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The Study of Bus Rapid Transit (BRT) System at University Road Peshawar, Pakistan

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Abstract: *The paper is part of an ongoing research project on traffic management strategies for Peshawar Pakistan. A survey of all the existing public transport stops on University Road Peshawar conducted for identification of bus lane. Peak hour demand was calculated in terms of actual Passengers per hour per direction (Pphpd)along the entire corridor which acts a warrant test for the provision of a separate lane for public transport vehicles in Bus Rapid Transit (BRT) System. Saturation Levelsand Dwell Times (sec)at every stop both for busses and for wagons usingfrequency, clearance time, amount of boarding and alighting passengers and journey time of existing public transport system were analyzed.From data analysis, theSaturation Levels and Dwell Times at every stop were found higher than the recommended values mainly because of the obstruction due to private vehicles in front of public transport vehicles,a comparatively high percentage of private vehicles with respect to public transport vehicles and the prolong stay of drivers atbus stops. The Saturation Levels and Dwell Times (sec) for the proposed BRT system was re-analyzed. Finally, result of the proposed BRT system was incorporated in S-Paramics software to develop a public transport model.*

Keywords: *Peak hour Demand, Warrant test, SaturationLevels, Dwell Times.*

I. Introduction

An efficient and cost effective public transport system is essential for daily mobility of people. For many cities where effective public transport has been forgone, leaving mobility needs exclusively in the hands of private vehicles and un-coordinated Para transit operators. BRT system is increasingly recognized as amongst the most effective solutions in providing high quality transit services on a costeffective basis to urban areas both in the developed and developing world. BRT is high-quality, customer-orientated transit that delivers fast, comfortable and cost effective urban mobility[1-3].

BRT systems are generally built on corridors where mixed traffic congestion is already a problem, or where congestion is likely to occur in the near future [4]. There is bus/wagonpublic transport system operating mixed with private vehicles has not only resulted un-necessarily increased travel time but also have decreased the capacity of roads. The corridor of University Road Peshawarwas selected in this research because of some specific problems observed such as:Traffic congestion at corridor, high waiting times at stop, non-punctuality of public transport vehicles, traveling at speed less than the design speed, increased travel time, interference of private vehicles. The selected corridor consists of six lanes with three lanes in each direction.

BRT system at a corridor may be achieved by considering improvements to the existing infrastructure, vehicles and by proper scheduling [5].

Improvements in Existing Infrastructure:Such as provision of segregated right of way that is without interference from other modes of traffic in order to encourage modal shifts from private vehicles to public transport to overcome overall congestion.Provision of enhanced stations that are convenient, comfortable, secure and weather protected so that more passengers are attracted towards the stations in spite of locations other than the stations.

*Improvements in Vehicles:*Reduce operating costs. (Old tech vehicles consumes more fuel than new tech vehicles)
Improve riding quality. (New tech vehicles can minimize the discomfort of slowing and stopping vehicles)
Increase capacity. (By use of standard sized or articulated type buses)
*Proper Scheduling***:**This includes for example the frequency of the service that should minimize the waiting times for the passengers standing over the stop. The service speed of the vehicles so that to minimize travel times; and the capacity to fulfill the existing as well as expected passenger demand.

The objective of this research was to investigate the current and projected passenger demand on University Road by use of innovative infrastructure and proper scheduling to provide a service that is faster and more frequent than the existing bus/wagon operations.

II. Methodology

Traffic surveyfor identification of existing public transport stops at University Road was conductedfrom Gora Qabristan towards Phase-3 Intersection(Figure 01).Traffic demand analysis that serves as the base for the planning design workwas performed.Demand analysiswas used to determine the solution for various demands over the corridor. It acts as a warrant test for the provision of a separate lane for public transport vehicles in BRT System. Demandwas calculated in terms of Passengers per hour per direction, Pphpd (Actual) along the entire corridor. At every stopping bay, buses and wagonspassengers were counted for 15 minutes in peak hours on three days of the week i.e. Monday to Wednesday as one hour interval would provide less insight into peak and non-peak conditions. Thus 15 minutes interval provides a reasonably fine level of peak identification. Pphpdat every stop for buses and wagons were estimated using interpolation and by summation of all the Pphpdat every stop, Pphpd (A) for the entire corridor was calculatedfor the specified day. Instead of peak one value of the three days, An average value of peak hour demand was taken for further analysis and design, so that the profitability of the system do not suffer.

Pphpd (A) = Pphpd (Buses) + Pphpd (Wagons)

Sample Table for data collection

Data for Passengers per hour per direction (Actual) (For Peak Hours Scheduling)							
Day	Stop name	Direction	Time (15 minutes)		Total no of passengers on stop	Bus passengers	Wagon passengers
			Start time	End time		No of passengers over stop	No of passengers over stop
Mon		Gora Qabristan to Phase-3					
Tues							
Wed							
Average No of Passengers over stop from Mon-Wed Till 15 minutes							
Average No of Passengers Per Hour Per Direction (Pphpd) for this stop							

Direction indicatesthe travel from Gora Qabristan towards Phase-3 Intersection.

Table-01: Typical solutions for different demand levels (BRT Planning Guide 2007)

Transit passengers per hour per direction	**Type of BRT Solution**
Less than 2000	Simple bus priority, normally without physical segregation, possible part-time bus lane
2000 to 8000	Segregated bus way, single lane, single stopping bay per station
8000-13000	Convoy system (Without Passing lane)
Greater than 13000	Multiple stopping bay with Passing lanes

In order to add the effect of modal shift, private vehicles (Cars, Motor cycles & Taxies) were counted on the selected corridor. The purpose of this counting was to provide an early indication of how many passengers could potentially switch from private transport to public transport. The experience of other cities lends some basis for prediction. In most reasonably well designed systems, around 5 to 20 percent of the motorists switch from private vehicles to BRT along a given corridor [1, 7-9].

Pphpd (AM) including Modal shift = Pphpd (Buses) + Pphpd (Wagons) + Modal Shift

Table-02: Projected modal shift impact [1]

Type of BRT Corridor	**Projected Modal Shift Impact from private vehicles**
Little congestion, buses > 30% of the vehicle fleet	5%
Some congestion, buses around 25% of vehicle fleet	10%
Many links congested, buses around 15% of vehicle fleet	15%
Very congested, few buses on the corridor	20%

The analysis of existing saturation level (XE) was done at every stop both for busses and wagons. The saturation level of a station refers to the percentage of the time that a stopping bay is occupied by vehicles. According to BRT Planning Guide, the equation for saturation level is:

$$X = [(tc \times F) + (Pb \times Tb) + (Pa \times Ta)] / 3600$$

X = Saturation level at stop
tc = Clearance time (Seconds/vehicle)
F = Vehicle frequency (Vehicle/hour)
Pb = Number of boarding passengers/hour
Pa = Number of alighting passengers/hour
Tb = Average boarding time per passenger (Seconds/passenger)
Ta = Average alighting time per passenger (Seconds/passenger)

For calculating existing saturation level (XE) at every stop, data was collected from Monday to Wednesday in the direction towards Phase-3 Intersection. Arrival and departure time noted for every bus and counted the number of buses and boarding & alighting passengers until 15 minutes. Through interpolation, number of buses and boarding & alighting passengers per hour were estimated. The time per passenger was calculated by taking difference between the arrival and departure time of bus and divide it by the sum of boarding and alighting number of passengers to get average boarding and alighting time per passenger. By doing so, the extra time that any vehicle passes over the station was included. Clearance time, which is the time, spent in decelerating and accelerating the vehicle and in opening and closing the doors was determined. It was found that public transport vehicles require about 10 seconds to open and close their doors and pull in and out of a station. Thus from all this data, existing saturation level of the public transport system at every stop for buses was analyzed.The same procedure was applied for wagons.

Sample Table used for collecting data for existing saturation level (XE):

Data for Existing Saturation level (XEB) at every stop (For Buses)														
DAY	**STOP**	**DIRECTION**	**TIME INTERVAL (15 minutes)**		**No of Buses**	**Frequency (No of Buses/hour)**	**Till 15 minutes**		**Per hour**		**Time Difference (minutes)**	**Till 15 minutes**	**Average Ta & Tb (Minutes/Pass)**	**Average Ta & Tb (Sec/Pass)**
			Arrival Time	**Departure Time**			**Pa**	**Pb**	**Pa**	**Pb**		**Pa+Pb**		
Mon		Gora Qabristan to Phase-3												
Tues														
Wed														
Average value of Frequency, Pa, Pb, Ta & Tb from Mon-Wed for this stop														

The amount of time that any given vehicle is occupying a given stopping bay is known as the dwell time. The equation for Dwell Time is [6]:

$$td = [(Pb \times Tb) + (Pa \times Ta) + toc] / 3600$$

td = Dwell Time
toc = Time for opening and closing the doors
Pb = Number of boarding passengers per bus
Pa = Number of alighting passengers per bus

Dwell time under existing condition was analyzed from the collected data. Finally the Saturation Levels and Dwell Times (sec) for existing public transport system were re-analyzed and comparison graphs of these two factors with the existing public transport system were plotted [Figure 02 and 03].

III. Analysis & Results

After a detailed survey on University Road from Gora Qabristan to Phase-3 Intersectionthe stops counted were as:

1) Gora Qabristan stop
2) Thahkal stop
3) Tanbwaanstop
4) Gul Hajji stop
5) Arbab Road stop
6) Jahangir Abad stop

7) Town Thana stop
8) KTH stop
9) Islamia College Gate 1 stop
10) Islamia College Gate 2 stop
11) Board Bazaar stop
12) Phase-3 stop

Detailed locations of these bus stops are shownin Figure 01. The existing number of bus stops at the selected 7.20 Km lengthwere found less than the recommended number of bus stops [6]. According to principles of public transport, there should be at least 2 stops per Km (3 or 4 per mile) [6].

It was found from demand analysisthat there is need for the provision of a segregated bus lane for Bus Rapid Transit (BRT) system[Table03a]. The demand of public mobility on selected corridor is 1723 passengers per hour in the direction of Gora Qabristan towards Phase-3 Intersection. In order to avoid delay under present condition, the length of alternative routes use by public transport is almost 3 times more than the University Road. Thus considering the expected demand to be 2 or 3 times more than the demand on the University Road satisfy the condition for the provision of a separate lane.The outer lane (kerb lane) was consideredsuitable for bus rapid transit system in analysis. Due to thirteen U- turns at various locations on selected corridor, the inner lane was foundnot useful for BRT. Consideringmiddle lane would either requirenew (elevated or underground) bus stops otherwise the buses will continuously interrupt the outer lane for collecting passengers. Therefore, kerb lane was selected for analysis of BRT system may be suitable in context of the present situation on university road Peshawar.

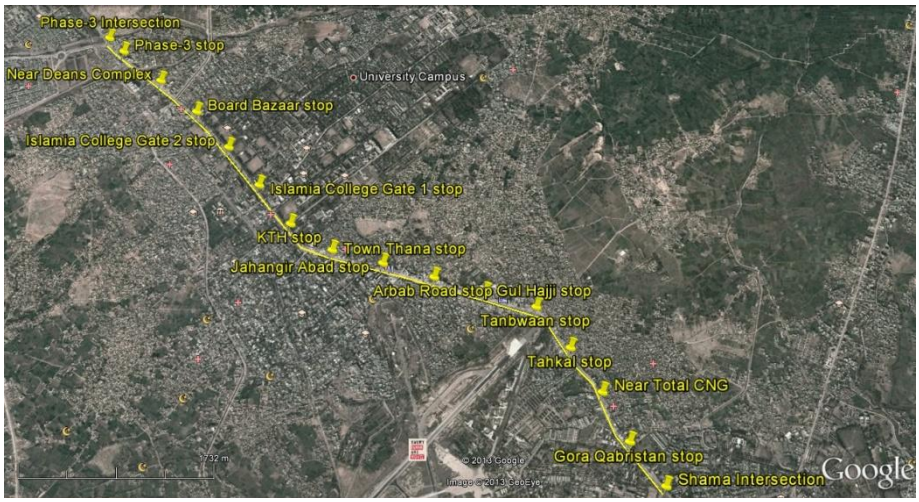

Figure01Location of stops at university Road Peshawar

Table 03(a):Demand Analysis

Gora Qabristan towards Phase-3 Direction		
Description	Detail	Remarks
Pphpd (Buses)	1007	Existing demand for buses.
Pphpd (Wagons)	716	Existing demand for wagons.
Pphpd (A) (Buses + Wagons)	1723	Warrant to provide Segregated bus lane is satisfied.

The observed existing public transport vehicles (Buses+Wagons) were found5.1% of the private vehicle fleet per hour. Thus for a new BRT system, 20% projected Modal shift from private vehicles to public transport was added to the existing demand[Table02, 03] [9, 10]. The detail is shown in the table 03.

Table 03(b):Gora Qabristan towards Phase-3 Direction

Description	Detail	Remarks
Pphpd (Buses)	1007	Existing demand for buses.
Pphpd (Wagons)	716	Existing demand for wagons.
Pphpd (A) (Buses + Wagons)	1723	Warrant to provide Segregated bus lane is satisfied.
Existing Frequency of Buses over stop	20	
Existing Frequency of Wagons over stop	22	
Private vehicles frequency per hour	829	
Percentage of Public transport vehicles (Buses+Wagons) with respect to private vehicles per hour	5.1%	For new BRT system, 20% Projected Modal Shift from private vehicles should add.

20 % projected private vehicles per hour to the new BRT system	166	
Projected number of passengers per hour from private vehicles	332	Assuming average two persons per private vehicle.
Pphpd (AM) (Buses) including Modal shift	1201	Pphpd (Buses) are 58% of the total public transport passengers, thus assumed same percentage of the projected number of passengers towards buses.
Pphpd (AM) (Wagons) including Modal shift	854	Pphpd (Wagons) are 42% of the total public transport passengers, thus assumed same percentage of the projected number of passengers towards wagons.
Pphpd (AM) (Buses + Wagons)	**2054**	**Total proposed demand for buses and wagons.**

The saturation leveland dwell time (sec) at stops for the existing public transport system were analyzed as shown in the table 04.

Table04Analysis (Existing Public Transport System)

Gora Qabristan to Phase-3 Direction							
For Buses:							
Stops	**Frequency (No of Buses/hr)**	**No of boarding passengers/hr (Pb)**	**No of alighting passengers/ hr (Pa)**	**Average boarding & alighting time per passenger (Seconds/passenger)**	**Saturation level (XEB)**	**Boarding & Alighting passengers per Bus**	**Dwell Time (sec)**
Gora Qabristan	17	67	64	10	0.43	8	81
Thahkal	19	69	83	10	0.50	8	87
Tanbwaan	20	75	69	9	0.41	7	66
Gul Hajji	20	77	84	8	0.43	8	70
Arbab Road	20	76	85	10	0.51	8	84
Jahangir Abad	21	79	69	10	0.46	7	70
Town Thana Stop	21	73	80	10	0.49	7	74
KTH Stop	21	84	93	11	0.58	8	89
Islamia College Gate 1	21	73	88	8	0.41	8	60
Islamia College Gate 2	20	59	87	9	0.41	7	66
Board Bazaar	21	93	113	12	0.75	10	119
Phase-3	21	59	93	9	0.45	7	68
AVERAGE	20	74	84	10	0.50	8	78
For Wagons:							
Stops	**Frequency (No of Wagons/hr)**	**No of boarding passengers/hr (Pb)**	**No of alighting passengers/ hr (Pa)**	**Average boarding & alighting time per passenger (Seconds/passenger)**	**Saturation level (XEW)**	**Boarding & Alighting passengers per Wagon**	**Dwell Time (sec)**
Gora Qabristan	24	44	25	19	0.44	3	58
Thahkal	24	52	56	15	0.53	5	71
Tanbwaan	24	60	60	10	0.41	5	53
Gul Hajji	23	65	61	10	0.41	6	57
Arbab Road	23	51	52	15	0.49	5	71
Jahangir Abad	23	60	65	10	0.41	6	56
Town Thana Stop	20	32	40	18	0.42	4	68
KTH Stop	20	69	88	11	0.54	8	89
Islamia College Gate 1	20	44	61	12	0.41	5	65

Islamia College Gate 2	19	24	61	15	0.42	5	72
Board Bazaar	20	49	79	19	0.73	6	124
Phase-3	20	25	69	13	0.41	5	66
AVERAGE	22	48	60	14	0.47	5	71

The existing saturation level (XE) at all the stations both for buses and wagons (as in Table04) are greater than 0.4. According to 2007 BRT Planning guidelines of Institute for Transportation & Development Policy USA, the saturation level of stations should be less than or equal to 0.40 so that to achieve an acceptable level of service[11,12]. An acceptable level of service is typically defined as the ability to achieve an average commercial speed of 25 Km/h. The general assumption for achieving this level of service is a saturation of approximately 40 percent (X = 0.4) or less [13]. Thus the existing public transport system has not the ability to achieve an acceptable level of service and result in the delays and long queues at stopping bays.

The saturation level and dwell time (sec) at the stops for the proposed BRT system werere-analyzed as shown in the table 05 and in Figures 02 and 03.

Table05Analysis (Bus Rapid Transit System)

Gora Qabristan to Phase-3 Direction							
For Buses:							
Stops	**Frequency (No of Buses/hour)**	**No of boarding passengers/hour (Pb)**	**No of alighting passengers/hour (Pa)**	**Average boarding & alighting time per passenger (Seconds/passenger)**	**Saturation level (XPB)**	**Boarding & Alighting passengers per Bus**	**Dwell Time (sec)**
Gora Qabristan	35	123	48	3	0.24	5	18
Near Total CNG	25	47	45	3	0.15	4	14
Thahkal	25	69	79	3	0.19	6	21
Tanbwaan	25	104	99	3	0.24	8	27
Gul Hajji	35	154	161	3	0.36	9	30
Arbab Road	25	106	115	3	0.25	9	29
Jahangir Abad	25	107	98	3	0.24	8	28
Town Thana Stop	25	102	108	3	0.24	8	28
KTH Stop	35	167	177	3	0.38	10	32
Islamia College Gate 1	25	100	115	3	0.25	9	29
Islamia College Gate 2	25	80	108	3	0.23	8	26
Board Bazaar	25	97	112	3	0.24	8	28
Near Deans Complex	25	48	66	3	0.17	5	17
Phase-3	35	48	138	3	0.25	5	19
AVERAGE	28	97	105	3	0.25	7	25
For Wagons:							
Stops	**Frequency (No of Wagons/hour)**	**No of boarding passengers/hour (Pb)**	**No of alighting passengers/hour (Pa)**	**Average boarding & alighting time per passenger (Seconds/passenger)**	**Saturation level (XPW)**	**Boarding & Alighting passengers per Wagon**	**Dwell Time (sec)**
Gora Qabristan	30	46	19	3	0.14	2	11
Near Total CNG	30	30	27	3	0.13	2	11
Thahkal	30	44	47	3	0.16	3	14
Tanbwaan	30	68	68	3	0.20	5	19
Gul Hajji	30	79	75	3	0.21	5	20
Arbab Road	30	65	67	3	0.19	4	18
Jahangir Abad	30	64	69	3	0.19	4	18
Town Thana Stop	30	41	49	3	0.16	3	14
KTH Stop	30	87	105	3	0.24	6	24

Islamia College Gate 1	30	48	65	3	0.18	4	16
Islamia College Gate 2	30	33	71	3	0.17	3	15
Board Bazaar	30	45	67	3	0.18	4	16
Near Deans Complex	30	24	42	3	0.14	2	12
Phase-3	30	27	59	3	0.15	3	14
AVERAGE	30	50	59	3	**0.17**	4	**16**

The saturation levels of the stations along the corridor calculated for the proposed BRT system were not more than 0.4 both for buses and wagons. Thus the proposed BRT system will have the ability to achieve an average commercial speed of 25 Km/h with adequate capacity that may handle the existing as well as expected modal shift demand with higher frequency than the existing condition. This will also minimize the passengers waiting times at the stops.

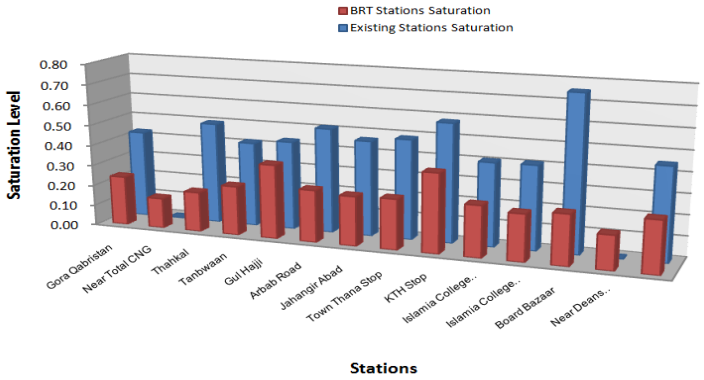

Figure02 Comparison stations' saturation levels

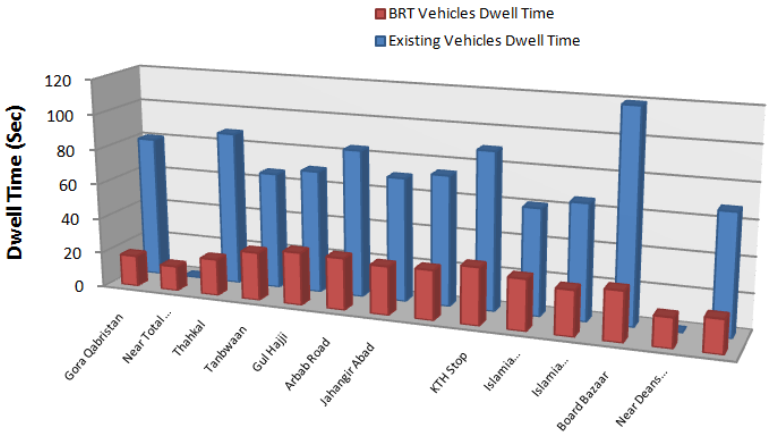

Figure 03 Comparison of dwell times

IV. Micro-simulation in S-Paramics

Micro simulation a computer modeling system which represents the behavior of individual vehicles and their drivers in a road network was applied to the data[14]. Vehicles were modeled to observe the rules of the road and to interact with other road users through simple rules[Figure 4]. The cumulative effect of modeling individual vehicles realistically represents road traffic flow on a physical road network. The technique was applied to present the output as a real-time visual display. University road that was manually analyzed was also modeled in S-Paramics [Figure 5]. Out of three lanes in each direction, the kerb (outer lane) was usedfor simulation of BRT. This public transport model simulates the public transport system and is mainly use to investigate the flow of buses throughout the entire system.

Figure 04 modeling in S Paramics

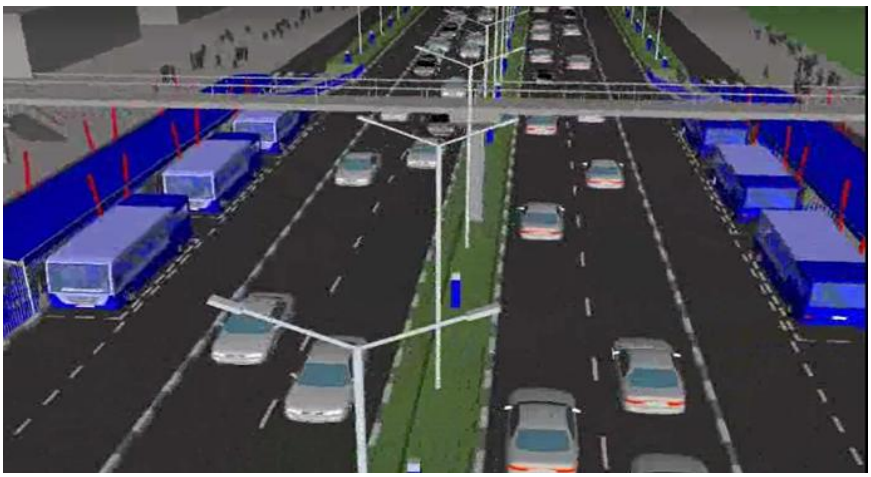

Figure 05BRT Simulation in S-Paramics

V. Conclusion

- Existing stops Dwell Times and Saturation levels are higher than the recommended values to achieve an acceptable level of service.
- Scheduling of the trips is very unpredictable in existing public transport system.
- Due to randomness (Undisciplined stopping for boarding and alighting) and improper management, the existing public transport system has not the ability to handle the demand comfortably on the corridor.
- There is the need for the provision of segregated bus lane for Bus Rapid Transit (BRT) system on the studied corridor.
- BRT Simulation Model shows that the proposed system will have the ability to achieve an acceptable level of service with adequate capacity and frequent service.

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