CMBT arm.

The pedestrian crossing is counted who are crossing through the zebra line [i.e. walking across the roads] for both morning and evening peak hours are represented in the figures. [Figures 2 and 3]

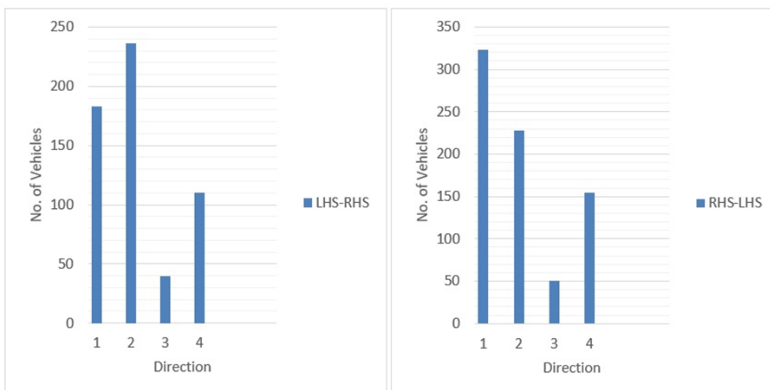


Fig 2. Morning Peak Hour(8.00-9.00am) vehicle count

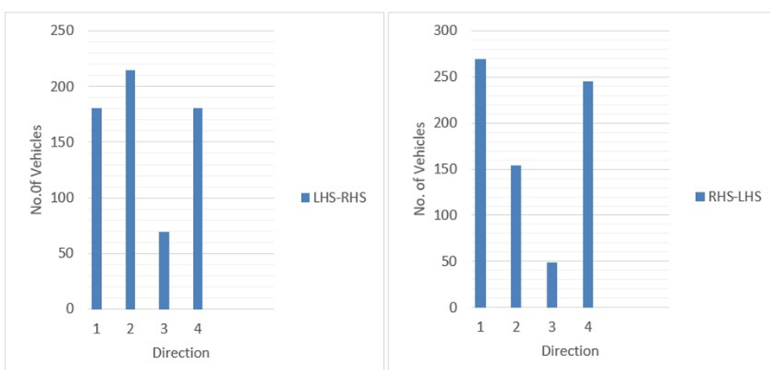


Fig 3. Evening Peak Hour(6.00-7.00pm) vehicle count

Since the evening pedestrian volume is peak, it is considered for simulation & further study

2.2.4 Stop Delay Survey

Stopped-time delay is defined as the time a vehicle is stopped in queue while waiting to pass through the intersection. It begins when the vehicle is fully stopped and ends when the vehicle begins to accelerate.

The intersection contains 10 possible turns so, all the stop delays in all the directions are noted and given in Table 2 .

Table 2. Stop Delay in All the Directions

Turnings	Stop Delay
Mogappair – Padi	73.88 sec
Mogappair – Anna Nagar	85.45 sec
Mogappair – CMBT	98.09 sec
Padi – Mogappair	223.77 sec
Padi – Anna Nagar	199.77 sec
Padi – CMBT	200.45 sec
CMBT – Mogappair	169.57 sec
CMBT – Padi	190.94 sec
CMBT – Anna Nagar	198.36 sec
CMBT – CMBT	175.76 sec

2.2.5 Queue Length Survey

Queue lengths are important parameters in traffic engineering for estimating the capacity and the quality of the traffic control system. The length of queue from the signal heads are measured in terms of meters and are given below. There are three supply arms so, queues will be formed in those arms.

Mogappair direction: 178.1m

Padi direction: 249.9m

CMBT direction: 398.59 m

2.3 Pedestrian - Vehicle Analysis

Pedestrian crossing warrants are guidelines used around the world for safe pedestrian crossing movements. Where P is the pedestrian volume and V is the vehicular volume.PV^2 based pedestrian crossing, warrants are used in India[(6)].

As there are four arms, vehicle volumes are converted in to passenger car units (PCU) by multiplying appropriate PCU factors recommended by Indian Road Congress -106:1990

The obtained PV^2 values Table 3 are compared with pedestrian warrant charts and the pedestrian facilities are recommended as follows

Mogappair- Pedestrian Signal (3 - Lane 2 Way)

Padi- Pedestrian Signal (2- Lane 2 Way)

CMBT – Pedestrian Signal (2- Lane 2 Way)

Anna Nagar – Zebra Crossing

Table 3. Pedestrian Vehicle Interaction

Direction	Pedestrians (P)	Vehicles (V) (Incoming + Outgoing)	V^2	Pv^2
Mogappair	450	5224.85 PCU	27299057.5	$1.228X10^{10}$
Padi	369	3004.9 PCU	9029424.01	$3.33X10^9$
Anna Nagar	118	2010.4 PCU	4041708.16	$4.76X10^8$
CMBT	426	4853.3 PCU	23554520.8	$1.003X10^{10}$

2.4 New Signal Design

A suitable signal timing should be designed newly because additional pedestrian signal is to be provided based on the PV^2 analysis. The signal timing is designed for the existing intersection by Webster method[(7)]. The volume of turnings from each supply arm is converted into PCU.

Highest critical volumes are considered in each supply arm

Vc_1 = 1215.65 PCU

Vc_2 = 870.7 PCU

Vc_3= 2067 PCU

$\sum vc = vc_1 + vc_2 + vc_3$

= 1215.65 + 870.7 + 2067

= 4153.35 PCU.

By Webster method,

$y_i = vc_i / s_i$

Where,

y_i = critical flow ratio

vc_i= critical volume

s_i= saturation flow

Since, there are 3 supply arms, critical flow ratios for all the supply arms are calculated.

Optimum cycle length = (1.5L+5) / (1- $\sum y_i$)

Lost time (L) = (lost time per phase * no. Of. Phases) + all red time

$\sum y_i = y_1 + y_2 + y_3 = 0.22 + 0.24 + 0.56 = 1.02$

Since, it is greater than 1, the Webster method is not applicable. So, signal control time has to be decided by trial and error process. For trial consider the following cycle lengths.

C = 120 sec, 140 sec, 180 sec, 240secs

Now considering above cycle lengths individually and calculate effective green time by the formulae below

$t_g =$ [cycle length – total lost time in all phases]

Actual green time for 120 seconds

Phase – 1: g_1 = 33.19 – 3 + 2.2 = 32.39 ~ 32 sec

Phase – 2: g_2 = 23.77 – 3 + 2.2 = 22.97 ~ 23 sec

Phase – 3: g_3 = 56.43 – 3 + 2.2 = 55.63 ~ 56 sec

Actual green values for 140 seconds

Phase – 1: g_1 = 39.04 - 3 + 2.2 = 38.24 ~ 38 sec

Phase – 2: g_2 = 27.96 - 3 + 2.2 = 27.16 ~ 27 sec

Phase – 3: g_3 = 66.38 - 3 + 2.2 = 65.58 ~ 66 sec

Actual green values for 180 seconds

Phase – 1: g_1 = 50.75 - 3 + 2.2 = 49.95 ~ 50 sec

Phase – 2: g_2 = 36.35 - 3 + 2.2 = 35.55 ~ 35 sec

Phase – 3: g_3 = 86.29 - 3 + 2.2 = 85.49 ~ 85 sec

Actual green values for 240 seconds

Phase – 1: g_1 = 67.68 - 3 + 2.2 = 66.88 ~ 67 sec

Phase – 2: g_2 = 49.01 - 3 + 2.2 = 48.21 ~ 48 sec

Phase – 3: g_3 = 116.2 – 3 + 2.2 = 115.4 ~ 115 sec

2.4.1 Pedestrian Time

It can be calculated by the formulae

$G_p = (dx / u_p)$

Where, G_p= green time for pedestrians

u_p is the walking speed of pedestrians which is 15^th percentile speed.

Generally, assumed as 1.2m/sec

For phase – 1: [Mogappair] G_p = 17.5 sec

For phase – 2: [Padi] G_p = 5.83 sec

For phase – 3**:** [CMBT] G_p = 5.83 sec

Here, total pedestrian timing = 17.5 + 5.83 + 5.83 = 29.16 ~ 29 sec

The designated signal timing is shown in the figures. [Figures 4, 5, 6 and 7]

Fig 4. Phase Diagram For 120 Seconds

Fig 5. Phase Diagram For 140 Seconds

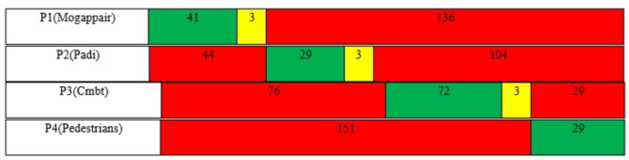


Fig 6. Phase Diagram For 180 Seconds

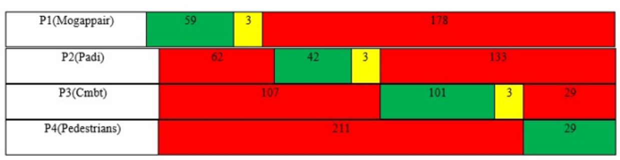


Fig 7. Phase Diagram For 240 Seconds

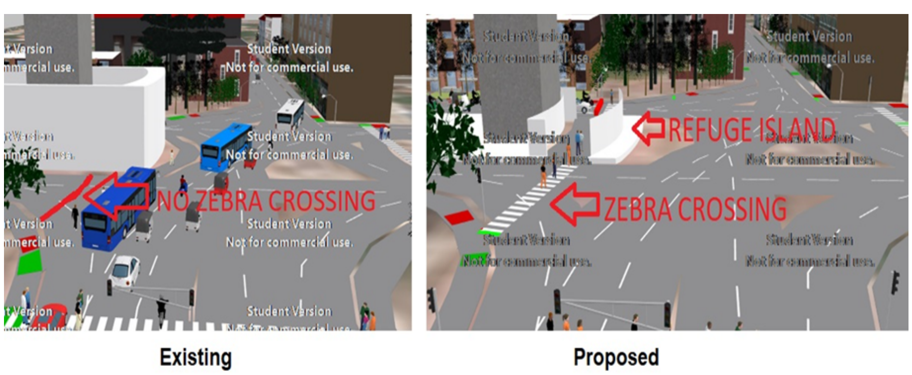


Fig 8. PTV Vissim model of the Existing & Proposed Intersection

The finalized cycle lengths are micro simulated in Vissim software to get the optimum cycle length.

2.5 New Signal Design

The PTV Vissim modelling [Figure 8] consist of evaluation and validation of the road network. It is carried out as per [8]

2.5.1 Evaluation

For evaluating the existing signalized intersection, a particular software is used called Vissim 2020. In this software the vehicle volume, existing road layout, signal control timing etc. Given as inputs and simulated as a video. The parameters generated by vision software are Stop delay, Queue length, Density, Level of service, Vehicular delay,Emission cox, nox.The evaluated results are recorded.

The simulation runs in the software are done by giving random seed numbers starting from 5 to 50 with seed increment of 5 so, totally 10 simulation runs are done for evaluation.

The simulation run results of selected parameters are taken for validation.

2.5.2 Validation

The validation is comparison between the generated parameters by software and the observed parameters from site. Validation can be done by calculating mean absolute percentage error (MAPE).

MAPE = {(actual value – simulated value) / actual value} x100

From 10 random seed results only three seed numbers which almost nearer to the observed site values are taken for validation. And the average of those three seeds are taken calculation of MAPE.

The parameters used for validation are as follows:

1. Stop delay

The stop delay values generated by Vissim software are given Table 4.

Table 4. Average stop delay validation

Directions	Seed no	Simulated stop delay values	Average stop delay
	5	63.31	
Mogappair-Padi	25	62.91	63.7
	10	64.9	
	5	71.9	
Mogappair-Anna nagar	30	71.56	73.31
	45	76.47	
	30	84.06	
Mogappair-Cmbt	35	80.89	84.59
	40	88.83	
	15	167.86	
Padi-Anna nagar	25	164.92	165.07
	40	162.44	
	15	162.93	
Padi-Cmbt	35	161.03	163.69
	50	167.12	
	15	182.15	
Padi-Mogappair	40	186.92	184.29
	45	183.73	
	5	136.65	
Cmbt-Mogappair	25	135.04	136.81
	35	138.75	
	20	153.54	
Cmbt-Padi	45	152	153.18
	50	152.87	
	30	157.54	
Cmbt-Anna nagar	35	159.13	158.52

Continued on next page

Table 4 continued

	40	158.9	
Cmbt-Cmbt (U-turn)	25	137.95	139.04
	30	139.39	
	45	139.8	

The average of mean absolute percentage error for simulated Stop Delay Validation base model is 17.23 %. This is the average of values given in the Table 5.

Table 5. Stop Delay Validation

Directions	MAPE Error%
Mogappair	13.91
Padi	17.78
CMBT - CMBT	20.01

2. Queue length

The Queue length values generated by Vissim software are given Table 6

Table 6. Queue length values generated by Vissim software

Directions	Seed no	Queue length At site(m)	Queue length Simulated values(m)
Direction 1	5-10-20-25-30-40-45	181.1	158.11
Direction 2	10-15-25-35-40-45-50	249.9	213.26
Direction 4	5-20-25-30-35-40-45-50	398.59	321.44

The average of mean absolute percentage error for simulated base model is 15.08 %. This is the average of values given in the Table 7 .

Table 7. Queue Length Validation

Directions	Average Queue Length	MAPE Error %
Direction1 (Mogappair)	158.115	11.22
Direction 2 (Padi)	213.26	14.66
Direction 4 (CMBT)	321.44	19.35

Since the MAPE error is below 20% in all the cases, our developed base model is good.

The trial cycle length (120,140,180,240) is given as input in the Vissim software & the results are compared with the base model to optimum cycle length.

The vehicular delay parameter of the base model is compared with all the trail cycle lengths to get the optimum.

From the Vehicular Delay Comparison (Table 8), the Model with 180 sec has less percentage of vehicular delay when compared to other cycle length so the cycle length of 180 seconds is taken as optimum.

Table 8. Vehicular Delay Comparison

Average Base Model Delay	120 Sec	140 Sec	180 Sec	240 Sec
1668.11	2228.1	1935.06	1806.39	1885.42

In a study conducted by Alvin Jose James, Amal Prasad, et.al [9] on Kurupanthara junction in Kerala and the main problem identified is the traffic congestion and which can be eliminated by increasing width of the road (from two lanes to three lanes) as suggested by them, but in the case of Thirumangalam junction in Chennai the problem is pedestrian-vehicle collision due to traffic congestion and inadequate pedestrian facilities. Hence, suggested to increase the pedestrian facilities for the free flow of pedestrians and vehicles, which can reduce accidents. In another study conducted by Risni Salim, Leena Samuel, et.al [10] they used Webster method to regulate the traffic for converting non-signalized intersection to signalized intersection in the junction.

Unfortunately, in the case of thirumangalam junction Webster method cannot be used due to its limitations. Hence the signal design is done by trial-and-error method.

The key issues addressed by the present study of Thirumangalam junction which regulates traffic of 15,904 PCU per critical peak hour in all directions, which causes a lot of major pedestrian fatalities due to lack of pedestrian facilities. The PV^2 warrant charts are analyzed and appropriate pedestrian facilities like pedestrian crossing, pedestrian signal timing are suggested in the junction.

In thirumangalam junction the traffic is regulated with the cycle time of 120 seconds, but in the peak hour the traffic is regulated manually with the help of traffic official. As the pedestrian crossing time has to be included it is suggested to redesign the signal to 180 seconds for the optimum flow of traffic.

By implementing this there would be slight vehicular delay drawback due to the increase in cycle length of signal by 60 seconds, i.e, 120 -180 seconds. As we consider the pedestrian facility for the safety of pedestrians and free flow of traffic.

3 Conclusion

The present study focuses on suggesting improvement proposals for the Signal Intersection of Thirumangalam in Chennai Metrocity. To calculate the vehicle flow through each approach, a thorough traffic survey is done. The optimal signal cycle time, which corresponds to the shortest overall delay for all vehicles on the approach roads to the intersection, is established, and a signal is designed using by trial-and-error process. Microsimulation models are then developed using PTV VISSIM software by using these values.

The existing vehicular flow and pedestrian flow in thirumangalam junction necessitates improvements for good riding quality and safety. The traffic and pedestrian survey have been carried out and found that large number of vehicles are plying in the junction arms. Pedestrian intervention facilities are checked with pv^2 warrants and appropriate facilities are provided. As the critical flow ratio is greater than 1, the Webster method became invalid so the signal design is done by trial-and-error process.

The improved junction is developed in the Vissim software and the road improvements suggested will ensure the good riding quality and safety to all road users and pedestrians. Pedestrian crossing in the direction 2 (Padi) must be provided with refuge island through the divider. The cycle length of the intersection must be fixed as 180 seconds. Adequate road furniture comparing of road signs, delineators, guard posts, road markings must be provided. Appropriate awareness must be given to change the driver's behaviour in order to avoid fatalities.

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