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Public Transport: Punctuality Index for Bus Operation

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***Abstract*—**Public bus service plays a significant role in our society as people movers and to facilitate travels within towns and districts. The quality of service of public bus is always being regarded as poor, or rather, underestimated as second class means of transportation. Reliability of service, or the ability to deliver service as planned, is one key element in perceiving the quality of bus service and the punctuality index is one of the performance parameters in determining the service reliability. This study concentrates on evaluating the reliability performance of bus operation using punctuality index assessment. A week data for each of six city bus routes is recorded using the on-board methodology to calculate the punctuality index for city bus service in Kota Bharu. The results revealed that the punctuality index for the whole city bus network is 94.25% (LOS B).

***Keywords*—**Punctuality Index, Reliability Performance, Service Performance.

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I. INTRODUCTION

PUBLIC transport has a crucial role in supporting modal shift, i.e., underpinning alternative to private vehicles and to provide quality transport for those without private vehicle. It is well-known for the use to support sustainable access, better road safety and improved air quality [1]. The public bus is an important component of the public transportation industry. It provides access to facilities, which contribute to social inclusion, thus becoming the backbone to a city performance.

In order to fulfill the role as one of the essential public transport, public bus must serve quality means of travel and, from the passengers' viewpoint, can be evaluated with various measures. In particular, issues of reliability and punctuality should be assessed. Measuring the reliability of transit service is significant because both the transit passengers and the transit provider value reliable service. In addition, an accurate picture of service performance can provide passengers beneficial information to help them become active contributors in the transit policy and decision-making process and give agencies (or operators) input to identify and investigate service problems [2].

This study concentrates on reviewing the reliability performance of a bus service using the punctuality index calculation, and is interpreted in details in Section III.

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Reliability is the ability to deliver a service as planned, and is normally expressed in terms of the proportion of mileage 'lost' due to factors such as traffic congestion or mechanical failures [3]. In particulars, reliability is the capability of the transportation system to adhere to a schedule or maintain regular headways and a consistent travel time; which is the on-time or punctuality performance and headway evenness [4].

Punctuality of bus service is a quantitative measure of reliability. Punctuality, in particulars, is the comparison of actual departure times with scheduled departure times at station or stops. Chen et al [4] considered three types of bus reliability measures, taking into account on reliability assessment on route, stop, and network level with different formulations related to one another. These are punctuality index based on routes (PIR), deviation index based on stops (DIS), and evenness index based on stops (EIS). PIR is defined as the probability of a bus to arrive at the terminals in a given time period. DIS is the ability to maintain headways and minimize a typical passenger's waiting time at stop level, and EIS is the ability to determine consistency and evenness of the headway between vehicles.

Alternatively, Kho et al [5] defined Punctuality Index as an umbrella concept containing on-time performance and headway adherence, and suggested Punctuality Index P as an index indicating the magnitude of adherence (punctuality index P1), magnitude of regularity (punctuality index P2), and evenness (punctuality index P3). Table I shows the formulation of all three punctuality indexes.

The punctuality index P1 is an index indicating the magnitude of a time gap between actual arrival time and scheduled arrival time, punctuality index P2 as magnitude of a time gap between actual headway and scheduled headway, and punctuality index P3 is an index indicating the magnitude of a time gap between average headway of a day and each headway of successive buses.

Several studies have been conducted on punctuality index and on-time performance analysis of public bus service. A case study in Seoul [5] concludes that the punctuality index during weekends when there was no traffic congestion is higher than those of the weekdays.

Longer route length, more stops, and more number of passengers are among factors of punctuality to be worse. Another study in Perak, Malaysia has revealed that punctuality index of the public bus varies throughout the day at peak hour and off-peak hour due to traffic congestion, which led to higher travel time. However, punctuality index during weekdays and weekends are not significantly different [6].

TABLE I
PUNCTUALITY INDEXES

Item	P1	P2	P3
Punctuality Index	$P_1 = \frac{S_1^2}{h_t^2}$	$P_2 = \frac{S_2^2}{h_t^2}$	$P_3 = \frac{S_3^2}{(\bar{h})^2}$
Variables	$S_1^2 = \frac{1}{I}\sum_{i=1}^{I}(t_i - \tau_i)^2$	$S_2^2 = \frac{1}{I-1}\sum_{i=2}^{I}(h_i - h_t)^2$	$S_3^2 = \frac{1}{I-1}\sum_{i=2}^{I}(h_i - \bar{h})^2$
	h_t : Scheduled headways		
	I : Number of operations		
	t_i : Actual arrival time of i-th bus operation		
	τ_i : Scheduled arrival time of i-th bus operation		
	$h_i : t_i - t_{i-1}$ (i=2,…I): Actual headway of i-th bus operation		
	$\bar{h} = \frac{1}{I-1}\sum_{i=2}^{I}(t_i - t_{i-1})$: Average actual headway of successive bus operation		

II. STUDY AREA

Location selection is adopted through a process of revising existing studies on the reliability of public bus service. A number of studies in Malaysia are conducted in Penang [7], [8], Perak [9], [10], Kedah [11], and Sabah [12].

Kota Bharu is located in the east coast area of Peninsular Malaysia. It has a population of more than 500,000 residents with population density of 1264 per km^2 [13]. In Kota Bharu, the stage bus service is provided only by one company, the Cityliner–Kelantan Operations Sdn. Bhd. The company is given a legal monopoly by the authorities where it has exclusive privileges to offer the public bus service. The advantages of having monopoly stage bus operator are:

1) There will be no overlapping schedule with other operators.

2) Wide area coverage, the operator cannot choose the area with higher demand only, it must serve to all areas fairly.

However, having no competition, the company will require less effort to make the service more attractive. This is because passengers have fewer alternatives of mode of transit.

Cityliner–Kelantan Operations mainly focuses on stage bus operations, the services which allow passengers to board and alight buses at a number of designated stops along a route. In Kota Bharu, stage bus services utilize two types of buses; one type is the normal bus with 44 seats, and the second type is the smaller-sized 25-seater mini-buses [14]. The 44-seater is employed for buses connecting districts, while the 25-seater mini buses are for city bus service, which travels less than 30 kilometers per route only. 30 kilometers are applied as a benchmark due to a study that proved a route exceeding 30 kilometers yielded a more unreliable service [4].

There are twenty six (26) bus routes starting from Kota Bharu to other towns and districts; however, this study only concentrates on city buses, which cater for six bus routes. There are two bus stations in Kota Bharu, located within walking distance (200 m) from one another. Station Hilir Pasar is the current main station that caters for all stage buses in Kelantan, including three of the city bus routes, while Station Buluh Kubu is the previous main station which serves for only three bus routes (all are city bus routes).

Table II displays the city bus routes in Kota Bharu.

TABLE II
CITY BUS TRIP ID AND ROUTES

No.	ID	Bus Route	Station	Route Type
1.	4	Kota Bharu – Kompleks Sekolah – Padang Tembak	Hilir Pasar	Direct
2.	8	Kota Bharu – Kemumin – Sabak		
3.	9	Kota Bharu – Airport – Sabak		
4.	10	Kota Bharu – Penambang – Pantai Cahaya Bulan	Buluh Kubu	Loop
5.	61A	Kota Bharu – Lembah Sireh – Pasir Hor – Jalan Bayam		
6.	61B	Kota Bharu – Jalan Bayam – Pasir Hor – Lembah Sireh		

Direct route indicated the bus travels to another station at the end of the route, e.g. Bus ID 4 starts at Station Hilir Pasar and finishes the trip at Station Padang Tembak. As for loop route, the trip starts and ends at the same station. Detailed explanation of city bus service in Kota Bharu can be referred in previous publication [15].

III. METHODOLOGY

A. On-Board Data Collection

Data collection is achieved using on board methodology where required input is recorded during bus rides. The collected data are scheduled departure time, actual departure time, departure and arrival time at each significant stop and at final destination along with the number of passengers boarding and alighting. These data will be employed to generate the punctuality index, travel time, passenger loading, and reasons of delays. The author can also distinguish the bus condition, driver's conduct, road and traffic characteristics, as well as passenger's behavior. This lead to questionnaire survey which aim to determine passenger's travel characteristics and satisfaction [16].

Another method for this type of research is off-board

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methodology or referred as 'point check'. During a point check, checker is stationed at bus stop and records required data. This method captures more trips per hour but is usually more cost-effective than ride checks (on-board methodology) [4].

In Kota Bharu, Sundays to Thursdays are working days and weekends are on Fridays and Saturdays. On Fridays, the bus timetable is adjusted in honors of Friday prayers for Muslim, therefore Saturdays' data is considered adequate for the weekend, and Fridays can be eliminated. During school break or other holidays, data is not collected because the road and user characteristics will be different from usual e.g., traffic congestion.

B. Formulation

This study applies the formulation of punctuality index P1 as in (1) and (2) because data collected only complies with the specific formula. The formulation however, is taken into account with respect to departure time at the bus station. The reason is, occasionally a bus will arrive earlier than scheduled departure time, and therefore, the driver will wait until said scheduled time before departing. Besides, bus timetable at the bus station is based on departure time, not arrival time.

Nakanishi [2] pointed that departure times are more appropriate than arrival times for passengers waiting at the stop and those on the bus because heavy ridership can cause lengthy dwell times.

$$P = \frac{S^2}{{h_t}^2} \quad (1)$$

where h_t : scheduled headways and
S : variable with formulation as in (2).

$$S^2 = \frac{1}{I}\sum_{i=1}^{I}(t_i - \tau_t)^2 \quad (2)$$

where I : number of operations,
t_i is actual departure time of i-th bus operation, and
τ_i is scheduled departure time of i-th bus operation.

Punctuality index, P=0 if all buses arrive on time, and P=1 for complete random arrival. For convenience, punctuality index, P can be converted into percentage value as in (3).

$$P\,(\%) = (1-P) \times 100 \quad (3)$$

This makes P=100% if all buses arrive on time, and P= 0% for the worst service.

IV. Results and Analysis

In Kota Bharu, six routes are designed for the city bus's purpose only. Passengers from different parts of the city which are not covered by city buses can use the service provided by connecting buses (44-seater bus). These city buses are low-floored bus with 27 seats and seven standing passengers' capacity; however, passengers loading could exceed the capacity during peak hour. The Transit Capacity and Quality of Service Manual (TCQSM) categorized 25- to 35-seater buses in vehicle type Class B (see Exhibit 2-11 in the manual) [17].

The buses operate fixed-route service in mixed traffic, implying that there is no specific bus lane for the service. The mixed-traffic operation is straightforward for planning and political purposes, except resulted in buses being subject to delays caused by traffic. In mixed-traffic, a bus is exposed to automobile traffic congestion and slows the automobile as it stops to serve passengers [17].

Fig. 1 exhibits the map of Kota Bharu city inclusive of the city bus's routes which span across the city of Kota Bharu.

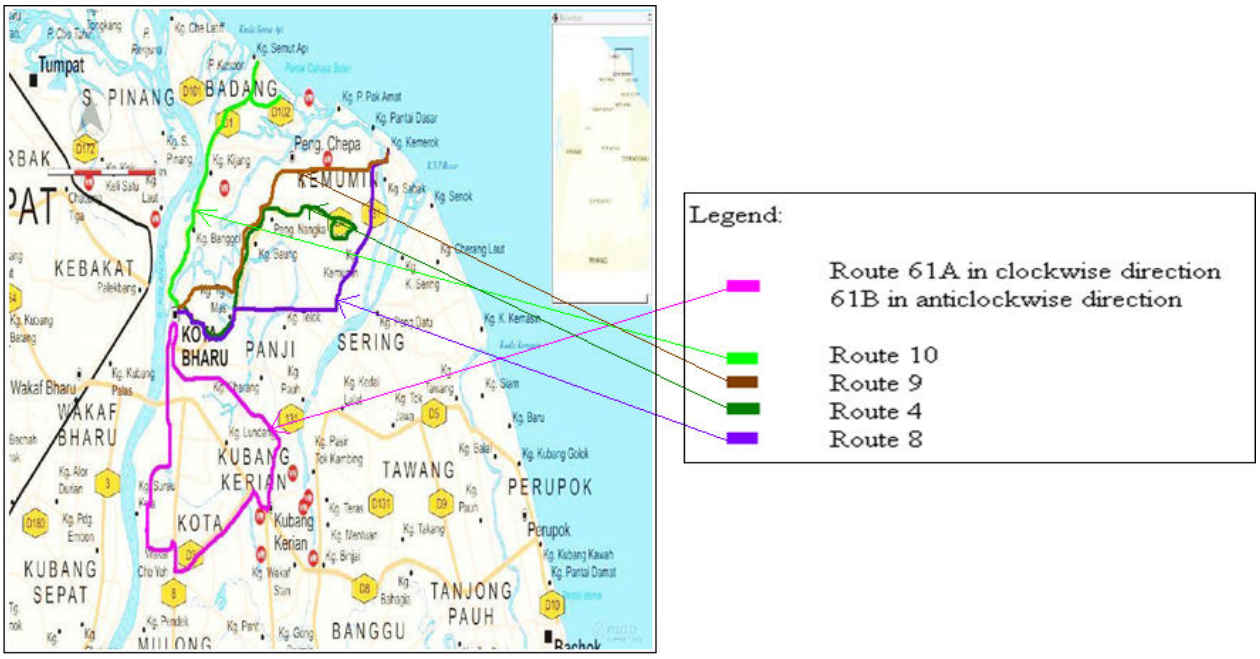


Fig. 1 Kota Bharu city bus routes [18].

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There are certain parts not covered by the service because the routes are already reserved for connecting bus service. If connecting buses routes overlap with city bus's routes, the buses will have to share passengers which are not good for business. Sharing route will ease passengers in affected areas due to options of buses that can be boarded, however it is not fair for the passengers in the non-affected area.

The reason is that, logically, when serving busy station during peak hour, the bus that departs first will be crowded. Therefore, the travel time will be greater due to traffic condition (peak hour) and the loading and unloading of passengers. This will eventually affect the punctuality of the bus for the next trip. Passengers who do not have other route options might miss the first bus due to crowded passengers and have to wait longer for the next trip. This condition will affect passenger's satisfaction on the service in the long run.

From information recorded during on-board data collection, punctuality index as in (1) for each route is calculated and presented in Table III. Note that P_{day} is the punctuality index for the day, and P_{route} is the punctuality index for each route in a week. It is observed that punctuality index for the city bus routes are significantly high. The highest would be the punctuality index for Route 61A on Wednesday (99.10%) and the lowest is from Route 8 on Sunday (81.90%).

The highest mean of punctuality index is on Tuesday (95.91%) and bus Route 61A is the most on-time service with punctuality index P_{route}=97.89%. It is revealed that the punctuality index for the whole network of city bus in Kota Bharu is 94.25%, which is LOS B in TCQSM Exhibit 3-29. LOS B indicates that there is one late transit service vehicles every week.

TABLE III
PUNCTUALITY INDEX FOR ALL ROUTES (%)

Day	Route 4	Route 8	Route 9	Route 10	Route 61A	Route 61B	P_{day}
Sun	93.76	81.19	92.63	94.87	94.20	92.24	91.48
Mon	93.07	98.30	96.40	87.01	98.41	98.23	95.23
Tue	93.47	89.10	98.32	97.11	99.10	98.40	95.91
Wed	90.44	98.07	90.86	92.73	99.18	97.89	94.86
Thu	92.69	93.45	98.05	88.24	98.67	97.10	94.70
Sat	88.89	88.15	96.82	91.45	97.81	96.70	93.30
P_{route}	92.05	91.38	95.51	91.90	97.89	96.76	94.25

The information in Table III is demonstrated graphically in Fig. 2 for a comprehensive view on the punctuality index in Kota Bharu city bus service. From observation, the punctuality indexes are not uniform due to traffic, driver and passenger's behavior because the characteristics vary randomly throughout the week.

From observation, the punctuality indexes are not uniform due to traffic, driver, and passenger's characteristics, as the characteristics vary randomly throughout the week.

From Fig. 2, the punctuality index is most uniform for Route 61A with lowest punctuality on 94.20%. Punctuality index for Route 8 and Route 10 fluctuates throughout the week. A T-test paired two samples for mean, one-tail, and 5% significant level between weekdays and weekends data reveals that punctuality index during weekdays and weekends has no significant difference. Therefore, a data for each route by day is compiled and presented in Fig. 3.

Fig. 3 confirms that the punctuality index for Route 61A is highest and most uniform. It indicates that Route 61A is the most punctual bus in the whole city bus network. Punctuality index for Route 4 however, fluctuates a lot showing that the service punctuality is unstable. The reason for low punctuality during the afternoon is due to traffic congestion and high volumes of passengers which slow down the travel time and resulting for the bus to delay, or worse, miss the next trip. This verifies the effect of traffic characteristics as mentioned by TCQSM [17] and supported by Kho et al [5] and Liu and Sinha [19].

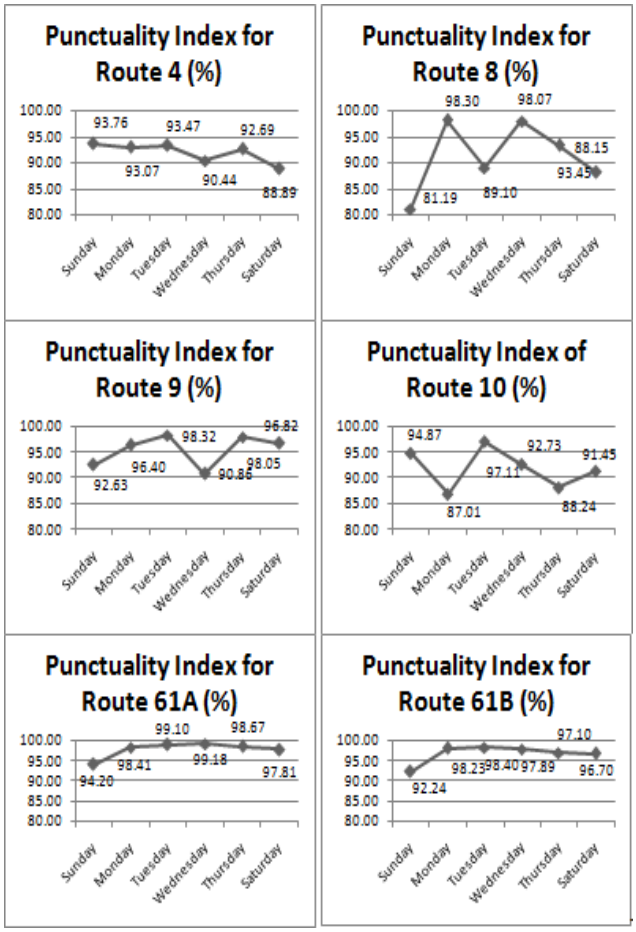


Fig. 2 The Punctuality Index for six city bus routes by week.

Meanwhile, some drivers would arrive early at the station, and then departed earlier or later than scheduled departure time. This action does not portray good punctuality and results in bad reliability. Other factors affecting the punctuality index of public bus service are road conditions, route length and number of stops, evenness of passenger demand, transit preferential treatments, operations control strategies, vehicle and staff availability, and difference in operator driving skills [19].

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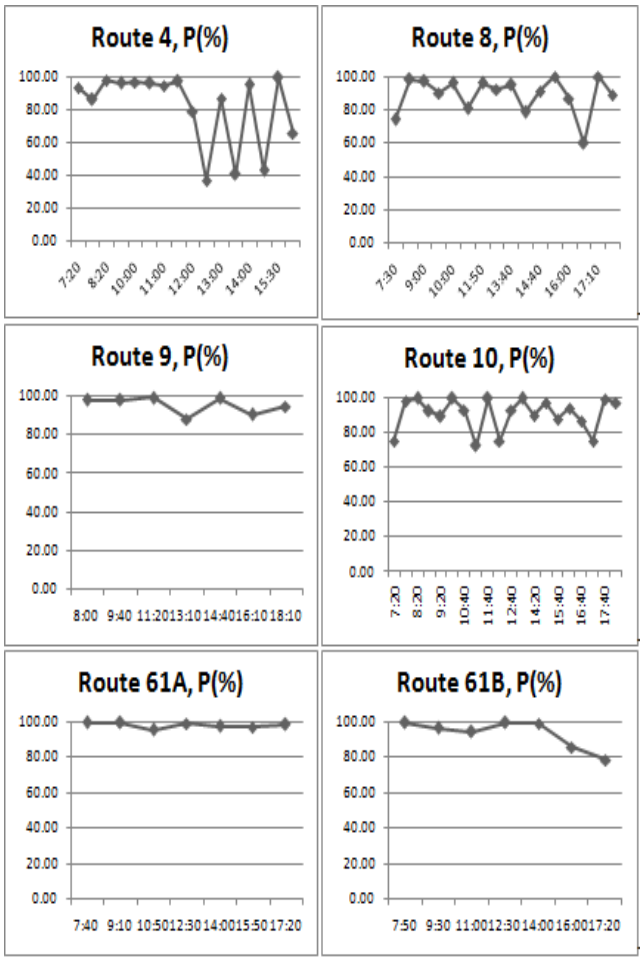


Fig. 3 The Punctuality Index for six city bus routes by day.

The punctuality index for direct route buses is computed by averaging out the punctuality index at both stations. By analyzing the punctuality index of average from two stations and punctuality index of the whole network (T-test paired two samples for means, one-tail, 5% significant level), the outcome shows that there is no significant difference for both indexes.

Table IV shows both punctuality indexes for Route 4 (direct route) where P_n is the punctuality index for the whole network, and P_{avg} is the average punctuality index for Station Hilir Pasar and Station Padang Tembak.

TABLE IV
PUNCTUALITY INDEX FOR ROUTE 4

Day	P_n (%)	P_{avg} (%)
Sunday	94.01	93.76
Monday	93.07	93.07
Tuesday	93.47	93.47
Wednesday	90.44	90.44
Thursday	92.69	92.69
Saturday	89.09	88.89
Mean	92.13	92.05

Punctuality index for the whole network is calculated by combining all scheduled and actual departure time into one array, while punctuality index P_{avg} is the average of punctuality index for Station Hilir Pasar and punctuality index for Station Padang Tembak. Note that punctuality index P_{avg} is only applicable to direct loop route, which has two stations; in this case, Route 4 and Route 9. As for Route 8, punctuality index used is the punctuality index for the whole network, P_n. The reason is that the route emphasizes more the scheduled departure time in the main station (Station Hilir Pasar) and does not have scheduled departure time at the second station.

The values of means are then paired for T-test and the result is reflected in table V. Information in Table V exhibits that the value for mean 92.13% and 92.05% are statistically similar.

TABLE V
T-TEST: PAIRED TWO SAMPLES FOR MEANS

	P_n	P_{avg}
Mean	92.13	92.05
Variance	3.72	3.79
Observations	6	6
Pearson Correlation	0.998	
Hypothesized Mean Difference	0	
df	5	
t Stat	1.568	
P(T<=t) one-tail	0.089	
t Critical one-tail	2.015	

The same T-test is applied for Route 9 and the results are equivalent, that there is no significant different between using punctuality for the whole network and by using punctuality of average from two stations. This test verifies that the data used for punctuality index calculation is valid statistically.

V. CONCLUSION

An on-board methodology is used to document required data to determine the punctuality index for the city bus service in Kota Bharu. The analysis reveals that punctuality index for the whole city bus service network in Kota Bharu is 94.25%, which is in LOS B. The highest punctuality index is on Route 61A at 97.89% (LOS A) and the lowest is Route 8 at 91.38% (LOS B). These results confirm that the punctuality index for city bus service in Kota Bharu is very satisfactory.

Based on statistical T-test, the punctuality index during weekdays and weekends are not significantly different. The study shows that punctuality index can be used as reliability performance indicator in fixed-route bus service operating in mixed-traffic, and supported by Suwardo et al [9].

Studies on punctuality index are prominent in evaluating the quality of service of bus routes and operators. If the subsidy to bus company can be discriminated based on the punctuality index, bus companies would try to improve the punctuality of bus operation [5]. There are more performance variables to evaluate the reliability of a public bus service, and punctuality index is only one of the parameters. Other parameters should be considered to expand the perspective of bus reliability research such as regularity or frequency of the bus service.

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