Analysis and Design of Parking Facilities for Nashik City

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Abstract

This paper includes the study of parking facility for Nashik city. Nashik's vehicle use statics are increasing day by day. It is a major issue for proper parking facilities in order to maintain traffic conditions and adequate traffic flow in congested area in the city. To overcome traffic and parking problems, we need to understand parking demands, so that we can improve parking facilities. So, in order to know the parking demand, we have to first analyze parking patterns. To avoid traffic congestion, proper design of parking space is very important. With the help of pricing model which gives revenue to municipal co-operation, and with the help of parking study we need to decide provision of parking facilities like (multi-store parking, mechanical parking) which should be provided in congested areas. Parking problems in other parts of the city can be solved by using these analysis and pricing models.

***Keywords*: Parking facility, parking patterns, parking space, parking study, traffic flow.**

I. INTRODUCTION

Traffic congestion and road accidents are two important externalities created by road users. Increased travel time caused by traffic congestion imposes social costs on road users, both in terms of economic loss and also in terms of reduced quality of life and mobility. The costs of road traffic accidents to individuals, property, and society in general have also been significant. Traffic congestion and accidents impose a burden on society. Therefore, it is important to reduce their impact. An ideal solution would be to reduce them simultaneously, but this may not be possible since it is speculated that there may be an inverse relationship between traffic congestion and road safety [9]. Shefer and Rietveld (1997) hypothesized that in a less congested road network, the average speed of traffic would be normally high, which is likely to result in more serious injuries or fatalities [10]. On the other hand, in a congested road network, traffic would be slower and may cause less fatalities and serious injuries. This increased traffic congestion may lead to more accidents due to increased traffic volume; however, such accidents may be less severe. The aim of this paper is to explore the effects of traffic congestion on parking study. Vehicle use in the world is increasing day by day. It is a major issue for proper parking facilities in order to maintain traffic conditions and adequate traffic flow. So, to overcome traffic and parking problems, we need to understand parking demands so that we can improve parking facilities. So, in order to know the parking demand, we have to first analyze the parking patterns. Proper design of parking space is very important for good transportation system. It seeks a number of parameters which we need to know and find out with the help of simple data by applying some techniques [9].

A. Research Objective

- The main purpose of the project is to provide parking in the city to avoid the congestion on the busy streets of the city.
- Due to congestion, there is increase in the ratio of accidents on the streets, so provision of parking facility is

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important.

- Improve the existing parking facility in the city.
- Reduce the travel time due to congestion caused due to illegal parking on streets.
- Provision of improved parking facility in the city.

B. What is Congestion

A system is said to be congested when demand exceeds the capacity of the road. Traffic congestion can be defined as, 'A physical phenomenon relating to the manner in which vehicles impede each other's progression as the demand for limited road space approaches full capacity'.

II. TYPES OF PARKING

A. On-Street Parking Facilities

As discussed in [11], on-street parking facilities are also known as curb facilities. Parking bays are provided alongside the curb on one or both sides of the street.
On street parking includes:

a. Parallel Parking
b. Angle Parking

B. Off-street Parking Facilities

As discussed in [11], off-street parking facilities can be
a. Privately or publicly owned spaces,
b. Surface lots and garages,
c. Self-parking garages, and
d. Attendant-parking garages.

Off-street parking includes:

a. Surface car parking,
b. Multistory car parking,
c. Roof parking,
d. Mechanical car parking, and
e. Underground car parking.

There are certain characteristics which have full impact on parking demand. These are :

- Parking accumulation : It is defined as the number of parked vehicles at a specified time.
- Parking duration : It is defined as the length of time for which a vehicle uses the facility.
- Parking volume : Parking volume means number of vehicles involved in parking activity.
- Occupancy : It is defined as the ratio of number of vehicles using parking facility to the number of parking facilities available at a specified time.

III. LITERATURE SURVEY

Singh [5] studied parking patterns for different parking facilities. This paper studies parking patterns so that parking facilities can be improved. Data were collected from different parking spaces in the University. Initially, we figured out what is the variation of PCU (Passenger Car Unit) with a certain time and then we compared all these data with the help of *t*-test to find out whether these parking pattern are same or different. Dandotia, Gupta, and Pandey [6] studied the analysis and design of multi level parking. In this paper, car parking has been a serious issue due to rapid increase in the number of vehicles, and to address this problem we require parking slots in important markets. We have limited land resource, so the construction of multilevel parking is very important as it accommodates large number of vehicles at one place. In this project we designed multi-level parking with a capacity of 600 cars and 550 bikes. Multilevel parking is G+2+2 basement having 13 shops on ground floor and its design is based on framed structure. In this work, we designed different components of multi-level parking, that is, raft foundation, retaining walls, beams, column, and flat slab using STAAD-Pro, manual bases, and AUTO-CAD software for making various structural drawings. For daily demand and fire demand, we also designed overhead tank and tank resting on ground. Reddy and Laxmeshwar [7] studied the design and development of low cost automatic parking assistance system. He found that parking of cars was quite a challenge in congested parking bays and for inexperienced drivers. Automatic parking assistance systems (APAS) are limited to high-end cars in India. This paper discusses the design of APAS for Hyundai Santro, and development of an automatic parking assistant system for a scaled down prototype model using a stepper motor mounted ultrasonic sensor to scan the obstacles. 3-point unequal rotating radius algorithm is used to identify parking path shifting points and parking trajectory. Path shifting control algorithm based on timing and distance traversed was developed using Microprocessor Lab Integrated Development Environment (MPLAB IDE). A prototype was developed on a scaled down model of a vehicle and performance of the APAS system was verified. Accuracy of the system is ±10%, which is acceptable for low cost solution developed. Repeatability of APAS is tested,

which is ±15%. This can be improved with closed loop control in parking process. Cost of the developed system is reduced by more than 50% of the commercially available APAS systems. From the results, it can be seen that APAS system can be used for small segment cars with little changes in logic. Path traversed can be used as feedback to further improve the accuracy of APAS system. Kaur and Singh [8] studied the design and implementation of car parking system on Field Programmable Gate Array (FPGA). In this paper, parking system is implemented using Finite State Machine modeling. The system has two main modules, that is, identification module and slot checking module. Identification module identifies the visitor. Slot checking module checks the slot status. These modules are modelled in High Density Lipoprotein (HDL), and implemented on FPGA. A prototype of parking system is designed with various interfaces like sensor interfacing, stepper motor, and LCD. Wang, Quddus, and Ison [9] studied the impact of traffic congestion on road safety: a spatial analysis of the M25 motorway in England. Traffic congestion and road accidents are two external costs of transport and the reduction of their impacts is often one of the primary objectives for transport policy makers. The relationship between traffic congestion, and road accidents however, is not apparent and less is studied. It is speculated that there may be an inverse relationship between traffic congestion and road accidents, and as such this poses a potential dilemma for transport policy makers. This study aims to explore the impact of traffic congestion on the frequency of road accidents using a spatial analysis approach while controlling for other relevant factors that may affect road accidents. The M25 London orbital motorway, divided into 70 segments was chosen to conduct this study and relevant data on road accidents, traffic, and road characteristics were collected. A robust technique has been developed to map M25 accidents onto its segments. Since existing studies have often used a proxy to measure the level of congestion, this study employed a precise congestion measurement. A series of Poisson based non-spatial (such as Poisson-lognormal and Poisson-gamma), and spatial (Poisson-lognormal with conditional autoregressive priors) models were used to account for the effects of both heterogeneity and spatial correlation. The results suggest that traffic congestion has little or no impact on the frequency of road accidents on the M25 motorway. All other relevant factors have provided results consistent with existing studies. Shefer and Rietveld[10] studied congestion and safety on highways. Congestion and accidents are important components of the externalities created by road users in metropolitan areas. In the present paper, we investigate the relationship between these two components. Among the factors which influence the number of fatalities on highways, speed, speed differences, and traffic composition. We pay special attention to the impact of congestion on the number of fatalities. The lower speeds which are caused by congestion would lead to lower numbers of fatal accidents. As a result, we expect a parabolic relationship between density and fatal accidents on highways. When densities increase, we would first have a positive relationship due to the increase in the numbers of cars in the system. However, when density becomes so high that speeds are infuenced negatively, the number of accidents will decrease. The conclusion is that in addition to the negative impact of congestion in terms of time losses, we also have a positive impact, since fatalities are reduced. Some supporting evidence is found for a number of countries where relatively low numbers of fatalities are observed during the morning peak.

IV. METHODOLOGY

The study methodology comprises of a stepwise sequence of studies as mentioned below :

- Literature study about :
  - City demographics, traffic, land use, economy, transportation systems etc.
  - Case studies for on-street and off-street parking at domestic and international level.
  - Pricing methods, management alternatives, engineering options, and policy analysis at domestic and international level.
- Identification of study area with construction of survey plan and data collection formats.
- Site visits and volume counts, road space inventory of primary data collection in the form of data sheets and questionnaires.
- Secondary data collection.
- Primary data analysis about elasticity studies and representative indicators for modeling.
- Selection of two cases and parking duration, and land use survey of data collection.
- Physical analysis of the area and parking lot alternative generation (on-street or off-street) by checking technical feasibility.
- Financial modeling and pricing model of technically feasible alternatives and elasticity analysis.

➢ Recommendations in form of draft policy directives to the administrative authority.

Enforcement plan to curb ill effects like bribe, spill over etc.

V. DATA COLLECTION AND ANALYSIS

A. Study Area Delineation and Case Selection

The study area is confined within the Nashik Munciple Corporation (NMC) limit shown in Fig. 1. There are many roads within the NMC limit that have been selected for the study. These are as follows:

1) MG Road.
2) CBS to Shalimar.
3) Gangapur Nakka to Jehan Circle.
4) ABB Circle to Jehan Circle.

B. Parking Volume Counts

Parking volumes were taken for all the sites for varying duration on varying days. To capture peak volume, the survey was conducted in two time slots, that is, the morning and evening slot. Parking volumes for cycles, 2-wheeler, 3-wheeler, and 4-wheelers were recorded. Apart from these categories of vehicles, pedestrian, and street vendor volumes were also recorded but have not been presented here.

Table I shows the length of various roads. Table II shows list of roads in NMC limits.

TABLE I.
LENGTH OF THE SELECTED ROAD

Location	Row (Mt.)	Length of Survey (Mt.)
MG Road	19	300
CBS-Shalimar	21	600
ABB Circle-Jehan Circle	21	2600
GangapurNakka- Jehan Circle	21	1800

Fig. 1. Study Area Location

Fig. 2. MG Road

Fig. 3. CBS to Shalimar

Fig. 4. ABB Circle to Jehan Circle

Fig. 5. Gangapur Nakka to Jehan Circle

TABLE II.
LIST OF THE ROADS IN NMC LIMIT

S. No.	Road Name
1.	MG Road
2.	CBS to Shalimar
3.	Gangapur Naka to Jehan Circle
4.	Model Colony chowk to Bhosla Gate
5.	Jehan Circle to ABB
6.	Kulkarni Garden side to Sadhu Vaswani road
7.	Kulkarni Garden to BSNL Office
8.	Behind Kulkarni Garden
9.	Jyoti Store/ Rushikesh Hospital to Gangapur Naka
10.	Melegaon Stand to Nimani Chowk
11.	Nimani Chowk to Chitrakut
12.	Melegaon Stand to Makhmalad Naka

1) MG Road

Table III and Fig. 6 show the parking volume counts for MG Road.

TABLE III.
PARKING VOLUME COUNTS (MG ROAD)

Location	Time	Cycle	2-Wheeler	3-Wheeler	4-Wheeler
	10:30-11:30	16	501	9	71
	11:30-12:30	26	549	20	88
MG Road	12:30-13:30	18	459	8	82
	15:30-16:30	21	385	17	69
	16:30-17:30	23	512	21	82
	17:30-18:30	22	477	18	75

2) CBS Shalimar

Table IV and Fig. 7 show the parking volume counts for CBS to Shalimar.

TABLE IV.
CBS SHALIMAR

Location	Time	Cycle	2-Wheeler	3-Wheeler	4-Wheeler
	10:30-11:30	40	400	98	70
	11:30-12:30	50	430	110	81
CBS-	12:30-13:30	34	385	85	69
Shalimar	15:30-16:30	17	250	90	61
	16:30-17:30	55	350	97	67
	17:30-18:30	46	415	115	75

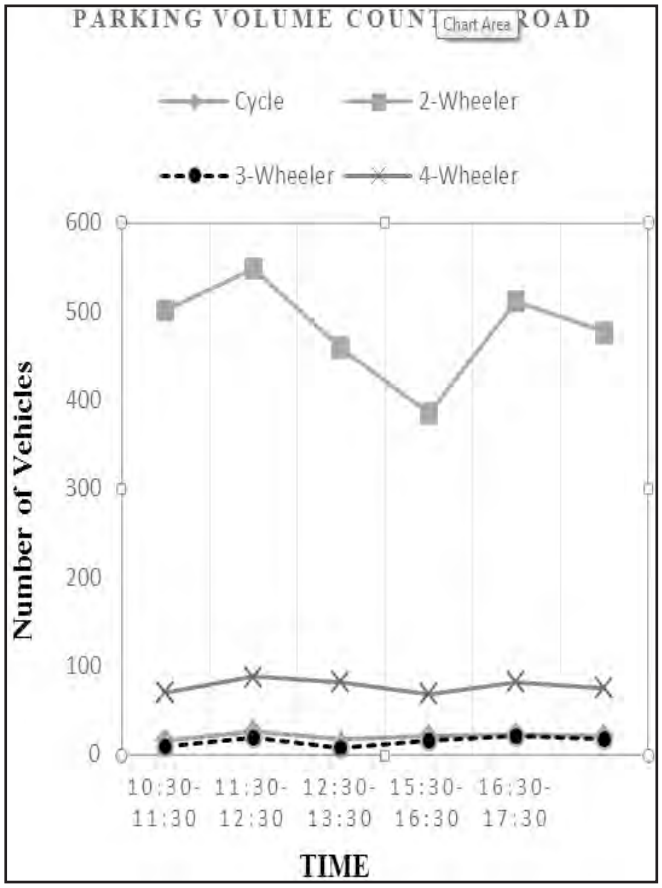

Fig. 6. Parking Volume Counts (MG Road)

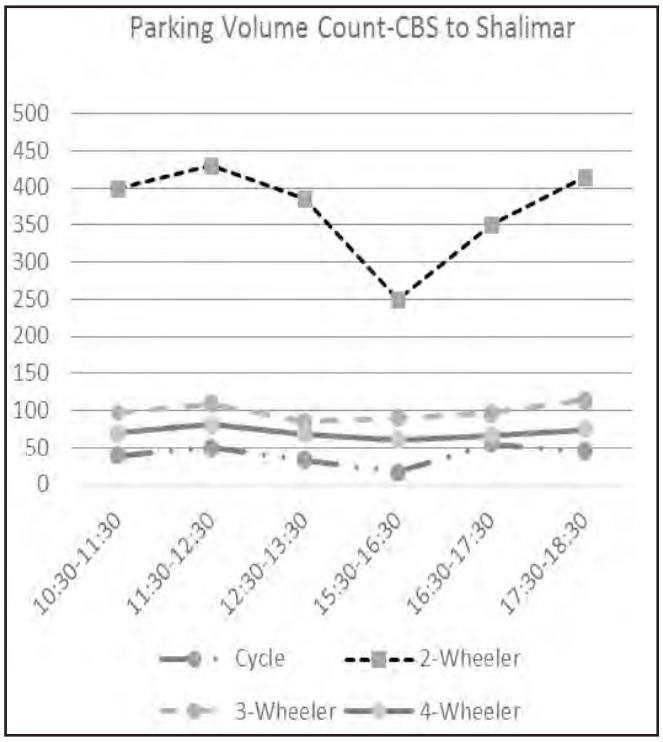

Fig. 7. Parking Volume Counts (CBS to Shalimar)

3) ABB Circle - Jehan Circle

TABLE V.

PARKING VOLUME COUNTS

(ABB CIRCLE - JEHAN CIRCLE)

Location	Time	Cycle	2-Wheeler	3-Wheeler	4-Wheeler
	10:30-11:30	25	412	51	210
ABB	11:30-12:30	35	475	43	215
Circle-	12:30-13:30	18	367	39	190
Jehan	15:30-16:30	17	325	35	170
Circle	16:30-17:30	23	390	37	185
	17:30-18:30	26	430	45	200

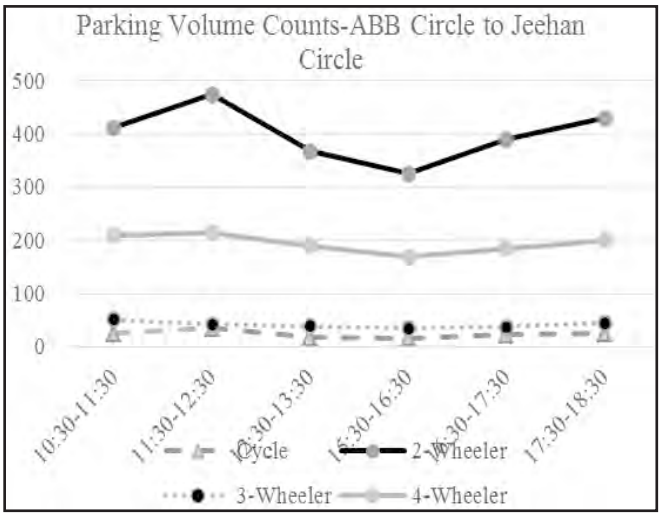

Fig. 8. Parking Volume Counts(ABB Circle – Jehan Circle)

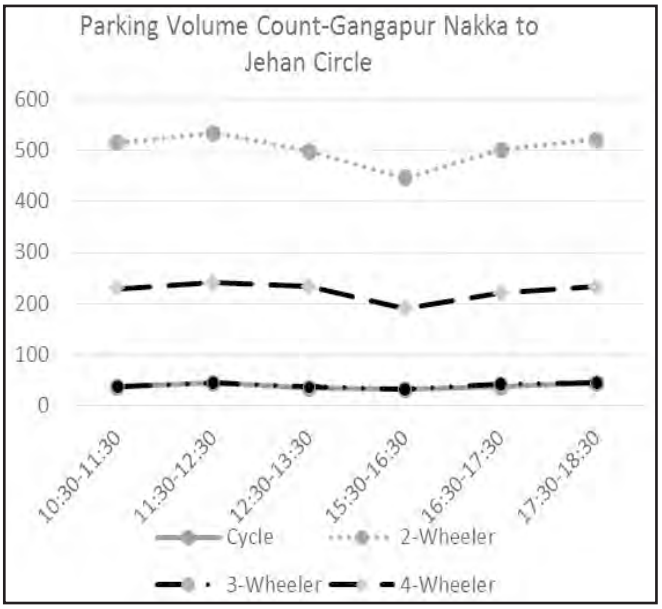

Fig. 9. Parking Volume Counts (Gangapur Nakka – Jehan Circle)

Table V and Fig. 8 show the parking volume counts for ABB Circle - Jehan Circle.

4) Gangapur Nakka - Jehan Circle

Table VI and Fig. 9 show the oarking volume counts for Gangapur Nakka - Jehan circle.

C. Land Use Survey

Land use survey of buildings facing the street was done to observe the relation between existing on-street parking demand and demand generation parameters. Land use was done in the form of use at different floor levels in the building. After identifying the land use on a particular stretch, we would later establish a co-relation between the land-use and parking volumes for the street. Table VII and VIII show the result of land use survey of MG Road and CBS - Shalimar respectively.

TABLE VI.

PARKING VOLUME COUNTS (GANGAPUR NAKKA – JEHAN CIRCLE)

Location	Time	Cycle	2-Wheeler	3-Wheeler	4-Wheeler
	10:30-11:30	38	515	38	230
Gangapur	11:30-12:30	45	534	45	241
Nakka-	12:30-13:30	35	498	37	234
Jehan	15:30-16:30	32	446	32	190
Circle	16:30-17:30	37	501	43	221
	17:30-18:30	45	521	45	233

TABLE VII.

LAND USE SURVEY (MG ROAD)

Section	Building Use	Number of Building	% Land Use	Average number of floors
Red Cross	Commercial	12	54	G+3
Signal-	Residential	5	22	
Meher	Public	2	10	
Chowk	Institutional	0	0	
	Mixed (Comm. + Resi.)	3	14	

TABLE VIII.

LAND USE SURVEY (CBS - SHALIMAR)

Section	Building Use	Number of Buildings	% Land Use	Average number of floors
CBS Police	Commercial	2	28	G+3
Station	Residential	1	14	
Bhardkali to	Public	0	0	
Samrat Sport	Institutional	0	0	
& Musical to				

Shalimar Bus Stop	Mixed (Comm.+ Resi.)	4	58	
Samrat Sport & Muscial to Shalimar Bus Stop	Commercial	16	69	G+2
	Residential	2	9	
	Public	1	4	
	Institutional	0	0	
	Mixed (Comm. + Resi.)	4	18	

TABLE IX.
LAND USE SURVEY (ABB CIRCLE - JEHAN CIRCLE)

Section	Building Use	Number of Buildings	% Land Use	Average Number of Floors
ABB Circle to Parijat Nagar Bus Stop	Commercial	14	15	G+3
	Residential	35	38	
	Public	3	3	
	Institutional	0	0	
	Mixed (Comm. + Resi.)	40	44	
Parijat Nagar Bus Stop to Bhosla Gate	Commercial	18	18	G+3
	Residential	41	42	
	Public	2	2	
	Institutional	1	1	
	Mixed (Comm. + Resi.)	35	37	
Bhosla Gate to Jehan Circle	Commercial	10	16	G+3
	Residential	28	48	
	Public	0	0	
	Institutional	0	0	
	Mixed (Comm. + Resi.)	21	36	

TABLE X.
LAND USE SURVEY (GANGAPUR NAKKA - JEHAN CIRCLE)

Section	Building Use	Number of Buildings	% Land Use	Average number of floors
Juna Gangapur Nakka to VidyaVikas Circle	Commercial	20	31	G+3
	Residential	25	39	
	Public	2	4	
	Institutional	0	0	
	Mixed (Comm. + Resi.)	17	26	
Vidya Vilas Circle to Prasad Circle	Commercial	19	27	G+3
	Residential	30	42	
	Public	1	2	
	Institutional	0	0	
	Mixed (Comm. + Resi.)	21	29	
Prasad Circle to Jehan Circle	Commercial	23	27	G+3
	Residential	35	41	
	Public	2	3	
	Institutional	0	0	
	Mixed (Comm. + Resi.)	24	29	

TABLE XI.
PARKING DURATION (MG ROAD)

Time	Location	Type of Vehicle	Parking Duration: Less than 30 min	30 min 1 Hr	1Hr-3Hrs	Greater than 3 Hrs	Total number of vehicles
Morning	MG Road	2w (Two-Wheeler)	150	90	51	20	311
		4w(Four-Wheeler)	50	22	18	15	105
Evening	MG Road	2w(Two-Wheeler)	178	83	54	21	336
		4w(Four-Wheeler)	43	24	19	13	99

Table IX and X show the results of land use survey for ABB Circle - Jehan Circle and Gangapur Nakka - Jehan Circle respectively.

D. Parking Duration

License Plate method of survey was used to calculate parking durations for the selected locations. This method of survey yields most accurate and realistic data but needs accuracy and speed in collection. Simple random sampling method was used to select vehicles from a parking lot to be listed for the survey. The survey was conducted one day each for both the cases in morning and evening hours. Duration counts were taken in 4 ranges of <30 min., 30 min. – 1 Hr., 1 Hr. to 3 Hrs. and 3Hrs. First class is termed as short term parking, next two classes can be termed as medium term parking, and the last class can be termed as long term parking. At MG Road six parking lots were considered for the study, and the recording was done by cruising on a 2-wheeler.

Table XI to XIV show the parking durations for different roads.

Table XII.

PARKING DURATION (CBS- SHALIMAR)

Time	Location	Type of Vehicle	Parking Duration: Less than 30 min	30 min 1 Hr	1Hr-3 Hrs	Greater than 3 Hrs	Total number of vehicles
Morning	CBS-Shalimar	2w(Two-Wheeler)	120	86	21	11	238
		4w(Four-Wheeler)	35	17	12	6	70
Evening	CBS-Shalimar	2w(Two-Wheeler)	135	57	21	26	239
		4w(Four-Wheeler)	29	17	9	5	60

Table XIII.

PARKING DURATION (ABB CIRCLE - JEHAN CIRCLE)

Time	Location	Type of Vehicle	Parking Duration: Less than 30 min	30 min 1 Hr	1 Hr-3 Hrs	Greater than 3 Hrs	Total number of vehicles
Morning	ABB Circle-Jehan	2w(Two-Wheeler)	167	89	75	68	399
		4w(Four-	89	67	40	56	252
Evening	ABB Circle-Jehan Circle	2w(Two-Wheeler)	198	79	56	67	400
		4w(Four-Wheeler)	93	57	39	69	258

TABLE XIV.

PARKING DURATION

(GANGAPUR NAKKA - JEHAN CIRCLE)

Time	Location	Type of Vehicle	Parking Duration: Less than	30 min 1 Hr	1Hr-3Hrs	Greater than 3 Hrs	Total number of vehicles
Morning	Gangapur Nakka-Jehan Circle	2w(Two-Wheeler)	268	151	90	76	585
		4w(Four-Wheeler)	112	78	57	51	298
Evening	Gangapur Nakka-Jehan Circle	2w(Two-Wheeler)	256	162	91	78	587
		4w(Four-Wheeler)	109	74	54	49	286

E. Parking Space Inventory

Parking space inventory captures the actual physical characteristics of the parking space. This survey is the first survey required to start physical design or parking load calculation. After delineation of the survey we tried to calculate the parking space inventory in the form of actual parking space available, parking patterns, street furniture etc. The following list shows the items that need to be observed during the survey:

i) Number of parking spaces currently available based on the pattern of parking.

ii) Location of bus stops, pedestrian crossing, signals, parking restriction signage, and other street furniture.

iii) ight of way available.

iv) Encroachments and temporary structure.

v) Special features like the BRT corridor etc.

vi) Characteristic of the street in form of median divided street, effective usable road width etc.

Table XV shows the parking space inventory.

F. Analysis

1) MG Road Analysis

Land use characteristics show that from Red Cross Signal to Meher Chowk, about 68% of land is used by commercial buildings. Most of the buildings don't have off street parking space for visitors that come for a commercial purpose, and they park their vehicles on the streets in random positions. The total length of the road is 300 m. and the available space for parking is 752 sq.m.

The parking space is calculated on the following assumptions:

Ÿ 2-Wheeler parking is done perpendicular to streets and 4-Wheeler parking is done parallel to the streets.

Ÿ Parking is done in front of the entrance of the building, at junctions, or in front of bus stop.

Ÿ Area required at peak hour (11:30-12:30) is 1966 sq.m. Equivalent Car Space (ECS).

Table XVI, table XVII, and table XVIII show the peak hour demand, parking area demand, and parking supply percentage for MG Road respectively.

The available total area for parking is 752 m^2 for

TABLE XV.

PARKING SPACE INVENTORY

Location	Row (m)	Effective Row (m.)	Parking Area sq.m.	Number of bus stops	Number of street furniture
MG Road	19	10.5	752	0	97
CBS-Shalimar	21	11	1092	1	73
ABB Circle-Jehan Circle	21	11	2570	3	83
GangapurNakka-Jehan Circle	21	11	3102	5	75

TABLE XVI.
PEAK HOUR DEMAND-MG ROAD

Section	Cycle (ECS)	ECS	Area (m^2)	2w (Two-Wheeler) (ECS)	ECS	Area (m^2)
MG Road	2.6	1.35%	19.5	91.8	47.71%	734.4
	3W (ECS)	**ECS**	**Area (m^2)**	**4w(Four-Wheeler) (ECS)**	**ECS**	**Area ($m^{2)}$**
	10	5.19%	111.5	88	45.73%	1100

TABLE XVII.
PARKING AREA DEMAND-MG ROAD

Section	Vehicle Type	Tota ECS	Peak Demand Area	% of Total Supply
MG Road	Cycle	12.6	19.5	3.00%
	2w(Two-Wheeler)	576	878.4	134%
	3w	31.5	111.5	17.00%
	4w(Four-Wheeler)	467	1100	168.00%
	Average	272	528	81%

TABLE XVIII.
PARKING SUPPLY PERCENTAGE-MG ROAD

Section	Time	Total ECS	Area Req. (m^2)	% of Supply
MG Road	10:30-11:30	177.3	975.15	149%
	11:30-12:30	210.4	1157.2	177%
	12:30-13:30	179.6	987.8	151%
	15:30-16:30	156.6	861.3	132%
	16:30-17:30	197.2	1084.6	166%
	17:30-18:30	181.7	999.35	153%
	Average	183.8	1010.9	155%

which an average daily demand as percentage of supply is 81%. Peak day demand exceeds the available supply by 55%, that is, parking on the illegal side is also counted in this demand. Thus, this exceeded demand causes congestion on this road. To avoid the congestion, the parking space needs to be designed in a strategic manner to be able to counter the peak demand level.

2) CBS - Shalimar Road Analysis

Land use characteristics show that from CBS Police Station Bhardkali to Shalimar bus stop, about 44% of land is in use by commercial buildings. Most of the buildings don't have off street parking space for visitors that come for a commercial purpose, and they park their vehicles on streets in random positions. The total length of the road is 600 m and the available space for parking is 1092 sq.m.

TABLE XIX.
PEAK HOUR DEMAND-SHALIMAR TO CBS

Section	Cycle (ECS)	%ECS	Area (m^2)	2w (Two-Wheeler) (ECS)	ECS	Area (m^2)
Shalimar-	5	2.20%	37.5	86	37.88%	688
CBS	**3W (ECS)**	**ECS**	**Area (m^2)**	**4w(Four-Wheeler) (ECS)**	**ECS**	**Area (m^2)**
	55	24.22%	613.25	81	35.68%	1012.5

TABLE XX.
PARKING AREA DEMAND- SHALIMAR TO CBS

Section	Vehicle Type	Total ECS	Peak Demand Area	% of Total Supply
	Cycle	24.2	37.5	3.45%
CBS to	2w(Two-Wheeler)	446	688	63%
Shalimar	3w	297.5	613.25	56.15%
	4w(Four-Wheeler)	423	1012.5	92.71%
	Average	298	588	55%

TABLE XXI.
PARKING SUPPLY PERCENTAGE- SHALIMAR TO CBS

Section	Time	Total ECS	Area Req. (m^2)	% of Supply
	10:30-11:30	131	589.5	54%
	11:30-12:30	227	1021.5	94%
CBS to	12:30-13:30	191.9	863.55	80%
Shalimar	15:30-16:30	158.1	711.45	71%
	16:30-17:30	191	859.5	79%
	17:30-18:30	220	990	91%
	Average	186.5	839.25	78%

Table XIX, table XX, and table XXI show the peak hour demand, parking area demand, and parking supply percentage for Shalimar to CBS respectively.

3) ABB Circle - Jehan Circle Road Analysis

Land use characteristics are divided into three parts because the total length of the road is more. First, from ABB Circle to Parijat Bus Stop, about 30% of land is in use by commercial buildings. Second, from Parijat Bus Stop to Bhosla Gate, about 28% of land is in use by commercial buildings. Third, from Bhosla Gate to Jehan Circle, about 26% of land is in use by commercial buildings. Most of the buildings don't have off street parking space for visitors that come for a commercial purpose and they park their vehicles on the streets in random positions. The total available space for parking is 2570 sq.m.

TABLE XXII.
PEAK HOUR DEMAND-ABB CIRCLE TO JEHAN CIRCLE

Section	Cycle (ECS)	ECS	Area (m^2)	2w(Two-Wheeler) (ECS)	ECS	Area (m^2)
ABB Cricle -Jehan Circle	3.5	1.10%	26.75	95	28.35%	760
	3W (ECS)	**ECS**	**Area (m^2)**	**4w(Four-Wheeler) (ECS)**	**ECS**	**Area (m^2)**
	21.5	6.41%	239.72	215	64.14%	2687.5

TABLE XXIII.
PARKING AREA DEMAND- ABB CIRCLE TO JEHAN CIRCLE

Section	Vehicle Type	Total ECS	Peak Demand Area	% of Total Supply
ABB Circle-Jehan Circle	Cycle	14.4	26.25	1.00%
	2w(Two-Wheeler)	479.8	760	25%
	3w	125	696.87	22.50%
	4w(Four-Wheeler)	1170	2687.5	87.00%
	Average	447	1043	34%

TABLE XXIV.
PARKING SUPPLY PERCENTAGE- ABB CIRCLE TO JEHAN CIRCLE

Section	Time	Total ECS	Area Req. (m^2)	% of Supply
ABB Circle-Jehan Circle	10:30-11:30	320	1600	52%
	11:30-12:30	335	1675	55%
	12:30-13:30	284.7	1423.5	46%
	15:30-16:30	253.2	1266	41%
	16:30-17:30	213.8	1069	35%
	17:30-18:30	314.1	1570.5	51%
	Average	286.8	1434	47%

The average demand as a percentage of supply is 34% throughout the day, while parking supply percentage demand is 47%. As per the analysis, the demand of parking in this route is minimum, so the traffic congestion is minimum. For the current situation there is no need of any changes in the parking facilities.

4) Gangapur Nakka-Jehan Circle Road Analysis

Land use characteristics are divided into three parts because the total length of the road is more. First, from Juna Gangapur Nakka to Vidya Vikas Circle, about 29 % of the land is in use by commercial buildings. Second, from Vidya Vilas Circle to Prasad Circle, 28% land is use by commercial buildings,. Third from Prasad

TABLE XXV.
PARKING AREA DEMAND- GANGAPUR NAKKA TO JEHAN CIRCLE
(a)

Section	Cycle (ECS)	%ECS	Area (m^2)	2w(Two-Wheeler) (ECS)	ECS	Area (m^2)
Gangapur Nakka-Jehan Circle	4.5	1.18%	33.75	106.8	28.49%	854.4
	3W (ECS)	**%ECS**	**Area (m^2)**	**4w(Four-Wheeler) (ECS)**	**%ECS**	**Area (m^2)**
	22.5	6.00%	250.87	241	64.30%	3012.5

TABLE XXVI.
PARKING AREA DEMAND- GANGAPUR NAKKA TO JEHAN CIRCLE
(b)

Section	Vehicle Type	Total ECS	Peak Demand Area	% of Total Supply
Gangapur Nakka-Jehan Circle	Cycle	23.2	33.75	1.50%
	2w (Two-Wheeler)	630	854.4	33%
	3w	120	750.8	29.30%
	4w(Four-Wheeler)	1349	3012	117.00%
	Average	531	1163	46%

TABLE XXVII.
PARKING SUPPLY PERCENTAGE- GANGAPURNAKKA TO JEHAN CIRCLE

Section	Time	Total ECS	Area Req. (m^2)	% of Supply
Gangapur Nakka-Jehan Circle	10:30-11:30	355.8	1956.9	77%
	11:30-12:30	374.8	2061.4	81%
	12:30-13:30	355.6	1955.8	77%
	15:30-16:30	298.4	1641.2	64%
	16:30-17:30	346.5	1905.75	75%
	17:30-18:30	364.2	2003.1	78%
	Average	349.2167	1920.69	75%

- Circle to Jehan Circle about 28.5 % of land is in use by commercial buildings. Most of the building don't have off street parking space for visitors that came for a commercial purpose and they park their vehicles on the streets in random positions. The total available space for parking is 3102 sq.m.
- The average parking area demand of total supply is 46% throughout the day, while parking supply percentage demand is 75%. From table XXVI we can say that the demand of the parking is minimum, so there will

no congestion on the roads. In the peak hours, the parking area demand is slightly greater, but due to more available space for parking the congestion on that road is minimum, as compared to other roads in the city.

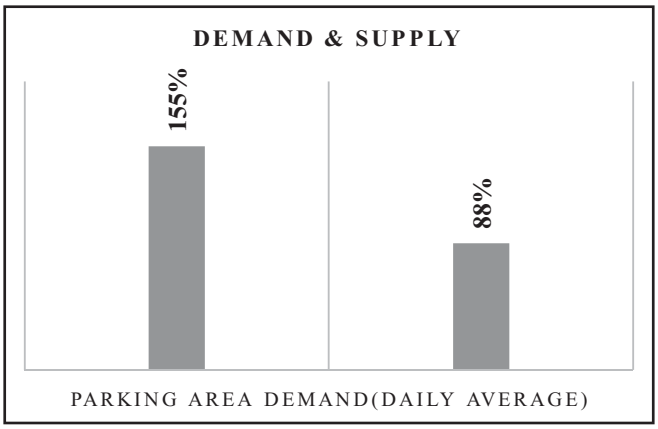

Fig. 10. Demand & Supply (M.G Road)

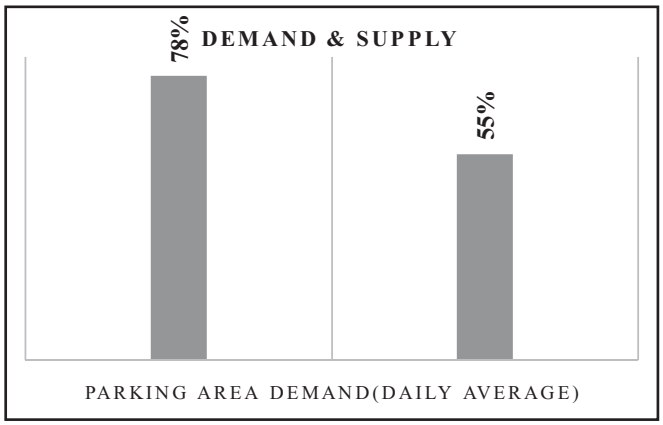

Fig. 11. Demand & Supply (CBS-Shalimar Road)

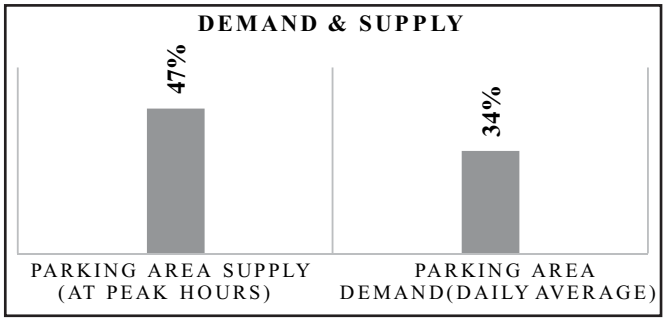

Fig. 12. Demand & Supply (ABB Circle – Jehan Circle)

VI. RESULT AND PROPOSAL

A. Result

1) M.G. Road: The total length of the road from Red cross signal to Meher Chowk is 300 m, and the space available for parking is 752 m^2. From the previous analysis, at the peak hours the load is 55% more than average daily demand of the parking due to shortage of space for parking at MG Road.

2) CBS-Shalimar Road: The total length of the road from CBS Police Station Bhardkali to Shalimar Bus Stop is 600 m and the space available for parking is 1092 m^2. It can be seen from the analysis at the peak hours that percentage of supply is 78%. It is greater than daily average supply percentage of the parking demand, due to the slight congestion at this route is caused.

3) ABB Circle - Jehan Circle Road: The total length of the road from ABB Circle to Shalimar Bus Stop is 2600 m and the space available for parking is 2570 m^2. From the analysis it can be seen that there is no traffic congestion due to sufficient parking space, and at peak hour there is lot of space for parking vehicles.

4) Gangapur Nakka - Jehan Circle Road: The total length of the road from ABB Circle to Jehan Cricle Bus Stop is 1800 meter and the space available for parking is 3102 m^2. From the analysis it can be seen that there is no traffic congestion due sufficient parking space and at peak hour there is lots of space for parking vehicles.

B. Proposal

1) Financial Model & Pricing:

In [1] it is said that to manage parking demand or congestion, parking pricing is one of the several

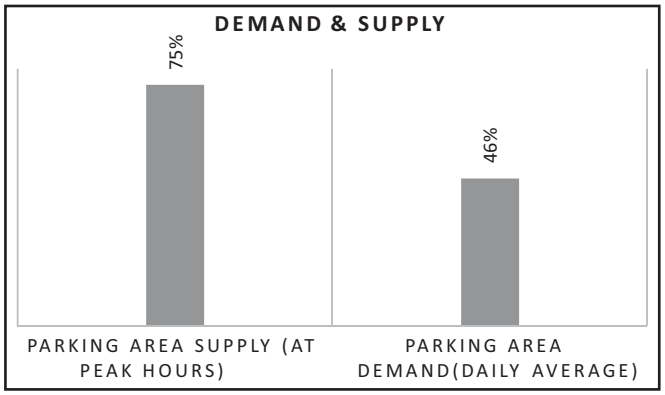

Fig. 13. Demand & Supply (GangapurNakka-Jehan Circle)

mechanisms. For this study, there is very little existing data, and negligible past data that can help to start the study for the city. Parking pricing is the tool selected to investigate and regulate the existing parking demand, and achieve the objective of promotion of pedestrian movement and bicycle use. MG Road has been selected as the pilot case to understand the parking behavior, and implement parking management program. According to a study, on-street parking in combination with free off-street parking lot is a suitable strategy to allocate space for existing demand. We try to provide a pricing mechanism that makes the scheme financially viable. Three pricing schemes have been proposed out of which the most efficient one shall be recommended. Following are the pricing schemes proposed:

a) Flat rate pricing scheme: The parking fee under this scheme shall be for a long duration in the first slot, for example, for 4 hours, and additional for subsequent hours. The study shows that the average parking duration for vehicles at MG Road is 35 minutes, which is much lower than the time duration of the first slot. Volume of long term parking vehicles is also less than 25%. This scheme is invariably promoting long term parking of vehicles and thus, promoting congestion by penalizing short term parking vehicles. This scheme is currently being employed at Kalupur railway station off-street parking facility, and provides service to daily commuters from the railway. Charge for 2-w is ₹ 5, while charges for 4-w are ₹ 10. This scheme is not based on any demand management principles, and has been put in place to generate revenue from railway land. This pricing scheme cannot be used for the demand management mechanism because intent is not to penalize short term parking vehicles by imposing long term fee, but it tries to provide incentive to short term trips having minimum frequencies by charging lower fees in proportion to long term parking vehicles.

b) Hourly Parking Fee: The fee for every hour is same and thereby, increases in a linear pattern. This pricing is an hourly flat rate mechanism that does not incentivize short term parking vehicles over long term parking vehicles. Since past data did not exist in terms of volume of vehicle category, it was difficult to determine the price elasticity of demand. This can be considered as one of the pricing strategies to be implemented.

c) Short term incremental pricing: Basic concept of this mechanism is classifying parking vehicles in smallest possible time slots based on the average parking duration. The study adopts 30 minutes as the minimum time slot for parking since average parking duration is 35 minutes. Parking fee in this mechanism rises with fixed percentage over previous time slot to regulate, and minimize long term parking vehicles.

The objective of this pricing mechanism is to achieve objectives of demand management in the form of reduction in parking duration, reduction in frequency of trips, shifting out long term parking vehicles from congested areas, provide controlled parking space, and easy traffic movement etc. The proposed scheme provides parking facility in combination with paid on-street parking system, and free off-street parking scheme. There are the two basic costs involved. These are :

i) Physical infrastructure costs
ii) Management costs

Fig. 14 shows the process of pricing for the proposed facility. This can be considered as general pricing mechanism for demand management in the city. Following are the assumptions on which the model has been based :

i) Life of the project is 12 years after which the scheme needs to be redesigned (consultation with MG Road paid parking facility management).
ii) Payback period of the project is considered as 3 years for computing parking pricing and servicing the future demand through suitable review methods.
iii)Project development duration is 12 months.
iv) Growth rate of 2w (Two-Wheeler) is 21% per annum, and of 4w (Four-Wheeler) it is 14% per annum with an average of 18% per annum.
v) Parking space for 3w and cycles shall not be charged in both on and off street spaces.
vi) Pricing shall be designed for supply level of either 100% and or 85% to propose pricing mechanism.

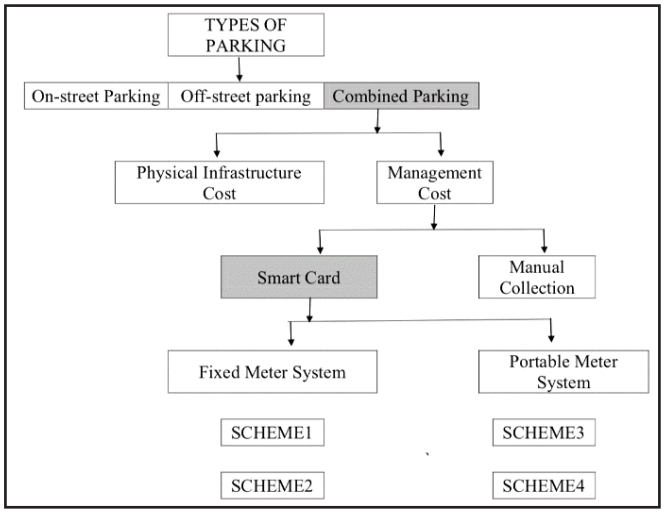

Fig. 14. Types of Parking & Parking Schemes

vii) Fee increment factor of 12% has been considered for every subsequent time slot for incremental pricing linear pricing model (Demand peaks and drops by approximately 12% in morning peak hours).
viii) Facility shall be funded and operated/managed by the municipality considering risk free rate of return of 7.5% (return on government bonds), and 5% rate of inflation for calculating break even time or entirely contracted to private sector.
ix) The pricing shall be reviewed at the end of first year of operation, and revised based on the change in rate of return and increment in rate of demand.
x) The demand is expected to double every five years on the basis of vehicular growth rate and land use pattern (Traffic study GIDB 2004).
xi) Off-street parking lot is at ground level and provided free.
xii) There exists no subsidy component in the model and the price increment is taken as 10% YoY which is subject to change upon the annual review of the project

Limitations of this model are as follows:
i) There exists no past data that can provide a base price to start with and understand the price elasticity of demand.
ii) The proposed case has no formal parking arrangement existent.
iii) Schemes like park and ride facility, off-street parking space sharing etc. cannot be implemented currently since trip lengths are short and off-street spaces are of low capacity.
iv) The model has three basic parameters of demand, supply, and price out of which one needs to be kept constant (supply).

As proposed, pricing shall be applicable only to 2w (Two-Wheeler) and 4w (Four-Wheeler) volumes with 30% deduction in daily revenue as experienced in MG Road. This deduction is because of absence of attendant, problems with meter, break time/shift change, and other reasons. Daily cost per ECS of the project is ₹ 22,483 and daily demand is almost 3,212 ECS with 320 ECS during peak hour. 2w (Two-Wheeler) turnover is high that contributes to high daily ECS volume. Preliminary fare calculation is done by calculating expected revenue per day at 12.5% RoR which is ₹120 ECS/day. This amount gives break even at 7 years and 10 months which cannot be considered as an appropriate pay back duration if the work is supposed to be contracted. Pricing schemes were therefore, calculated taking into consideration different pay back periods and a payback period of 4 years was found to provide with acceptable pricing scheme. This calculation gave the following linear and incremental pricing schemes:

i) Linear pricing scheme: The daily revenue was distributed into two vehicle categories based on percentage of vehicle in different time slot. This pricing scheme gives a payback in a period of 4 years but has few drawbacks as follows:

- The duration slots are hourly that don't incentivize the short term parking vehicles.
- Due to linear pricing possibility of converting long term parking into short term parking reduces since hourly fee is same.

ii) Incremental pricing scheme: Incremental pricing scheme tries to minimize long term trips by charging exponentially higher than short term parking vehicles as per the following pricing scheme.

This pricing scheme collects less revenue than linear pricing but has fair chance of converting long term trips to short term trips, and increasing the turnover. Other pricing schemes can be time of day pricing, eco-pricing (based on emission levels of different vehicle categories), and real time pricing (based on instantaneous parking demand).

Implementation of these schemes, and the success depends highly on the field staff, and collection mechanism on ground. Two major contributing factors for success of any parking scheme are enforcement, and institutional arrangement to operate and manage the facility.

TABLE XXVIII.

LINEAR PRICING SCHEME

Vehicle revenue	1 hr	2 hr	3 hr	4 hr	5 hr	Monthly Type
2-Wheeler	₹ 6	₹ 12	₹ 18	₹ 24	₹ 30	₹ 4,85,352/-
Number of vehicles	2269	300	201	95	0	
4-Wheeler	₹ 10	₹ 20	₹ 30	₹ 40	50	₹ 4,56,540/-
Number of vehicles	916	248	175	37	19	

TABLE XXIX.

INCREMENTAL PRICING SCHEME

Vehicle Type	1 hr	2 hr	3 hr	4 hr	5 hr	Monthly revenue
2-Wheeler	₹ 3	₹ 6.36	₹ 10.12	₹ 14.34	₹ 19.1	₹ 2,54,335/-
Number of vehicles	2269	300	201	95	0	
4-Wheeler	₹ 10	₹ 21.2	₹ 33.75	₹ 47.8	₹ 63.55	₹ 4,89,297/-
Number of vehicles	916	248	175	37	19	

VII. CONCLUSION

From the analysis and results, we came to the conclusion that in this project for selected roads in the city, there are some roads which have traffic problem which cause congestion. These are discussed as follows:

A. M. G. Road

From the study and analysis, we came to know that at peak hours there is parking problem to overcome this problems. We can provide On-Street parking with pricing proposal, which is given above which is beneficial for Municipal Corporation. It gives revenue to the municipal corporation due to which financial stability is increased.

B. CBS-Shalimar Road

From the study and analysis, we came to know that at peak hours the there is a slight parking problem to overcome these problems, we can provide on-street parking with pricing proposal or off-street parking at BD Bhalekar high school ground, which is near the Shalimar Bus Stop which is given beneficial for Municipal Corporation.

C. ABB Circle – Jehan Circle Road

According to the study and analysis of this road, we came to know that at peak hours there is minimum parking problem to overcome this problem. There is provision of on-street parking due to which parking problems are minimum at this road, but here on this road we can provide on-street parking with pricing proposal given above which is beneficial for Municipal Corporation. It gives revenue to the municipal corporation due to which financial stability is increased.

D. Gangapur Nakka – Jehan Circle Road

According to the study and analysis of this road, we came to know that at peak hours there is very low frequency parking problem. To overcome this problem, we can use the road width on which we can provide on-street parking marking with pricing models due to which parking problems can be minimized, and this will be beneficial for Municipal Corporation. It gives revenue to the municipal corporation due to which financial stability is increased.

VIII. FUTURE SCOPE

i) Using the analysis & pricing models discussed in the project, parking problems in other parts of the city can be solved.
ii) Parking problems in other cities can be solved with help of this analysis & pricing model.

Fig. 15. BD Bhalekar High School Ground

Fig. 16. On-Street Parking Marking of ABB-Jehan Road

Fig. 17. Open Space on Gangapur Nakka – Jehan Circle Road

REFERENCES

[1] N. Vidwans and A. Pandey, "Management plan for parking in Ahmedabad," Department of Policy Studies, TERI University, New Delhi, 2009.

[2] Perth Parking Policy, Transport Report 393, May 1998.

[3] S. K. Khanna and C. E. C. Justo, "Highway and Transportation Engineering," Nemchand Brothers, 1976.

[4] Ministry of Urban Development, Government of India, "National Urban Transport Policy 2014." Retrieved from http://www.itdp.in/wp-content/uploads/2014/11/NUTP-2014.pdf

[5] S. K. Singh, "Study of parking patterns for different parking facilities," *International Journal of Civil and Structural Engineering Research*, vol. *2*, pp.35-39.

[6] U. S. Dandotia, R. Gupta, M. Pandey, "Study of analysis and design of multi-level parking," vol. *4*, no. *2*, pp. 1412-1414, 2016. *International Journal of Engineering Development and Research*. [Online]. Available: https://www.ijedr.org/papers/IJEDR1602251.pdf

[7] Reddy, V. K. and S. Laxmeshwar, "Design and development of low cost automatic parking assistance system," *International Journal of Computer Applications,* pp. 17-22. [Online]. Available: https://pdfs.semanticscholar.org/b318/411980628558c20ac52f02d988c04222cd25.pdf

[8] R. Kaur and B. Singh, "Design and implementation of car parking system on FPGA (Field Programmable Gate Array)," 2013.

[9] C. Wang, M. A. Quddus, and S. G. Ison," Impact of traffic congestion on road accidents: A spatial analysis of the M25 motorway in England," Accident Analysis & Prevention, vol. *41*, no. *4*, pp. 798-808, 2009. doi: 10.1016/j.aap.2009.04.002

[10] D. Shefer and P. Rietveld, "Congestion and safety on highways: Towards an analytical model," *Urban Studies,* vol. *34*, no. *4*, pp. 679-692, 1997. doi: https://doi.org/10.1080/0042098975970

[11] T. V. Mathew and K. V. K. Rao, "Parking," In *Introduction to Transportation Engineering*, pp. 1-10, 2007. [Online]. Available: https://nptel.ac.in/courses/105101087/downloads/Lec-38.pdf

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