PSPRI Model - parking space predictor for road intersections in T. P. Schemes

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Abstract: Congested urban road intersections planned to use a tool of Town Planning Scheme in Surat triggered for an intervention. Urban mobility and parking of vehicles has a unique relationship. For a rapidly developing territory as of Gujarat state in India, urbanization trends are booming reportedly making it 10th most populous state in India. Urban spaces recorded with a hiked 42.6% of total population in the year 2011 [1] against a national average of 30.1% [2]. Maybe a strong reason to believe for paced urbanization in Gujarat is its Town Planning Scheme (T.P.S.) mechanism of urban land management under the provisions of The Gujarat Town Planning and Urban Development Act, 1976. The Act has certain drawbacks that is well reflected in the provision of parking as a specific component although, there is a provision for about 20% land allocation for transportation land-use. The 20% is however, mostly consumed by the roads with wider Right of Use (ROU) to accommodate increasing vehicles. Integration of parking as an important component was visualized by the authors and an attempt was made to conduct a study around road intersections of developed T.P.S. to understand vehicle parking behavior. Certainly, it is believed that the land-use has an important interaction with transportation however, an extent of the relationship between parked vehicles to a planned land-use was found to be unattended study so far. With a vision to develop T.P.S. of future having provision for parking space around intersections became the aim of the study. Surat city emerged as the ninth largest city in India [3]. There are about 128 T.P.S. planned in the city covering 177.21 Sq. Km. of restructured urban land [4]. Current study attempted building of a mathematical model to find parking area in terms of Passenger Car Unit (PCU) count on intersections based on land-use composition of existing T. P. S. and observed parked vehicle count on the arms of intersections (Specifically on major intersections) which can be used for future T. P. S. development leading to systematic and well planned development. Field data was obtained by observing parked vehicles (converted to PCU using IRC recommended conversion weightages) in the peak hours at the intersection arms. In the initial intervention of relating road arm width and parked vehicles, 165 arms of intersection were tested parametrically. Upon dissatisfactory relationship deduction, another intervention that included land use as a set of variables was tested. The test was performed for 59 arms of roads. While checking data reliability through Cronbach Alpha test, result shown the presence on inconsistency however, positive value of Cronbach Alpha for field observations suggested for further use of data-set for correlation and ANOVA. Correlation of the parked vehicle was found significant for road arms consisting commercial and institutional land use. The analysis suggested that the "road width" affects the parked vehicles as much as 60.5% similarly institutional and mixed land use generates parking with an effect of 34% and 8.5% respectively. Importantly, a relationship between residential area and parked vehicles was negative 30% which logically is correct in a way that residential areas rarely encroach road spaces during peak hours of the day. Keeping the dependent variable as "Average observed PCU" of parked vehicles on road arms of the intersection, six models were constructed and tested to predict the value of PCU counts from the values of different variables. One-way ANOVA based mathematical model PSPRI (i.e. Parking Space Predictor for Road Intersections) generated to predict parked vehicles on an arm of road intersection is formulated. The expression of model was predicting the results with an accuracy (goodness of fit) of upto 73.4%. The model was validated by obtaining reverse values of observed PCU. A total of 44 results (about 75%) of total 59, as prediction were in the desired range of observed PCU. The predicted PCU through PSPRI model can further be utilized as a measure scale for identification of parking space allocation requirement in terms of on-street or off-street mode. It can help in provisioning of dedicated parking facility to reduce traffic congestion, pollution, vehicle life increase and other such effects leading to evolve sustainable urban areas. It also can be adopted for predicting land allocation requirement for parking space around arms of road intersections while planning of T. P. S. (draft level) so as to avoid post-implementation problems (common urbanization challenge) after the T. P. S. is fully developed and roads are in full-operation in future.

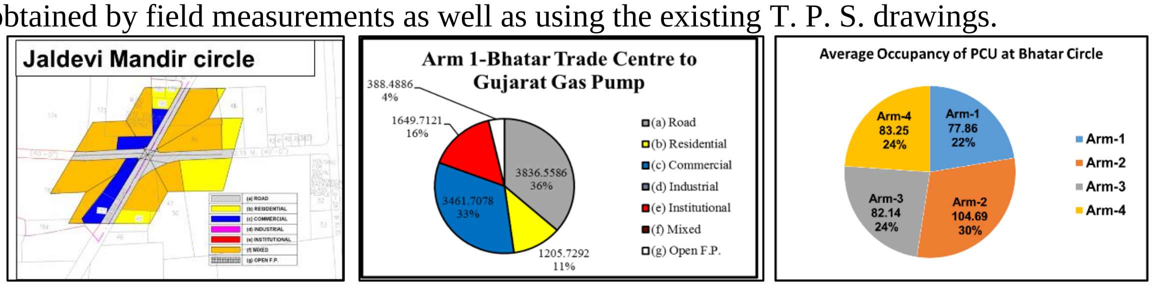
Keywords: Intersection, Land use transportation interaction, Parking, Sustainable transportation, Town Planning Scheme, Urbanization

Introduction

A research question was formulated to explore an extent to identify parking requirement prediction for intersections of city areas. An answer to this question was explored to an extent about the road width and land use surrounding the road intersection. The paper discusses about a work where an approach is developed to predict parking requirement based on study of parameters that are existing and similar in nature. Such an approach could be explored as there exist an urban area micro-level land development mechanism available and in practice, called T. P. S. These are prepared and implemented under the provisions of The Gujarat Town Planning and Urban Development Act, 1976 enforced in Gujarat State. As soon an area is declared as urban, the local authority become eligible to put a request for developing and sectioning a T. P. S. so as a systematic development of urban land is achieved avoiding haphazard growth of places. The land use is fixed in terms of percentage (range-bound) and road widths are fixed in a hierarchy while planning a T. P. S. Mostly, all the T. P. S. reflect similar development with minor variations as broadly, the land use percent do not have much of variation. A study was planned and performed in the city of Surat, Gujarat, India where there exist more than 100 T. P. S. having an average geographical area of about 100 Ha.

Data collection

On-street data was obtained with a motive to identify the quantity of vehicles parked near the arms of intersections selected as study locations. Also, information about existing land use was obtained to learn about prevailing extent on these arms. As an exploratory approach, a uniform length of 100 Mt from the centre of the intersection centre was taken up along with 50 Mt width on either side of each arms. Land use in terms of area and percentage was obtained by field measurements as well as using the existing T. P. S. drawings.



(1) Jaldevi Mandir Circle **(2) Arm-1 land use structure** **(3) Vehicle occupancy at an intersection**

Figure 1 Land use measurement and road occupying parked vehicles on intersections

Data about parked vehicles was observed for seven days on each arm of intersections in the selective study stretch during morning and evening peak hours at 15 minutes interval. In most of the cases, parking was observed consuming valuable road spaces and while observation, parking inside a plot premise was omitted considering purposed space utilization. For initial trial 165 intersections were studied for road width and parking correlation. Later due to time constraint, sample size was reduced to identify the effect of land use over the on-street parking if any.

Parametric data analysis

To address the aim of the research, it was important to identify the existing correlation among the set of variables. As the values are absolute, a reliability test on the collected field observations need to be performed before taking analysis further. In the present research, the reliability of data is checked using Cronbach's Alpha test, generally utilized in the Statistic analysis. Further, depending on the reliability, the analysis is taken up using correlation to understand the existing correlation among variables. The regression is attempted on data to establish a model to evaluate parking space requirement using existing data on parked vehicles about the width of the road and surrounding land-use.

Intervention one: Road width and parking of vehicles

As a general and prevailing tendency, for a wider road, citizens tend to park vehicles on-street for a while or for a longer duration. For the present intervention to derive relationship among road width (RW), parked vehicles (PV) and car space required for PCU, data consistency check is performed using a N=165 set of observed values. Here, the assumed hypothesis for checking relationship can be stated as ***"road width is responsible for the generation of vehicle parking on the road."*** The null hypothesis under testing is "Road width does not generate vehicle parking on road".

Data consistency check

The theoretical value of alpha can be in a range from zero to 1.00. The alpha is a ratio of two variances. The estimated value of alpha can be less than 1.00 and the value is dependent on the estimation procedure employed. At times, the alpha can have negative values however, only positive values are considered. [5] Higher values of alpha are more desirable. Professionals [6], as a rule of thumb, require a reliability of 0.70 or greater (it can only be achieved if the sample is substantial) prior the data is used as an instrument. It is however, advised to cautiously use this rule when α has been computed from items that analytically disrupt its assumptions [7]. Cronbach's α can be defined as,

$$\alpha = \frac{K\bar{c}}{(\bar{v} + (K-1)\bar{c})}$$

Where, ***K*** is as above, $\bar{v}$ the average variance of each component (item), and $\bar{c}$ the average of all covariance between the elements across the current sample. The Cronbach Alpha test was performed for three variable datasets:

1) Width of road (RW)
2) Average PCU observed and
3) Car space required for parking of observed vehicles (considering 18 Sq. Mt. of parking space for one car, referring to IRC: SP-12, 1988)

The result of data consistency test was obtained with a value of α = 0.163 but with standardization of 3 data, the value of α = 0.712 was obtained. As this value is higher than 0.7 having interpretation as the data has a bit of redundancy. However, data is consisting observed absolute values; correlation analysis is performed. Also, following table show that the values were obtained as a result of descriptive statistics.

Table 1 Descriptive statistics

Variables	Mean	Std. Deviation	N (Nos.)
Road Width (m)	25.22	13.74	165
Car space required for PCU (m^2)	810.85	448.82	165
Average Observed PCU (Nos.)	45.09	24.96	165

With above results of 165 arms on 45 intersections in T. P. S.s, it can be stated that the T. P. S.s are being planned with average major road arm width of around 25 Mt. Here, on an average, the arm roads at intersection observes around 45 PCU (standard cars) were found to be parked creating congestion on valuable road space. From the descriptive statistics, it is revealed that on an average, each arm irrespective of any other effect, consumes 810.85 Sq. Mt. of road space.

Correlation coefficient

In addition to above consistency analysis, another check on correlation was also performed on the same set of variables. The correlation was obtained (as referred to table below) to be low (at 17.80% with a value of Pearson's correlation coefficient as 0.178) between the road width and the parked vehicles on a particular arm. Hence, a fact is revealed that only the road width is not responsible for on-road parking of vehicles. It, in particular, depicts for investigating other relevant parameters that may be affecting the cause of parking. Another set of data required, may be about the land use in surrounding of each of these arms of the intersection.

Table 2 Inter-item correlation matrix

	Road Width	Car space required for PCU	Average Observed PCU
Road Width	1.000	0.178	0.179
Car space required for PCU	0.178	1.000	1.000
Average Observed PCU	0.179	1.000	1.000

Further sections contain a description of analysis with inclusion of a land use as variables in the above data set to identify the relationship among land uses, road width, and parked vehicles which in turn consume valuable road space in the developed area through T. P. S. model.

Here, the variable "Car space required for PCU" is derived using multiplying 18 Sq. Mt. per PCU to the "Average observed PCU". Hence, removal of this term was found essential. After doing so, regression analysis was carried out to examine the dependency among variables. Keeping dependent variable as "Average observed PCU", variable entered was "Road width". The value of regression coefficient "*R*" was found to be 0.179. It means that observed vehicles are explained by the road width as a variable is only about 17.9%. It shows a considerable effect of the presence of other variables.

Linear regression model derived at the point is:

Average observed PCU = 36.908 + 0.324 (Road width in Mt.) ± 4.020

Above model can explain the relationship between variable only up to 17.9%. It shall not be accepted for further prediction and leads to search establishing relation using more variables. Also, the significance of RW variable is 0.22 which is very high to the standard acceptable value of 0.05.

As it can be seen in the Figure 2, the regression model is not able to explain the dependency of parked vehicle PCU through the sole effect of variable - Road width. Also, in the model, there is an error term with a value of 4.020. Hence, a hypothesis ***"road width is responsible for the generation of vehicle parking on road"*** is not completely accepted. Also, the null hypothesis cannot be completely accepted as the model is explaining about 18% dependency of road width on the parked vehicles on the road. Hence, intervention two is taken up to identify predictability through model having more variables.

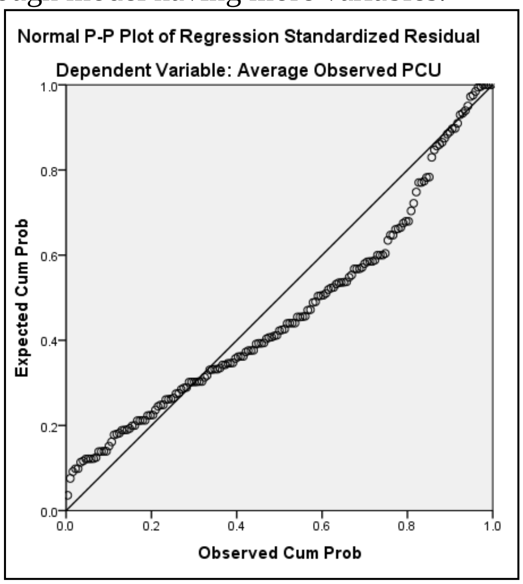


Figure 2 Observed vs. prediction on parked vehicle PCU through model

Intervention two: Road width, parked vehicles and land use

Moving further with inclusion of land use as a parameter in the analysis, data on land use was extracted manually considering the designed land use at the time of preparation of T. P. S. as well as planning for road width in accordance. All the arms are considered individual while extracting data regarding their road width, land use and observed PCU of parked vehicles. The segregation of land on an arm was done considering a 100 Mt. long and wide belt from the center of the road intersection. It can be referred in the earlier section of data collection and analysis chapter wherein each of the intersection land use area extraction analysis has been described. In the analysis, 59 records are analyzed. To begin with, following is the summary on data consistency test.

Here the assumed hypothesis for checking relationship can be stated as ***"road width and surrounding type of land use is responsible for generation of vehicle parking on road".*** Null hypothesis under testing is "Road width and land use type does not generate vehicle parking on road".

Data reliability test

Consistency among data that was collected through on-site observations needs to be verified for consistency i.e. reliability. Here again, Cronbach Alpha test is performed for data set with four variables of road width, total area under different land use, area under various types of land use and parked vehicles. Different type of land use is a sub-set of the total area of an arm but considered separately to establish independent of land use relationship with parked vehicles and road widths.

The analysis was carried out with a sample size N = 59. These are the number of road arms of intersections of T. P. S. where the land use was analyzed, and observed PCU count was obtained through field observations. The value of Cronbach alpha is obtained on observed records as $\alpha=0.113$ whereas adjusted value of $\alpha=0.229$ (standardization on ten records). These values are very less than $\alpha=0.7$ hence showing data behavior inconsistent. However, the positive value of α suggests for further analysis considering absolute records based on field observations.

Correlation among parameters

Below is a summary on Pearson's correlation coefficients among the variables. The analysis shown in here is considering the variable "Average Observed PCU" based on observations with the initial assumption it to be dependent on road width and land use areas. The table below shows the effect of other variables to the observed PCU of parked vehicles.

Table 3 Inter-Item Correlation Matrix

Variables	**Pearson is correlation coefficients**	**Significance (1-tailed)**
Road Width	.605	0.000
Average Observed PCU	1.000	-
Area of residences in total area (%)	-.303	0.010
Area of **Commercial** in total area (%)	.043	0.374 (>0.05)
Area of institutes in total area (%)	.340	0.004
Area of Mixed (Residential + Commercial) in total area (%)	.085	0.262 (>0.05)
Area of open spaces (%)	-.351	0.003

The analysis shows that "road width" affects the parked vehicles as much as 60.5% similarly institutional and mixed land use generates parking with an effect of 34% and 8.5% respectively. Important to note here is the relationship between residential area and parked vehicles is negative 30% which logically is correct in a way that residential areas do not encroach road spaces during peak hours of the day. Similarly, open spaces also affect negatively with a weightage of 35% on the vehicle parking on the road. Of course, no citizens will be interested in parking a vehicle in front of open spaces except exceptional reason to park. Commercial spaces have adequate parking facilities which is reflected through the correlation coefficient of 4.3% affecting on the vehicle parking on roads. Certain commercial spaces do not have adequate parking areas with the effect of which the valuable road space is consumed in vehicle parking. General impression is prevailing that provision of business areas encroaches the road space in parking. However, present analysis tells that in the T. P. S. area, the commercial spaces affects the parked vehicles on the road with a weight of merely 4.3%.

Additionally, in the correlation, it was found that the area of commercial and mixed land use is showing less significant effect. Respective significance values for both variables are 0.374 and 0.262 which both are higher than 0.05. It shall be verified/ resolved using yet a larger sample size.

One-way ANOVA model

Keeping the dependent variable as "Average observed PCU" of parked vehicles on road arms of the intersection, following models were created and tested to predict the value of PCU counts from the values of different variables. Entry of each variable was made one-by-one in the model to check the significant effects of each variable for the prediction.

1. Predictors: (Constant), Road Width
2. Predictors: (Constant), Road Width, Area of road in total area (%)
3. Predictors: (Constant), Road Width, Area of road in total area (%), Area of residences in total area (%)
4. Predictors: (Constant), Road Width, Area of road in total area (%), Area of residences in total area (%), Area of Commercial in total area (%)
5. Predictors: (Constant), Road Width, Area of road in total area (%), Area of residences in total area (%), Area of Commercial in total area (%), Area of institutes in total area (%)
6. Predictors: (Constant), Road Width, Area of road in total area (%), Area of residences in total area (%), Area of Commercial in total area (%), Area of institutes in total area (%), Area of Mixed (Resi+Comm) in total area (%)

Following table shows the summary of these models.

Table 4 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.605[a]	.366	.355	14.416
2	.609[b]	.371	.349	14.489
3	.609[c]	.371	.337	14.618
4	.609[d]	.371	.325	14.752
5	.645[e]	.416	.361	14.353
6	**.734[f]**	**.539**	**.486**	**12.870**

The above table indicates that model "f" can explain the prediction up to 73.4% through the effect of entered variables with an error term. Here, the values obtained of "R" depicts the effect of latent (hidden or unknown) variables which may explain the prediction through model yet significantly. Identification of these latent variables can be assumed to further fine tuning of the current model. Hence, the **Parking Space Predictor for Road Intersection**

(PSPRI) model was formulated in standard regression form ($Y_{ij} = \beta + \beta_i X_i + \ldots + \beta_j X_j \pm e$) as below:

Y = - 15.078 + 0.800 RW + 0.484 RA + 0.354 RE + 0.416 CO + 0.951 IN + 0.478 MX ± E

Where,

Y = Average observed PCU of parked vehicles

RW = Road width in Mt.

RA = Road area within identified intersection arm in percentage

RE = Residential area in percentage

CO = Commercial area in percentage

IN = Institutional area in percentage

MX = Mixed (residential + commercial) area in percentage

E = Error term (= 0.255 RW + 0.237 RA + 0.139 RE + 0.146 CO + 0.341 IN + 0.128 MX)

Important to note that the industrial land use is omitted as the study was carried out on road arms at intersections of T. P. S. areas. Below table show the values of "t" and significance for all variables that are operating in the model. The values of "t" are above t=1, which is accepted with higher values of "t" in all operating variables. Also, the significance values of all variables are lower than 0.05. Hence, the model "f" seems to be valid towards accepting the hypothesis, and null hypothesis may be rejected.

Table 5 Model variable significance values

Model		**(t)**	**Significance (s)**
f.	(Constant)	-1.240	.220
	Road Width	3.130	.003
	Area of road in total area (%)	2.041	.046
	Area of residences in total area (%)	2.544	.014
	Area of Commercial in total area (%)	2.861	.006
	Area of institutes in total area (%)	2.792	.007
	Area of Mixed (Resi+Comm) in total area (%)	3.731	.000
Excluded variable from model	Area of Open spaces in total area (%)	-0.938	0.353

Also, the effect of variable "Open spaces" was excluded from the above model while performing one-way ANOVA due to its values of "t" and significance were not acceptable. The Figure 3 shows the cumulative probability to predict PCU counts of model-fit obtained through linear regression i.e. one-way ANOVA for the observed values as the effect of different variables.

The model "6" can perform a proper distribution of probabilities as seen in the Figure 4 below. The frequency distribution of predicted values of observed PCU is showing a normal distribution that shows the statistical significant of the relationship between dependent and independent variables.

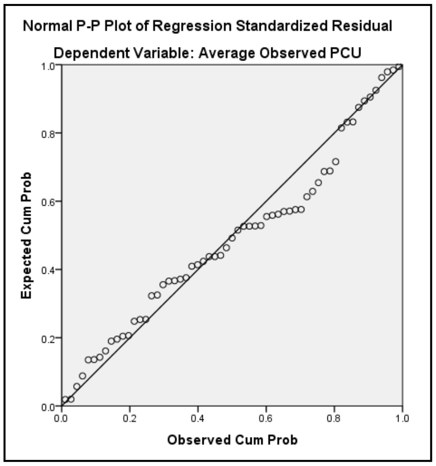


Figure 3 Observed vs. predicted values through model

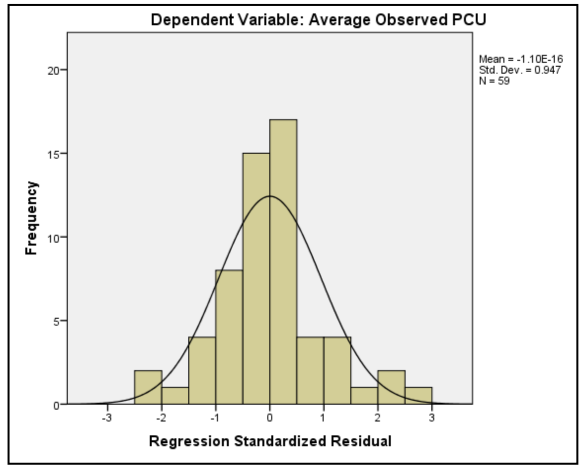


Figure 4 Histogram frequency of average observed PCU

Goodness of fit

For the goodness of fit for PSPRI Model, following values were obtained. All the values of R, R^2 and $R^2_{adjusted}$ are well within the suggested standard values that show the desired model quality as illustrated in the table below.

Table 6 Goodness of fit for model

Model	R	R Square	Adjusted R Square
F	0.734^f	0.539	0.486
Values of model	> 0.7	$0 < R^2 < 1$	> 0.4

The formulated PSPRI model can fit 73% relationship with the presence of latent variables. The PSPRI model can predict for phenomena for future requirement of vehicle parking requirement while planning a T. P. S. Road intersection with land use in surrounding area. The results from the prediction through PSPRI model can provide parking requirement on intersection arms with an accuracy above 70% with a feed (through draft planning) on a minimum of road width and area (road and surrounding land use). The aim was to predict requirement of parking space around road intersections which can be fulfilled with the given PSPRI model.

Prediction of results using model

The data that was observed as parked vehicles regarding PCU count was found using the formula of the model. The expression of the model was predicting the results with an accuracy of 73%. A total of 44 results out of total 59, as prediction were in the desired range of observed PCU. Hence, the model as formulated can be used for predicting land allocation requirement for parking space around arms of road intersections while planning of T. P. S. (draft level) to avoid issues after the T. P. S. is fully developed and roads are in operation in future.

Conclusion

The predicted PCU through PSPRI model can then be used as a measuring scale to allocate parking space on-street or off-street i.e. dedicated parking facility. It shall result in maximization of road usage and minimization of traffic congestion, pollution, vehicle life increase and other such effects leading to a better economic performance in urban areas. The PSPRI model can be used for predicting land allocation requirement for parking space around arms of road intersections while planning of T. P. S. (draft level) so as to avoid issues after the T. P. S. is fully developed and roads are in operation in future.

Future scope of work

Future scope of work may be taken up as to identify factors that lead to yet precise predictions and revision in obtained PSPRI model in present research work.

1. Other variables that can be added in the analysis (of course on trial and error basis) may be as type of parked vehicle, height of buildings, lane of roads, traffic volume in specific duration, FSI (ratio of built-up area and plot area), seasonal/ hour/ time interval and so on. The effect of each variable may affect the prediction (parking space requirement for parked vehicles) to be more accurate (above 73%) to a certain extent.
2. In addition to above, sample size can yet be increased to achieve yet generalized model.
3. Traffic behavior (parking of vehicles around road intersection) can also be studied for T. P. S. of different cities; this shall further generalize the model.

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