

## Impact of Socio-economic Factors on Parking Demand in Developing Cities

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**Abstract:** The friction created in the traffic flow owing to unauthorized on-road parking is a major cause of congestion in many mega cities in the developing countries. As the car ownership grows day by day with the improved socio-economic conditions the situation acerbates. City authorities in different parts of the world, including Dhaka, have flat regulations for parking in practice. However, it is likely that the socio-economic and demographic conditions of a city will have impact on its parking demand of various land use. This research aims at obtaining an independent view of the relationships between socio-economic conditions and parking demand applying Multiple Linear Regression. The result indicates that flat parking policy and regulation may lead to over/under design in case of developing cities as socio-economic and demographic factors have positive relation with various land use. The manuscript also provides solutions to this by proposing to have flexible parking facility design.

*Keywords:* Parking, Car Ownership, Socio-economic, Land Use, Parking Demand

### 1. INTRODUCTION

Parking is seen as a service to be provided based on measurable demand (Levy et al., 2015). It is becoming a crucial issue in managing the transportation system since it affects the overall accessibility of a city (Litman, 2012). It has gained increased significance as an integrated factor for urban transportation planning due to the substantial rise in car ownership and absence of adequate land space for parking (Mingardo, 2015). Substantial number of studies has been conducted over the past few decades on parking demand, its associated problems and probable solutions. It is widely believed that in order to understand the impact and appeal of parking on urban accessibility parking policies are obligatory (Marsden, 2006). Most of the existing studies on parking have been based on the data from North American (Shoup, 2005; Litman, 2006; Barter, 2010, Young, 2010) and European countries (Mingardo, 2015), reflecting their policy and planning experience. Such studies included parking policies as a substitute to road pricing from an economic point of view (Verhoef et al., 1995; Calthrop et al., 2000, 2006; Shoup, 2005 Button, 2006); Arnott and Inci (2006) presented finest possible parking policies in urban areas, whilst some other authors addressed the hypothetical aspect of parking problems in specific areas such as the Central Business District (Ligocki and Zonn, 1984; Voith, 1998) or residential areas (Merriman, 1995). Shoup (2006) explored the impact

of the time spent in searching for parking space on traffic congestion. Outcomes of transport policy and parking demand cannot be well-defined without considering the factors affecting parking as it is an integrated part of the transport system of a city. Recently Rowe *et al.* (2013) described the effects of land use, transit and walk access on residential parking demand.

Parking regulations can be considered as the core of parking policy and can be defined as “guidelines that regulate who, when, and how long vehicles may park at a particular location in order to prioritize parking facility use” (Litman, 2006, Mingardo *et al.*, 2015). Parking regulations typically include three factors which are; parking pricing, users’ restrictions, and time restrictions. The earliest one is probably the most dominant and from an administrative point of view, a controversial tool of parking policy (Mingardo *et al.*, 2015).

It is presumed that the “Economic (welfare) Theory” gave the foundations of parking regulation as it has the characteristics of a private good (Glazer and Niskanen, 1992). In 1960’s the Netherlands were first to introduced parking pricing policy and since then, it has been continuously expanding in the European countries. First parking meters were introduced to control on street parking in London in 1958. However, after 1991, when local authorities became able to take over parking enforcement from the police; improvement in parking policies ensued (Mingardo *et al.*, 2015). Additionally, parking needs space which is a scarce resource, the use of it should be charged. However, in practice the scenario is quite different. Very few cities have applied parking fees that reflect the costs of providing parking (Van Ommeren *et al.*, 2011). Several authors have recognized that one of the vital or main sources of disorganization and ineffectiveness in urban transport is due to the large percentage of car drivers who park for a price far below the marginal cost (Arnott *et al.*, 1991; Shoup, 1995, 1997; Small, 1997; Calthrop *et al.*, 2000). Parking regulation especially in South Asia, recommended that some building owners would prefer less parking than regulations requirement (CSE India, 2009) and this is apparently gives an opportunity to the local government for corruption (Mahmud, 2007). In Ahmedabad and Dhaka, the practice has led to enforcement action involving demolitions of basement shops that were occupying space which was designated as parking in the approved plans. Diversification of required parking was also reported in Bangkok, Beijing and Hanoi (Barter, 2012).

Due to the divergent socio-economic conditions in different cities the demand of parking requirements are also not the similar which is reflected by the customized parking regulations adopted by various cities. Engel-Yan *et al.*(2007) identified positive relationship between parking supply and different land use pattern. Jakle and Sculle (2004) explored the larger issues of parking and land use, including the regulation and modification of curbside parking spaces. Their research on off-street parking, however, focused on commercial parking lots and garages, rather than private automobile storage. Most of the guidelines are developed considering socio-economic conditions as a significant factor. Hence, it is quite unlikely that the parking guidelines used in developed countries will be same as the guidelines of a developing country. Sometimes it is seen that a insufficient parking space is recommended in the guidelines of a developing country. In a developing country like Bangladesh, residential flat (1400-2000 sq. ft.) uses 2 car parking per 3 units, restaurants use 1 parking per 1000 sq. ft. Gross area, shopping centers use 1 parking per 2000 sq. ft. Gross areas, Educational institutes use 1 parking per 2000 sq. ft. office uses 1 parking per 2000 sq. ft. gross area (Rajdhani Unnoyan Karthipakkho (RAJUK), Bangladesh; 2009). This might have a relationship with the difference in car ownership and other social factors between the developing and developed countries.

Several studies have claimed that a major factor of the extent of car parking space is the planning system and also presented that minimum parking policies to be common in many cities (Shoup, 2005; Barter 2011, 2012; Manville, 2013; Chester *et al.*, 2015, Taylor *et al.*,

2017). According to Barter (2011), developed Asian countries like Tokyo, Hong Kong and Singapore have extremely low or no minimum parking standards. In Japan, except small buildings; has no free on-street parking; and in residential areas it has an energetic private market for parking. Mapping exercises have shown surface car parking to be almost half of the total land area of central commercial zones in Albuquerque, New Mexico and Buffalo New York (Shoup, 2005, Taylor *et al.*, 2017) but in case of Asian country it is very little. To be exact, Davis *et al.* (2010) found it accounting for 6.7% area of an Indiana County whereas Chester *et al.* (2015) showed it 15% of the total Los Angeles County area. Inci (2015) stated that, studies of car-parking's effect on car use have mainly dealt with how parking at the end destination influences travel behavior. Again several other researchers revealed the influence of car parking in the factors like destination choice, trip timing, mode choice, car occupancy (Feeney, 1989), as well as car ownership (Guo, 2013) but none of them explain the influence of socio economic factors on parking demand.

We can observe a difference in the car ownership in different cities of a developed and developing countries as the socio-economic factors in these countries varies largely (Table 1). Similarly difference in car ownership is more likely to result in difference in parking demand. People have a tendency to buy more cars when they have more money. So, there might have a relation between socio economic factors and parking demand where car ownership that can act as a link between them.

Table 1. Comparison of car ownership in developed and developing countries

Developed Countries	Motor vehicles (per 1000 capita)	Developing Countries	Motor vehicles (per 1000 capita)
United States	797	Bangladesh	3
Norway	584	Nepal	5
Italy	682	Uganda	8
Canada	662	Pakistan	18
Spain	593	Afghanistan	28
Germany	572	Indonesia	69

Earlier regression models are used by different researchers to estimate road traffic volumes which was functioned as an easy, quick, and cost-effective method (Zhao and Chung, 2001; Ohio DOT, 2012; Wang *et al.* 2013; Selby and Kockelman, 2013). These models attempted to identify the socio economic variables that have impact on parking demand. Previous researches show that socio-economic conditions can have significant amount of influence on car ownership (Chaniotakis and Pel, 2015; Klein and Smart, 2017). As there is a vast difference in car ownership between developed and developing countries, so the parking requirements suggested by the guidelines of the developed world may act as an over estimator for cities in the developing countries. Parking requirements are generally suggested by a term named "Parking Ratio" whereas it is also suggested that least parking ratios are fixed policies that should be re-examined (Shoup, 2005). This is not being considered as a standard in countries like the USA and Australia (Shoup 2005; Barter, 2011; 2012; McDonnell *et al.*, 2011; Manville, 2013) but occasionally they differ in use in European countries and Chinese cities (Wang and Yuan, 2013; Mingardo *et al.*, 2015). The principle objective of this research is to identify the impact socio-economic and demographic factors on parking demand, which will be helpful for developing better parking legislations and for more accurate prediction of future demand. The objective of this research has two folds. Firstly, whether the parking demand is affected by socio-economic and demographic variables and secondly, what is the nature of the influence i.e. the effect of individual variables (socio-economic and demographic factors) on the parking demand.

## 2. STUDY AREA AND SCOPE

Dhaka, the capital city of Bangladesh, has been deliberately chosen as the study area which is home to 14 million people (WorldAtlas, 2013). The city public transport system is heterogeneous, i.e., consisting of both motorized and non-motorized vehicles. It generates around 70 million trips per day (STP, 2005) and there are around 1 million motorized vehicles plying on the streets of Dhaka (Bangladesh Road Transport Authority Website, 2016). The city sustains traffic congestion cost of US\$3 billion a year and losses over 8 million work hours daily (Osman, 2011). A study conducted by Rahman (2007) revealed that 60% of the vehicles parked in Motijheel, the busiest commercial area of the city are private cars, which is a key reason for congestion. As pointed out by Mahmud *et al.* (2012), the problem is worsened by the absence of any effective parking policy for Dhaka where illegal on-street parking is a common scenario in every busy street. This constricts the available carriageway for traffic, thus posing as one of the major contributor to traffic jam. To improve the parking problems of Dhaka city, Mahmood *et al.* (2009) suggested to identify available parking spaces and the introduction of metered parking or monthly-parking permits to control parking demand (Zannat *et al.*, 2013). (Not clear)

As this paper aims to describe the impacts of socio-economic factors impact on parking, it is needful to consider land use pattern, as it is the function or functions that humans apply to the land available to them and is one of the vital socio economic factor.

Land use information provides information about one or more of the following attributes concerning the current use of the land,

- Purpose of activities undertaken.
- Geographic location and spatial extent.
- Temporal aspects of various activities undertaken
- Technologies employed.
- Quantitative measures.
- Reasons underlying the current land use.

This research is particularly aimed at the variations of land use types within a developing city. (Dhaka city, Bangladesh). The different types of land use have been considered in this research are as follows:

- 1) Residential
- 2) Restaurant
- 3) Shopping
- 4) Hospital
- 5) Hotel
- 6) Mosque
- 7) Educational Institute
- 8) Commercial

## 3. METHODOLOGY

The adopted site selection criteria in this research were based on the criteria set by the Al-Sahili, *et al.* (2016).

- Site should be mature (i.e., at least two years old).
- Occupancy.

- Sites should be clear for the purpose of controlling parking counts on it.
- No abnormal condition besides selected site such as constructions.
- Accessible by the surveyors for collecting whole information

### 3.1 Filed Survey and Data Collection

This research puts major emphasis on the field survey because it is the primary source of our parking data. Variation in parking demand, peak/off-peak hours, ease of access and parking area has been taken into consideration before conducting the field survey. The activities related to the survey were as follows

- Preparation of survey form based on the variables.
- Identifying the suitable sites.
- Identifying the peak hours for carrying the survey.
- Counting the number of vehicles parked both on street and off street on interval of 15 minutes
- The number of stopping vehicles (5 minute count).

A survey form is used for the tabulation of actual parking demand, on street parking, off-street parking, stopping vehicle count, basic information, including floor space for parking and the actual parking supply. These parameters were selected because of their importance both from parking perspective and also from socio-economic point of view. The survey was conducted at least 3 periods during the day, including all times with peak demand. Counting on weekend (Friday and Saturday) was also to evaluate the weekend demand. The value of four different explanatory variables other than floor space and average house hold rent used in Table 2 for different land use types are collected from the Community Report of Dhaka Zila (Bangladesh Bureau of Statistics, 2012). After collection of necessary data, these are tabulated according to different land use types for regression analysis.

### 3.2 Regression Model

Regression analysis is a form of predictive modelling technique which investigates the relationship between a **dependent** (response) and **independent variable (s)** (predictor).

Multiple Regression is an extension of simple linear regression which is most widely used statistical techniques in educational and technical researches. Multiple linear regression is defined as a multivariate technique for determining the correlation between a response variable Y and some combination of two or more predictor variables, X (Tamhane and Dunlop, 2000; Shakil, 2008). Due to the nature of this research and the suitability of the data with the assumptions of Multiple Linear Regression, it is selected as the analysis method of this research. It expresses the value of a response variable as a linear function of one or more explanatory variables and an error term,

$$y_i = b_0 + b_1x_{i,1} + b_2x_{i,2} + \dots + b_kx_{i,k} + e_i \quad (1)$$

Where,

- $x_{i,k}$  : Value of  $k^{th}$  predictor in year  $i$ ,
- $b_0$  : Regression constant,
- $b_k$  : Coefficient of the  $k^{th}$  predictor,
- $k$  : Number of predictors,
- $y_i$  : Predictand in the year  $i$  and

$e_i$  : Error term.

Most statistical tests rely upon certain assumptions about the variables used in the analysis. When these assumptions are not met, the results may not be trustworthy, resulting in a Type I or Type II error, or over- or under-estimation of significance or effect size(s).

The development and evaluation of the models are performed with the following factors under consideration, R Square and Adjusted R Square is used a measure of goodness of fit of an entire parking model. The “R-Square” statistic tells us how much of the change in the dependent variable (Parking demand in our study) is accounted for by the changes in the independent variables (the socio-economic and demographic characteristics). The R-Square must be between zero and one, with a higher number indicating more “goodness of fit” which means higher accountability of the model. (Kurt G., 2008).

The Analysis of Variance (ANOVA) test is performed to check for the significance of the overall model. This test uses the F-statistics, with Significance-F as the output. A small Significance of F (<0.05) confirms the validity of the Regression output.

The effect of each significant variable in the developed models is found by checking the P-values and the coefficients of each variable. The magnitude and sign of the coefficients of each variable suggests the nature of its influence. Hypothesis are formulated to find whether a variable is significant or not,

Where,

Null hypothesis  $H_0$ :  $b_i = 0$  ( $i = 1, 2, 3\dots$ ) (which indicates variable is not significant if it is true)

Alternate hypothesis  $H_1$ :  $b_i \neq 0$  (which indicates variable is significant if it is true)

The hypothesis test is performed using the T-test and evaluated on the basis of p-values of the T-statistic. If the p-value is <0.05, we can reject the null hypothesis and conclude that the variable is significant. The lower the p-value, the higher the likelihood that that coefficient or Y-Intercept is valid.

#### 4. ANALYSIS AND RESULT

This section focuses on the analysis of data acquired from the on field survey and secondary survey. The variables selected in this research for conducting multiple linear regression are denoted in the following way:

Dependent Variable(Y) = Parking Demand is the dependent variable as this research focuses on investigating effects of other variables on this variable.

Independent variables:

$X_1$  = Floor Space

$X_2$  = Average household rent

$X_3$  = Population Density

$X_4$  = Literacy Rate

$X_5$  = Household Density

$X_6$  = Growth Rate

The core focus of this research is given on the relation between diverse socio economic factors with parking demand so that we can develop a model which describes the effect of different socio economic factors on parking demand. Earlier in this research it is stated that many researchers gave emphasize on factors like mode choice, parking price, car ownership or sometimes a particular socio economic factor to develop a parking demand model but none of them adjusted all the necessary socio economic factors which can be vital

to ration the parking demand. As developed and developing countries socio economic condition is not similar so if we can develop a model which describes the relation of socio economic factors and parking demand then by doing necessary adjustments we can convert a particular model for a specific country same land use pattern for other country. That is why these six factors (floor space, average household rent, population density, literacy rate, household density, growth rate) which are identified as the most common socio economic factors to describe the socio economic condition of any city or country, carefully taken as the independent variables of our generalized equation for multiple linear regression analysis (MLR).

### Generalized Equation

$$Y=aX_1+bX_2+cX_3+dX_4+eX_5+fX_6+g \quad (2)$$

Using this MLR we generate different models for different land use pattern; showed in Table 2.

Table 2: Results from Multiple Linear Regression (MLR) of Parking Demand with study characteristics.

Model No	A	B	C	D	E	F	G	H
Description of explanatory variables	Educational Institution	Hospital	Hotel	Mosque	Residential	Restaurant	Shopping	Commercial
Floor Space (square feet)	0.00014 (0.014*)	-	-	0.0037 (0.001*)	0.00017 (0.001*)	-	0.00012 (0.000*)	0.000780 (0.038*)
Number of rooms	-	-	0.0005 (0.003)	-	-	-	-	-
Average Household Rent(BDT per square feet)	-	-	2.03 (0.024*)	-	-1.056 (0.016*)	0.91 (0.009*)	2.25 (0.002*)	-
Population Density (per square km)	-	-	-	-0.0016 (0.006*)	-	-	-0.0022 (0.000*)	-0.00186 (0.092**)
Literacy Rate (%)	-	4.78 (0.09**)	-	-	-	1.65 (0.015*)	11.65 (0.000*)	-
Household Density (per square km)	-	-	-	0.0074 (0.013*)	-	-	-	-
Growth Rate	-	-	-	-5.88 (0.025*)	-	-	17.58 (0.000*)	-
Square R	0.66	0.39	0.98	0.98	0.92	0.82	1	0.62
Adjusted square R	0.61	0.30	0.97	0.97	0.89	0.74	1	0.47
F-statistics	0.01*	0.09**	0.004*	0.0028*	0.0019*	0.01*	0.000*	0.09**
# of observation	8	8	7	8	8	8	8	8

-Not Relevant; \*\* Significance at 10% level; \* Significance at 5% level

The findings from the analysis in this research were quite interesting as simple MLR models developed with huge limitation of data could identify different variables having substantial impact on parking demand. Based on the nature and magnitude of the co-efficient of each variable, their effects are discussed below:

Floor space shows influence in case of educational land use type. It is logical because more floor space accommodate more students creating the possibility of more trips to schools, which result in a positive influence on the parking demand generation. Educational institutes being public institutions might be the reason behind these effects. Moreover, it shows positive effect with the parking demand in mosque, residential area, shopping centers and commercial areas. Floor space might influence in a manner which creates accommodation for more people to pray and puts impact on the parking demand. In the residential areas, floor space may have an influence because of privately owned cars and car ownership is related with financial condition of an individual. It is likely to influence the number of shoppers by increasing the number of trips to shopping centers by own car, resulting in a positive influence on parking demand. Also, in case of commercial areas, floor space is related with the number of employees in an office, which can be directly related to the number of trips made to the office or any other commercial building which mostly comprise of offices.

With 1 unit increase of numbers of room in the hotel may increase the parking demand of a Hotel by 0.0005 unit. It seems logical as higher number of rooms likely mean more guests which exert a positive influence on the parking demand.

Household rent might also have an effect as higher average household rent suggests guests with good financial stability will tend to go to hotels rather than rent a house and also they prefer to travel with private cars, influencing the parking demand. So clearly, hotels are public institution and a person's economy has an effect over its parking demand. The effect of average household rent on parking demand in residential area is negative. The effects are reasonable as floor space and average household rent may have an influence as major parking generation in residential land use type occur because of privately owned cars and car ownership is related with financial condition. The relation between household rent and financial condition might also be the reason for the impact of average household rent on parking demand generation as people with higher income tend to have family dinners and other social gatherings held at restaurants quite often. For the demand in shopping centers, average household rent seem logical as they likely have a clear relationship with a person's economic condition and an individual's ability to spend money for shopping may influence the number of trips made to shopping centers.

Population density seems to have a negative impact on the parking demand in mosque, shopping centers and commercial areas. The reason may be as population in Bangladesh is increasing day by day and the exponential growth of car ownership also increases subsequent severe traffic congestion. Usually, in a city like Dhaka, where due to higher public demand now almost every community has mosques, so people living nearby the mosques prefer walking over using personal vehicles. Also due to severe traffic congestion the fuel cost of personal vehicle tends to increase which often forces people to reside in the places from where they can easily go to their desired destinations by walking or using the common paratransit modes like rickshaw, so the parking demand is decreasing in these places. Another factor which justify the result is that, due to speedy growth of population in recent years the government is promoting the public bus services (AC/Non-AC) which also lowers the uses of personal vehicle thus lowers the parking demand.

Literacy rate shows influence in case of hospital land use type. It seems rational because people tend to go to hospitals with private cars and car ownership is related with



financial condition and usually financial condition is closely related with literacy rate. It is reasonable because hospitals are public institutions and a person's economy likely has an effect over the mode of transport and parking demand. Increase of parking demand in restaurants and shopping centers is affected by the increase of literacy rate. It may be logical as less literate people may not have the courage to go for restaurant or in shopping. Most of the time they go to street markets. Also, employment and income is proportional to the literacy rate as well as availing car ownership.

Dhaka is a city with a large number of mosques and people usually travel to mosques from their houses. So larger household density of an area is likely to generate more trips to mosques, affecting the parking demand.

Growth rate might affect the parking demand in an interesting manner. As the model shows negative influence for growth rate, it is probably indicating that an increase in the number of mosques should take place along with the increase in growth rate, resulting in a decrease in the parking demand for a particular mosque in consideration. Also, with the increase of growth rate, parking demand in the shopping centers may be increased.

## **5. CONCLUSION**

The outcomes of this research show positive results for the hypothesis that parking demand is affected by socio-economic and demographic conditions. Multiple Linear Regression models developed in this research have shown that socio-economic and demographic variables do tend to show influence on the parking demand for any particular zone within a developing city with distinguishable socio-economic and demographic condition. Out of the eight types of land use considered for model development in this research, seven have shown that at least one socio-economic and demographic variable do tend to influence the parking demand. Four and three variables have shown significant influence for consequently shopping and religious land use type. The R-square values for MLR models for educational, commercial and hospital land use types are found to be below 70%. The R-square values of the models for all the other land use types are greater than 80%. Average household rent appears to be the more influential variable showing significance for four models, followed by literacy rate and population density, which show significance in three models. Growth rate occurs significant in two models. The level of influence of socio-economic and demographic variables is found to be smaller in the models developed for educational, hospital and commercial land use type. This suggests that socio-economic conditions may not have impact on the parking demand in these land use types. This research has identified some probable reasons behind the insignificance. Firstly, all these facilities are public facilities. Hence, users of these facilities are general city dwellers. This signifies the fact that it is highly unlikely for all the users of these facilities to be either of the same socio-economic and demographic conditions or the same zone. The users usually belong from various parts of the city, for example, for a public facility like a hospital. Similarly, the socio-economic conditions of the zone where the facility is situated do not necessarily represent the condition of all the users. Secondly, the use of public transport can have a huge impact on parking demand. Previous researches have shown that increase in parking facilities can result in an increase in popularity. It may be said that majority the users of the public facilities usually reach by public transport. This can be safely assumed as the car ownership in developing cities like Dhaka city is lower when compared to the number of people who use public transport. The positive side for public transport is that it does not create parking demand for the users and thus resulting in a higher number of users without parking demand for the public facilities.

In conclusion, this paper has taken an attempt to better understand the relationship between the socio-economic and demographic variables and the parking demand. However, the data used were limited in size. It also intended to investigate if such a model can be developed and if it can provide insights into parking related problems. Specially pointing out that flat regulations formed without considering the variation in socio-economic and demographic variables even within a city might not always result in accurate prediction of parking demand and consideration of such variables can aid for better predictions and informed decision making.

Every project has a design life which varies with different projects. If the parking demand can be predicted more accurately, it can help the projects in such a way that provisions can be made in the design for handling future parking demand. This can reduce the chance of unexpected situations where the parking management system of the project can collapse in future under over demand. More socio-economic conditions can be taken into account to check for significance. A large scale survey with higher number of sites can be undertaken for calibrating the model. This may be used as a superior replacement to the existing flat regulation approach. The models developed can be considered as the initial stage which is expected to undergo a series of adjustments to expand its prediction proficiencies in future.

Given the lack of research into the relationships between Socio-economic conditions and demographic aspects with parking demand and its implications in context of developing cities, this research aims to find “an appropriate balance between the parking demand and parking supply”. The results of this study will provide insight to policy makers as well as transportation engineers and planners for better designing and decision making.

The findings of this study can be utilized in two ways. The models developed in this research can be used to predict the future demand of parking for residential, shopping or religious type land use more accurately if the expected future socio-economic conditions of the area and other infrastructural variables are known. Secondly, commercial projects normally have long design life. If demographic and socio-economic indicators suggest that the facility does not require maximum number of parking spaces allocated to the land use it belongs to, it can be constructed in such a way that it retains the possibility to increase parking spaces as its demographic and socio-economic indicators change, however, at this moment, the reserved parking spaces can be used for other purposes.

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