APPRAISAL OF CONGESTION AND TACTICS TO COUNTER IT IN CENTRAL BUSINESS DISTRICT (CBD) OF A CITY: CASE STUDY- MAHARAJA BADA GWALIOR

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Abstract - *In most places in the world, traffic congestion is an issue that has adverse implications. The central business districts (CBD) of many big and medium-sized cities in India, in particular, face the challenges of traffic congestion and suffer the consequences of this mobility issue, congestion is brought on by an assortment of factors, including increasing population density, rapid urbanization and motorization and most importantly, the simultaneous integration of administrative, socioeconomic, and commercial activities in the CBDs. This paper examines the state of traffic congestion in the Maharaja Bada area of the city of Gwalior, which is an important CBD of the city but currently experiencing severe congestion issues. In this regard, spot speed, active road width, and volume of every kind of vehicle on the major roads of the Maharaja Bada area during peak hours on weekdays have been evaluated using manual counting and video recording techniques. The Level of Service (LOS), Speed Performance Index (SPI), and Active Road Performance Index (ARPI) have all been used as indicators of the level of traffic congestion in the research area. The results of these indices concluded that all the major roads in the study area are facing the worst traffic congestion state. Specific recommendations are proposed for improving the current congestion state of the study area. Hopefully, the findings of the study will make a valuable contribution to the field of sustainable development.*

Key Words: Congestion, Urbanization, Motorization, Central Business District, Sustainable Development

1.INTRODUCTION

Urban India is becoming more motorized than its urban population, most cities are seeing annual increases in automobile ownership of 15-20% according to reports of (The Ministry of Road Transport and Highway). Automobiles fulfill our need for mobility however, it leads to traffic congestion in cities .Traffic congestion is characterized as a physical phenomenon where there is a shortage of available road space, which results in slower driving speeds, longer travel times, and more motor vehicle queuing [1] . According to Blanco [2] the lack of adequate transportation amenities, such as adequate parking, road space, and traffic signals, leads to traffic congestion. One of the major cause of traffic congestion is due to lack of infrastructure for non-motorized vehicles in the cities, fast and slow moving vehicles frequently mingle on the same road, causing traffic jams in CBDs

Today many Indian cities are facing negative impacts traffic congestion but mostly these problems gets exaggerated in the central business districts (CBD) of the cities .Throughout history the CBD has been characterized by a number of land use changes that include industrial, residential, commercial, administration, and consumption [3] as a result CBD of cities is facing this congestion issues due to the nature and characteristics of these areas . Maharaja Bada is the most important CBD of Gwalior it has a centrally located chowk which is surrounded by thriving bazaars. It is one of Gwalior's and Madhya Pradesh's most prominent markets, Due to the importance of Maharaja bada it has to cater negative effects of urbanization and motorization every day which are problems like traffic congestion, parking issues, pollution in these area, these issues are exacerbated by factors like lack of traffic regulations, accessible public transportation and planning for Non-Motorized Transport (NMT), CBD areas of rapidly growing cities like Gwalior are congested all the time especially in peak hours of the day .Congestion relief and establishing an excellent transit infrastructure in CBD areas are two of the most critical challenges for any city's long-term economic success. The study aims to identify the current congestion scenario in the Maharaja Bada area of Gwalior, and to propose strategies for sustaining this area from the negative effects of congestion, Main objectives of the research are i- To determine the level of congestion through indices on the major roads of the study area through several congestion indices   ii-To identify factor responsible for traffic congestion in the study area. iii-To Identify strategies to tackle traffic congestion in study area. Several proposals are given at the end which can be used by government to shift the mobility planning towards more sustainable future of the area .

2. CITY OUTLINE

Gwalior is one of the counter magnet cities, located in Madhya Pradesh. It is 343 kilometers (213 miles) south of Delhi, 120 kilometers (75 miles) from Agra, and 414 kilometers (257 miles) from Bhopal the state capital (Google Maps) .Municipal Corporation covers an area of 372.22 sq. km. which is divided into 66 wards with population of 1600000 approx (Gwalior Development Plan 2035, 2021).
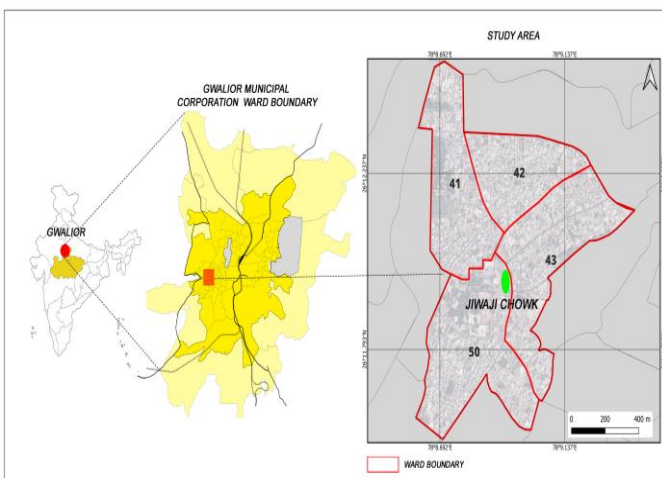
3. METHODS AND MATERIALS

1.1 Study Area

Figure 1 : Location of Gwalior and Study Area

Maharaja Bada is the most important CBD of Gwalior. It is one of Gwalior's and Madhya Pradesh's most prominent markets. Mainly 4 wards covers the maharaja bada area which are shown in Fig.1 and details of which is depicted in Table 1. There are several important and large markets in or near Maharaj Bada , including Sarafa Bazaar, Topi Bazaar, Subhash Market ,Nazarbagh Market, Gandhi Market, Daulatganj, and others. Aside from these large markets, there are a number of smaller markets in the Maharaj Bada area .

Maharaja Bada also has a historical importance for city Gwalior as many tourists visit jiwaji chowk as it is a magnificent grand square is flanked by seven different historic buildings which are built in various architectural styles.

Table -1 : Study Area Ward

Ward no.	Area in Sq kms	Population in 2011	Estimated Population in 2023	Population Density (2023)
41	0.35	11751	15976	45645
42	0.2	9669	13145	65726
43	0.32	12319	16748	52338
50	0.35	11232	15270	43629
Total	1.22	44971	61139	50114

1.1 Major Roads and Circulation

There are 5 primary roads that lead to the Jiwaji Chowk from which traffic can enter and exit. Traffic arrives from three entrance points - Daulat Ganj, Maharaja Bada Road, and Gandhi Market, and can exit from 2 routes which are Madhavganj road and sarafa bazar road as depicted in Fig. 2.
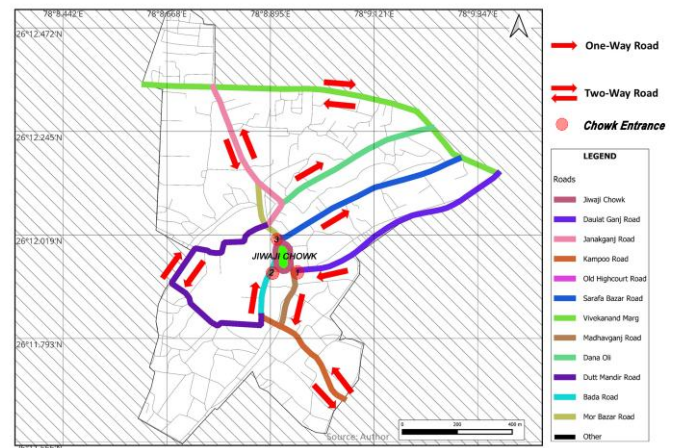

Figure 2 : Roads Circulation Map

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1.2 Methodology

1.2.1   Data Collection

To evaluate the traffic congestion status of the Maharaja Bada, mainly three congestion indices were introduced namely Active Road Performance Index (ARPI), Level of Service (LOS), Speed Performance Index (SPI index) further to analyze these indices several surveys were conducted which involves the measurement of traffic volume on all the major roads of study area, spot speed of vehicles on roads and active road width. These indices were analyzed to understand the intensity of congestion issues CBD is facing. It became apparent that NMT

transport and illegal hawkers have a significant impact on the neighborhood. All of the surveys were carried out between April 2023 and July 2023 during the busiest hours of the weekdays (6:00–7:00 PM). The surveys were carried out using manual counting and video recordings to the survey's requirements.

3.2.2 Level of Service (LOS) and Passenger Car Unit (PCU)

LOS provides a qualitative measurement of traffic on the roads. The type of facility, current traffic patterns, and other factors like heterogeneity of traffic, on-street parking, roadside commercial activities, pedestrian volumes influences level of service [4] . In this study, the Volume to Capacity ratio—a tried-and-true and accurate approach for calculating Level of Service—is used to determine the LOS of the Roads and junctions. [5]
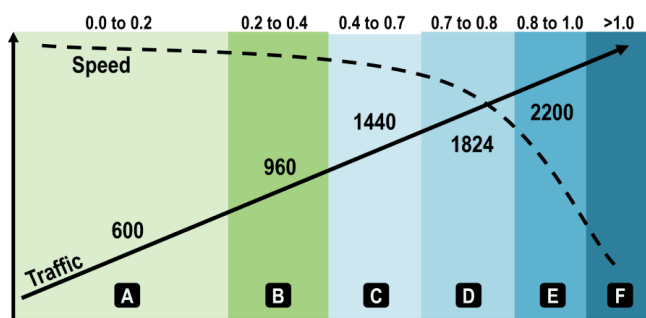

Chart 1- Levels of Services for Road Transportation (Source-Transportation Research Board (1994) Highway Capacity Manual, 3rd Edition.)

The LOS can be determined by measurement of hourly traffic volume passing at a particular section of the road (v) and by knowing the capacity of volume which can pass (C), the ratio of volume and capacity is calculated .The scale intervals of the volume-to-capacity ratio, as given in Chart 1, can be used to calculate the LOS of a roadway.

Each of the six service levels is identified and assigned a letter from A to F (Table 2). The best operating conditions are indicated by LOS A, and the worst operating conditions are indicated by LOS F. Thus with the help of LOS we can determine the quality of service road is providing for the traffic to flow .

Table -2 : LOS criteria as per V/C

LoS Class	Traffic State and Condition	V/C Ratio
A	Free flow	0–0.60
B	Stable flow with unaffected speed	0.61–0.70
C	Stable flow but speed is affected	0.71–0.80
D	High-density but the stable flow	0.81–0.90
E	Traffic volume near or at capacity level with low speed	0.91–1.00
F	Breakdown flow	>1.00

Passenger Car Unit - A metric known as the Passenger Car Unit (PCU) is used in transportation engineering to measure the rate of vehicles moving along an urban road. A method of transportation's effect on traffic characteristics (such as headway, speed, and density) relative to a single standard passenger car is measured in passenger car units. It's also referred to as passenger car equivalent [5] ,values as per IRC-65 are shown in Table 3.

Table-3 : Recommended PCU factors (irc-106-1990)

Vehicles	PCU	PCU If Percentage composition of vehicle>10%
Car	1	1
2-Wheeler	0.5	0.75
Auto	1.2	2
LCV	1.4	2
HCV	2.2	3.7
Cycle	0.4	0.5
Other	4	4

3.2.3 Road Inventory and Active Road Performance Index (ARPI)

Road inventory survey is a thorough survey that can be used to profile the roads in the study area. Features like road/pavement widths, pavement types, encroachments, the presence of vendors/street furniture, bus stops, etc. can be studied and detailed [6] , the data was used to analyze the Active Road Performance Index(ARPI).

ARPI determines the active portion or percentage of the road width, the usable road width when occupied by illegal hawkers, on street parking or other it narrows the active width of the road and often leads to congestion Active road width decreases and influences traffic congestion. The active road percentage at the chosen traffic nodes was calculated using ARPI in the present research. The greater the ARPI number, the less road width is used by unlawful parking or other types of activity [7] .The active road performances for the major Maharaja Bada roads were defined in this study using ARPI and is calculated using the following formula-

$$ARPI = \left(1 - \frac{RW_{bo} + RW_{op} + RW_{rb}}{RW_t}\right) \times 100$$

Where,
RW_{bo}-Road width occupied by informal activites, RW_{op}-Road width occupied by On-street Patking, RW_{rb}- Road width occupied by buildings

3.2.4 Speed Survey and Speed Performance Index (SPI)

The speed performance index has been proposed by **Beijing Traffic Management Bureau (BTMB)** as an evaluation indication of the state of urban road traffic

based on those data. The index value, which ranges from 0 to 100, represents the speed of the vehicle in relation to the maximum speed allowed. The two numbers (25, 50)

$$R_v = \frac{v}{V_{max}} \times 100$$

where,

R_v denotes the speed performance index;

v denotes the average travel speed, km/h;

V_{max} denotes the maximum permissible road speed, km/h.

are chosen by BTMB as the classification criteria for the state of urban road traffic. But in this study 3 thresholds value were taken (25,50,75,) for classification of urban road affic condition [8] The evaluation of Speed

Table 4-Quality of Flow as per thresholds value

Speed Performance Index	Traffic State Level	Description of Traffic State
[0,25]	Heavy Congestion	The average speed is low, road traffic state poor.
(25,50]	Mild Congestion	The average speed is lower, road traffic state bit weak.
(50,75]	Smooth	The average speed is higher, road traffic state better.
(75,100]	Very Smooth	The average speed is high, road traffic state good.

Performance Index will determine the quality of traffic movement along a route and the magnitude of delays along the same route. This enables the planners to make improvements. SPI index is calculated using the formula-Decrement in SPI index value represents high state of congestion on the road as shown in Table 4

4. DATA ANALYSIS AND FINDINGS

4.1 Assessment of Traffic Congestion scenario through indices

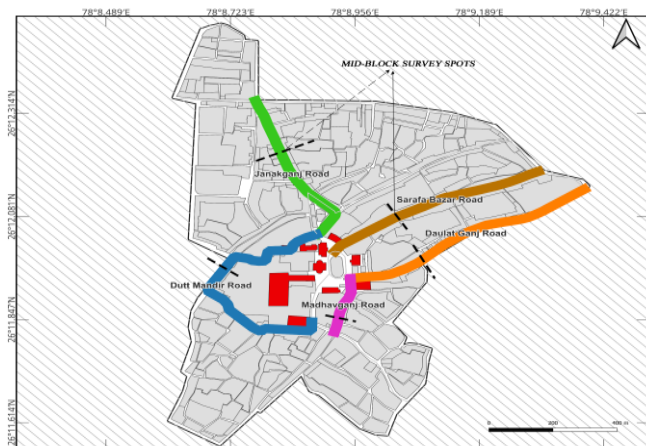### 4.1.1 Analysis of LOS and PCU through mid-block survey on major roads

Figure 3: Mid-block survey points

The purpose of the mid-block traffic count study was to collect existing traffic volume on major roads. studies of the current traffic scenario, the total vehicle count (TVC), PCU, PHF, and LOS of the main roads in the study area are all examined in this survey's data.

Five locations were chosen (as shown in Fig. 3) along a few key routes in the maharaja bada area to perform the traffic count survey. The survey was conducted with the help of video recording and manual counting during peak hours between 6:00 PM and 7:00 PM on usual weekdays from Monday through Wednesday, excluding public holidays.Except for Madhavganj, all main highways have V/C ratios greater than 1, which indicates that there is a breakdown of flow on these routes (Table 3) and all the roads has PHF of more than 9 which implies that there was no change in the volume of traffic during the analysis hour.

Table 5- LOS,PHF,,TVC of Major Roads of Study Area

Roads	Type	Volume/hr	PCU/hr	Max Permissible	V/C	Peak Hour Factor (PHF)	Level of Service (LOS)
Daulatganj	2 lane (one way)	2794	2260.6	1400	1.9	9.7	F
Madhavganj	2 lane (one way)	876	877.2	1400	0.6	9	C
Janakganj	2 lane (two way)	2712	2459.8	900	3.0	9.6	F
Sarafabazar	2 lane (one way)	3045	2724.4	1400	2.2	9.7	F
Khagsibazar	2 lane (two way)	1771	1053	900	1.9	9.5	F

Maharaja bada is considered as an important central business districts of the city Gwalior, mostly all the roads has LOS F during peak hours, which is a very negative sign for the neighborhood because this breakdown is to blame for the worsening of the study area as congestion not only affecting the area's living environment but also causing significant economic losses. It is evident that the roads are unable to handle this large amount of PCU as shown in The survey indicated that on the roads of the area traffic congestion is unavoidable.

The situation in peak hour is such that every vehicle follows the one in front of it, slowing down frequently as necessary. All the roads except Madhavganj generally has more demand than capacity Table 5, therefore it is evident that there is typically a capacity problem. The survey analysis shows that 2-wheelers are the most frequently used vehicles on all the major routes in Maharaja bada followed by auto rickshaws, and cars. Due to how convenient it is to park on the street and shop, there are an increasing number of 2-wheelers in the area, which leads to traffic gridlock and congestion. E-rickshaws and cars are also a contributor to the market area's traffic gridlock and jams.

The traffic volume count survey indicates the poor condition of the traffic in the study area .The survey indicated that on the roads of the area traffic congestion is unavoidable. The situation in peak hour is such that every vehicle follows the one in front of it, slowing down frequently as necessary. All the roads except Madhavganj generally has more demand than capacity therefore it is evident that there is typically a capacity problem.

4.1.2 Speed Delay Index (SPI)

The speed survey was conducted on 21/06/2023 on Wednesday during peak hours (6:00-7:00) .As there was mixed traffic on road all the vehicles were taken in equal amount as a sample to evaluate average speed on the major roads .The speed of the vehicles were measured by evaluating the time they were taking to cross 100m distance on the road by knowing the time of different vehicles at major roads SPI index was further evaluated using the formula as mentioned above [8].
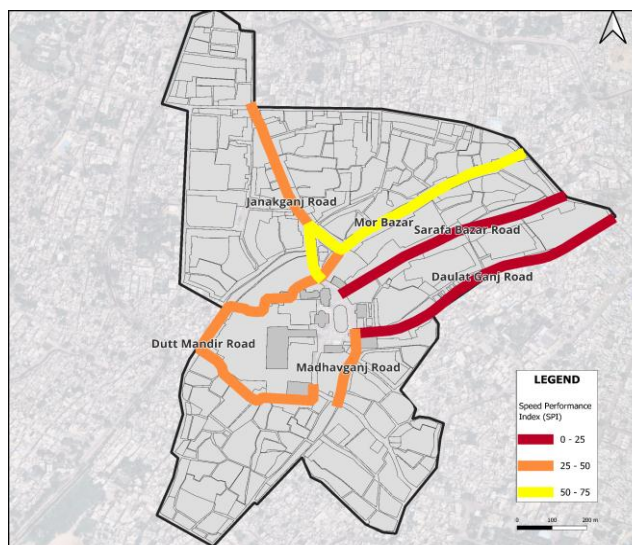

Figure 4 – SPI Index of Major Roads

The Daulatganj and Sarafa bazar road, with SPI scores below 25 as shown in Fig. 4, has the worst traffic conditions. Although the maximum permitted speed for these roads was 40 km/h, the average vehicle speed was observed to be between 7 and 9 km/h on theses roads, making it possible us to understand the level of congestion on these roads because, according to the SPI index, these roads will meet the criteria for heavy congestion. Only mor bazar road has a smooth flow as per the criteria of SPI index .

4.1.3-Active Road Performance Index (ARPI)

The survey analysis revealed that Daulatganj Road and Sarafa Bazaar Road have the lowest values of ARPI, which are between 30-40, this low percentage of ARPI was influenced by the presence of on-street illegally parked

two-wheelers and cars, roadside occupied by vendors, and illegal IPT halts on the roadside.

The level of service and speed delay survey of the roads are justified by the APRI index results. ARPI of all the major roads are shown in Fig. 5 .
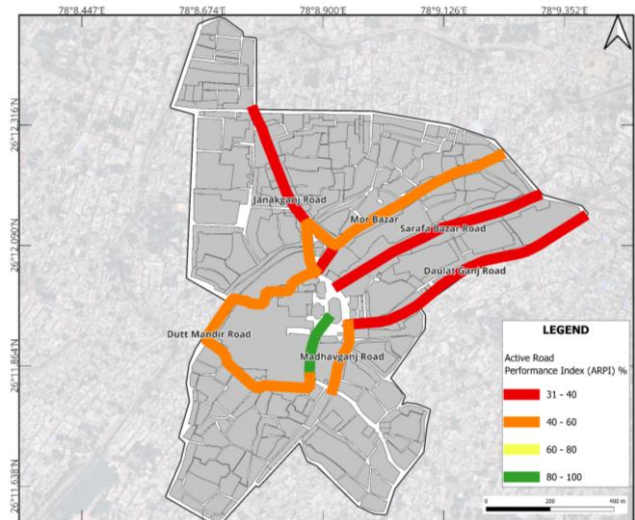

Figure 5 : ARPI of Major Roads

4.2- Congestion-causing factors in the study area

4.2.1 Illegal Road Occupancy by Street Vendors and Parked Vehicles

It was evident from ARPI Fig 5 that the active road width is reduced as a result of the presence of these illegally occupied informal businesses and parked vehicles, This encroachment of the road leads to severe level of congestion in the area. Due to this illegal road occupancy on both sides of the road as seen on the daulatganj and sarafa bazar roads in the region are experiencing considerable congestion; the detrimental impact of the encroachment was easily identifiable .Reduction of the active width of the roads effects vehicle speed and also reduces the Level of Service of the road, as seen in Fig. 4 and Table 5 respectively ,as shown in these analysis daulatganj and Sarafabazar roads have LOS F and have the lowest average speed of moving vehicles.

4.2.2- Insufficient Parking Spaces

Due to lack of parking spaces in the study area, citizens have become adapted to park their vehicles on the street, which leads to traffic jams and congestion in the area, all the major roads of the study area are occupied by on-street parking which causes congestion due to decrement of active road width as shown in Fig 5, It is therefore

necessary to provide structured and sufficient parking spaces in the area in order to increase the area's mobility and reduce congestion level.

4.2.3- Erratic execution of the rules and regulations

People in the area frequently violate traffic laws as a result of the authority's failure to enforce strict laws in the maharaja bada. The failure of the traffic police and authority was clearly visible in the area through illegal business occupancy of spaces, illegal parking of vehicles on public streets, vehicles moving the wrong way. The combination of these variables is the main cause of the congestion in the Maharaja Bada area.

4.2.4- Increment in Vehicle Population

One of Madhya Pradesh's cities that is expanding quickly is Gwalior. Increased economic activity, population growth, and urbanization all led to a rise in automobile activity in Gwalior. According to the study, all roads—with the exception of Madhavganj Road—had LOS F and have very high PCU values as shown in Table 5 (with daulatganj and sarafa more than 2000 PCU/hr) , which indicate a tendency towards increased vehicle traffic in Gwalior. Thousands of new automobiles are introduced each year and as a result, Gwalior City encounters a variety of road vehicles which causes congestion. During peak hours, most of Maharaja Bada's roads have speed index of below 50 (Fig 4).

5. DISCUSSION

Based on the results of these congestion indices (LOS,ARPI,SPI) it was evident that the major roads of maharaja bada especially Sarafabazar, Daulatganj and Janakganj roads are suffering from major negative impacts of urbanization and motorization mix with the effects of CBD . It has been strongly emphasized that long term inclusive planning and some immediate law enforcement should be targeted to tackle the traffic congestion in the maharaja bada area after assessing the problems that currently exist in the area and through the evaluation of congestion indices in the area. Inclusive planning in the study area is necessary to establish a thriving CBDs environment that relies on a sustainable, socioeconomic, and dynamic environment to support the local community at both the micro and macro levels.

The study found that there are significant traffic problems in the Maharaja Bada area and its surrounding areas as a result of a number of factors, including an increase in the number of vehicles, a lack of infrastructure for cyclists and pedestrians, which forces people to share the road with vehicles and cause delays and congestion, a lack of parking spaces due to which all the edges of the streets are occupied by on-street parked vehicles and most importantly lack of public transportation which is giving

rise to increasing count of IPT vehicles like e-rickshaws and auto rickshaws, these IPTs are causing traffic jams by occupying road spaces and taking halt at every entry and exit of the roads and as well as on the jiwaji chowk .

6. RECOMMENDATIONS

- **Improving Multimodal connectivity in the area and Encouraging NMT modes for commute in the area-**

  An effective multi-modal strategy can be achieved through proper planning , since the research found that the area is most affected by the parking issue, it is vital to consider offering parking facilities outside periphery of maharaja bada area to encourage drivers to park there and use another means of transportation to go to the business district the locations of these parking must be indentified near daulatganj, madhavganj, sarafabazar and janakganj road, a change of mode from personal vehicle to NMT must be ensure through these techniques –

  I. **Park and Walk** – To achieve this strategy authority must focus on providing continuous, free from encroachment pedestrian infrastructure on the major roads of the area only after this Park and Walk scheme will be effective as people will than park there vehicles outside the maharaja bada area in the available parking and than continue there visit to market by walking

  II. **Park and Ride -** A bike sharing system can be effective for maharaja bada area .The docking stations must be installed at all parking spaces and should be placed with effective density not too far from each other throughout the Maharaja Bada area. This will encourage people to park their cars and commute via e-bikes or cycles in the area, which will reduce traffic and improve the environment.

     However, before installing the docking stations, there are a few things that need to be considered an authorities must establish an effective bicycle infrastructure across the market area; otherwise, this strategy may backfire and worsen the congestion in the area as cyclists will be compelled to utilize the same roads as other mixed traffic **[9]**.

- **Discourage utilization of private cars-**

  The first action that the local government should take is to reduce the number of vehicles entering the Maharaja Bada area. However, this is a challenging task because, the city's vehicle

population is growing rapidly. As a result, the area will continue to see an increase in the use of cars and motorbikes in future also as individuals find it very convenient to commute from their own vehicles, which in turn leads to traffic congestion. Instead of the idea of actually reducing the number of automobile trips, attempts should be made to reduce automobile utilization to counter congestion .

Congestion Pricing- Britain is following this theory to reduce the congestion levels on there busy streets and was successful in reducing the congestion, Most people consider the London Congestion Charging programme to be successful. The London Congestion Charging programme is largely regarded as successful [10] in this programme, the area is marked as a congestion charge zone in this programme, and people entering this area with their cars have to pay congestion charges, forcing the commuters to use automobiles less frequently in the area, which will ultimately improve the level of service (LOS) and speed performance index (SPI) of the roads

- **Management of Off Street and On-Street parking in the study area-**

    The results of the field study are abundantly clear that parking is a major problem in the area because there is a demand for parking that is almost four times greater than the available space. As a result, people park their cars on the roads, which leads to congestion and traffic jams in the area, this parking problem is only capable of being solved by proper parking management plan in the area. As maharaja bada is a very densely populated area, there are very just a handful of open spaces and unoccupied plots available, which makes it difficult to build off-street parking, therefore, government-owned spaces is the only option left to facilitate the area with parking spaces as an example, GSCDC is currently building one multistoried parking space that will provide 465 ECS of parking in the area, but due to high demand of parking the construction of another space to relieve the pressure on the first in near future, more parking areas in the periphery of the bada must be identified so that park and ride scheme and park and walk scheme can be introduced in the area .Off-street parking must be made available on roads for shop owners and commuters, but with a proper parking policy, on-street parallel paid parking must be made accessible on the major roads in the area, such as Sarafabazar, Daulatganj, and Janakganj. This will reduce the utilization of vehicles by shop owners and commuters, and they will park their cars in

the off-street parking spaces, reducing congestion on streets.

- **Management of Street Hawkers-**

    vending uses up valuable street space by obstructing the sidewalk and parking spaces and aggravating other drivers but completely evicting these vendors is not at all a good solution as it will decrease livability of the market for this issue an inclusive design strategy must be adopted to facilitate these vendors ,proper planning is required for making the best use of existing space through better space management or time-sharing (eg: for an evening or Sunday market) ,vendors must given arranged spaces for selected time period this will also resolve conflicts between these vendors and between vendors and traffic police [11]

- **Strict law enforcement–**

    By effectively upholding norms and regulations and strictly enforcing traffic laws, traffic congestion can be reduced. If every traffic cop does their job, maintaining the regulations will be easy.

7. CONCLUSION

Due to the land use pattern, it has been noted that parking issues and traffic congestion are noticeable in the Maharaj bada business areas. The capacity to generate motor vehicles and pedestrian traffic is significantly high, parking spots and other amenities are also in high demand due to commercial Land use of the area. Parking issues and traffic congestion have later resulted from the current situation's disability to cope with the demand. The recommendations have been made in light of the field survey's findings. Finally, the parking and traffic issues in the Maharaja Bada area would ultimately become a thing of the past if all the recommendations made earlier are effectively put into practice .

8. References

[1]   A. Downie, "The World's Worst Traffic Jams," 2008 [Online].Available: <https://content.time.com/time/world/article/0,8599,1733872,00.html>.

[2]   Blanco et al., "Hot, congested, crowded and diverse: Emerging research agendas in planning," *ELSEVIER,* 2009.

[3]   G. Rice, "Central Business District," *ScienceDirect,* 2009.

[4]   K.   V. K. R. Tom V. Mathew, Introduction to Transportation Engineering, 2007.

[5]   HCM, "Highway Capacity Manual," 1994.

[6]   B. C. I. P. LTD.,"ROAD & STRUCTURE INVENTORY," [Online].Available: https://bpcipl.com/services/road-structure-inventory/.

[7]   V. T. Arasan and . R. Z. Koshy, "Methodology for Modeling Highly Heterogeneous Traffic Flow," *ASCE,* 2005.

[8]   F. He, X. Yan, Y. Liu and L. Ma, "A Traffic Congestion Assessment Method for Urban Road," *ScienceDirect,* 2016.

[9]   S. B. Osoba, "Appraisal of Parking Problems and Traffic Management Measures in," *Journal of Sustainable Development,* 2012.

[10]   R. L. Mackett, "Reducing Car Use in Urban Areas," *ResearchGate,* 2012.

[11]   REPL, "Street Vendors and urban planning," [Online]. Available: https://www.repl.global/street-vendors-and-urban-planning/.