Traffic Management of Ratnagiri City using Six-Sigma DMAIC

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Abstract: In the recent past years Ratnagiri city has observed rapid increase in the traffic intensity and it has emerged as one of the major challenges. Traffic congestion is a severe problem which results not only in driver fatigue but also vehicular emissions, noise and pollutants into the environment. Controlling the situation of congestion in Ratnagiri is of vital importance. In this paper, we have applied DMAIC based methodology for improving traffic issues. The proposed methodology comprises of three steps. In Step 1, we conducted a survey study to collect traffic congestion data in the Ratnagiri. In 2nd step we applied DMAIC methodology to analyze the survey data collected from Step 1. Descriptive statistics, Pareto analysis, Cause–Effect Diagram, Factor Analysis, and Control Charts (Individual and Multivariate) are used to analyze the survey data. In the 3rd step, we have generated recommendations for reducing traffic congestion and enhancing transportation service quality in Ratnagiri based on results of Steps 1 and 2.

IndexTerms **- Traffic congestion, Six Sigma, Control charts, parking management**

I. INTRODUCTION

Ratangiri city is one of the major townships in the Konkan region. Ratnagiri city is the headquarter of Ratnagiri district with a population of about 76 thousand (Census 2011). The availability of academic, medical facilities and development & establishment of industries have triggered the population migration from neighboring rural areas**.** It is also having significance for Alphonso Mango trade along with other agricultural products which are the reasons for economic growth of the region. Industries such as Finolex industries, JSW energy, Bharti Shipyard, J K Files, Georg Fischer and upcoming industries such as Jaitapur Nuclear power plant, Ratnagiri Refinery, etc in nearby areas has resulted into rapid increase in the population of the city. These advancements have resulted in considerable increase in the traffic intensity and it has emerged as one of the major challenges. Hence considering current and future situation, problem of traffic in Ratnagiri should be analyzed and solutions should be provided considering future development. To obtain a scientific solution for this problem, city officials approached Finolex Academy of management and Technology, Ratnagiri and hence the study was allotted to authors.

II. PROBLEM DEFINITION

To study the traffic problems and to suggest the measures, to improve the traffic management in the city. Area of consideration was from Bazar Peth to Kuwarbav which covers about 12 km distance. The scope of the study is to study and identify the major issues pertaining to traffic management in a systematic manner so that this subject draws attention of all the stake holders and they become truly aware and educated on this subject.

III. SOLUTION APPROACH

Methodology comprises of following three steps:

1. Data collection on traffic congestion using a questionnaire survey.
2. Application of DMAIC to analyse survey responses.
3. Propose recommendations for reducing congestion in the city based on results of Steps 1 and 2.

Step 1: Data Collection Using Questionnaire Survey

At first, causes that lead to traffic congestion in city were identified. As per observation, poor road facilities, road management, types of vehicles, people driving behavior, environmental conditions, etc are the main causes that lead to traffic congestion. For each of these causes, the Critical-to-Quality (CTQ) parameters were identified that can help improve the situation of traffic congestion in the city. CTQs that can improve the situation of traffic congestion are good management of transportation system, well-organized drivers and passengers, good transportation environment, and good facilities for transportation. Based on causes & CTQs, questionnaire containing 25 questions was designed to get information from the citizens such as their experience with the congestion, most congested time in a day/week, most congested roads, one-way driving distance & driving time, average waiting time when driving, effects of road facilities, effect of environment, effect of management factors and effect of operators' behavior on traffic congestion.

Step 2: application of DMAIC to analyses survey responses

Being continuous quality improvement technique DMAIC or six sigma technique was applied to identify long-term solutions to manage and continually improve the situation of traffic congestion in cities. Steps involved in DMAIC methodology are Define, Measure, Analyze, Improve and Control. The survey responses obtained from Step 1 are subject to DMAIC in Step 2. The techniques used in the five phases of DMAIC are presented in Table 1.

Table 1 Technique Used For Managing Traffic Congestion Using DMAIC

DMAIC step	Methodology	Technique used
Define (D)	Problem definition which is congestion monitoring and control in Ratnagiri	Descriptive statistics
Measure (M)	measurement of data related to congestion problem under study	Pareto Analysis
Analyze (A)	Investigation of the collected data and identification of causes for poor performance/ quality	Multivariate Factorial Analysis
Improve (I)	development of solution measures based on analysis of collected data for improvement	Cause and Effect Diagram
Control (C)	establish control measures for the process to prevent defects from occurring in future	Control Charts

Step 3: generate recommendations based on DMAIC results

On the basis of results obtained from Step 1 (questionnaire) and Step 2 (DMAIC) recommendations were generated for reducing traffic congestion. The main objective was to provide long-term solution that can continually help improve the situation of traffic congestion in Ratnagiri.

IV. CASE STUDY: RATNAGIRI CITY

The questionnaire was distributed among citizens of Ratnagiri and total 201 responses were obtained. Fig. 1 presents the distribution of living areas of the respondents which shows that responses were obtained from all parts of the city.

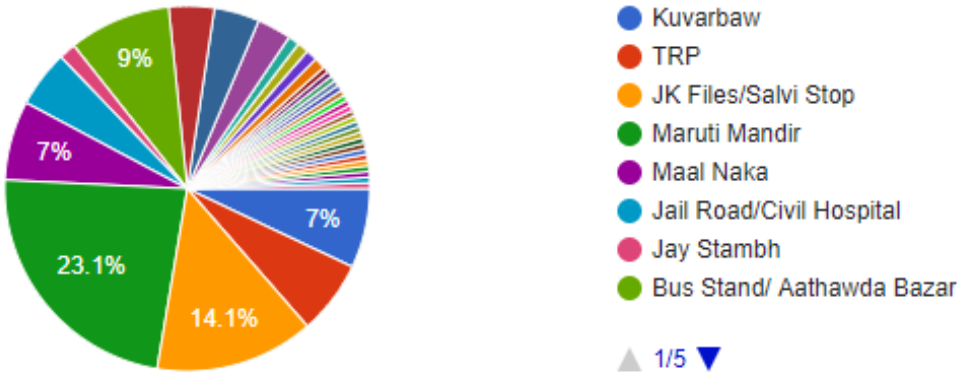

Figure 1 Living area of respondents

From the survey responses, we found that majority of the respondents were male (90.4%), age category 20–30 (65.8%), average travel duration 10-20 minutes (30.2%), average daily travel trip distance 3-5 km (28.25%). Majority of the respondents were students and others were from mixed profession like Manager, Technician, Driver, Service, Retired, Others. The DMAIC methodology was applied on the survey data and the results obtained are explained in further steps.

4.1 Define

Weighted congestion score matrix was used to indicate the congestion levels on city roads. The weighted congestion matrix contains congestion levels weighted according to location sources. The weights and contribution values were provided by the respondents (Table 2). For example, for Highways weight = 23.69%, Main road = 24.88%, Local road = 21.30%, Market area = 30.11%. Respondent 1 provided a score of 0 for Highways, 3 for Main road, 2 for local roads and 4 for Market area. Therefore, the weighted congestion level provided by Respondent 1 is given by 0.2369*0 + 0.2488*3 + 0.2130*2 + 0.3011*4 = 2.3768. Likewise, weighted congestion levels for all the 201 respondents were calculated. These values can be seen in the last column of Table 2. The average congestion is highest in Market area followed by main roads, highway and local roads. The average congestion level for Ratnagiri is 2.8545 which take into account weighted congestion levels of all location sources.

Note: In all tables sample calculation for 5 responses is shown whereas in last row results of all 201 responses are written.

Table 2 Weighted Congestion Score Matrix

Response no.	Highway 23.69%	Main Road 24.88%	Local Road 21.30%	Market Area 30.11%	Weighted Congestion Level
1	0	3	2	4	2.3768
2	3	4	4	4	3.7623
3	2	3	1	4	2.6376
4	3	2	3	4	3.0517
5	3	3	2	4	3.0875
Sample Avg	2.2	3	2.4	4	2.98318
Average	2.7533	2.8969	2.4922	3.5416	2.85456

Table 3 Congestion Scale

weightage	Level of congestion
1	No Congestion
2	Slight Congestion
3	Moderate Congestion
4	Extreme Congestion

4.2 Measure

Table 4 shows the results for various factors associated with congestion. It can be seen that majority of respondents believe that vehicle so many vehicles and lack of parking management are main causes of congestion. Pareto analysis was performed to analyses Table 4 responses in detail. According to Pareto's rule, under most conditions, 80% of problems are most likely led by 20% of causes which are the so called significant causes or core causes.

Table 4 Response for Causes

Sr No	So many vehicles	Peak hours	Road conditions	Bad management	Lack of traffic signal	Violation of traffic rules	improper parking
1	✔	✔				✔	✔
2			✔			✔	✔
3	✔						
4	✔		✔	✔			
5		✔	✔		✔	✔	✔
Sample Total	3	2	3	1	1	3	3
Total	100	34	62	54	61	71	80

Fig. 2 presents the Pareto diagram for the causes of congestion indicated by respondents. It can be seen that So many vehicles is most important (44%) followed by improper parking management and violation of traffic rules factor. These three factors along with road conditions and lack of traffic signal together contribute to 80.8% of congestion.

For other general questions such as congestion level in Ratnagiri only 4.97% of respondents considered there is extreme traffic congestion problem in Ratnagiri and 9.45% respondents feels that there is no congestion in Ratnagiri city. 43.78% of total respondents indicated moderate congestion and 39.98% indicated extreme congestion. For congested days, most of the respondents experience highest congestion on Monday and Saturday whereas for congestion time most of them experienced during peak periods i.e. 6–9 am & 6-9 pm.

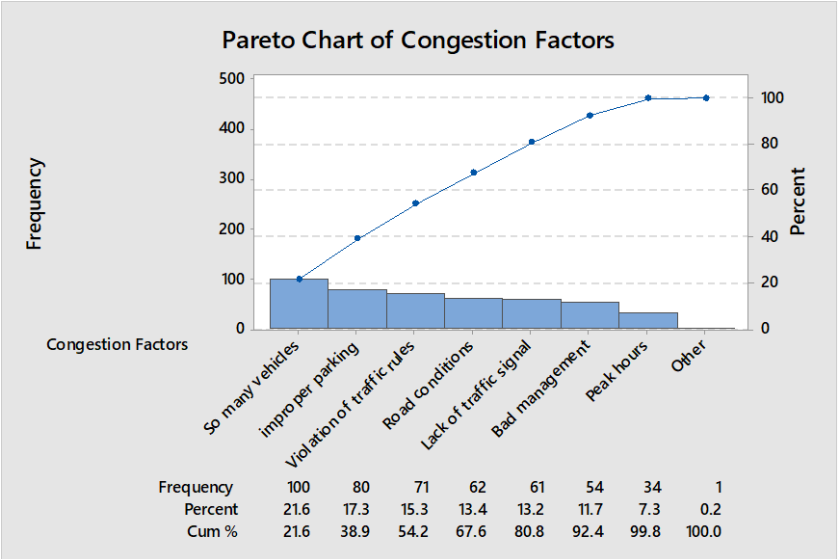

Figure 2 High Level Pareto Analysis of congestion factor

Table 5 presents the driving distance, total driving time and time spent in congestion by the respondents. It can be seen that the average driving time is 19.5 minutes/day for people, average driving distance is 5.51 kilometers and average congestion time encountered is 3.4 minutes. Average no of stops due to congestion are 2.82 and average waiting time for each stop is 63.53 seconds.

Table 5 Data of Driving Time, Driving Distance and Congestion Time

Response no	Distance (KM)	Time (MINUTES)	Stops	Stop time (sec)	Total time of stop (SEC)
1	4	8	4	40	160
2	2.5	16	0	40	0
3	7	16	0	20	0
4	7	16	2	40	80
5	4	16	0	20	0
Sample Avg	4.9	14.4	1.2	32	240
Average	5.51	19.5	2.82	63.53	204.79

4.3 Analyze

In this phase, the relationship between traffic congestion factors (*X*s) and weighted congestion level (*Y*) was analysed. Multivariate factorial analysis was done to obtain the relation between the two. So many vehicles, Peak hours, Road conditions, parking management and Lack of traffic signal were considered as *X*s. After doing factor analysis it was found that so many vehicles and Parking Management is the most significant factor influencing traffic congestion in Ratnagiri.

4.4 Improve

Cause–effect diagrams were developed in this phase to identity factors that can help to reduce no of vehicles and improve parking management which in turn will improve the situation of traffic congestion in the city. Fig. 3 & 4 present the cause and effect diagrams for reducing no of vehicles and improvement of parking system in Ratnagiri. It can be seen from these diagrams that better facilities, use of right methods, trained drivers and proper driving environment are vital in reducing traffic congestion in cities.

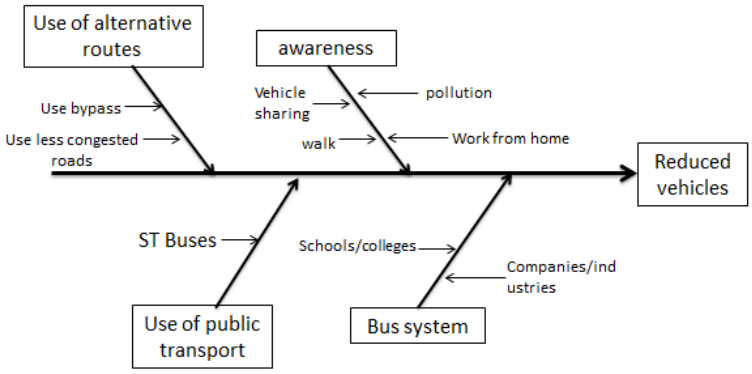

Figure 3 Cause and Effect diagram for So many Vehicles

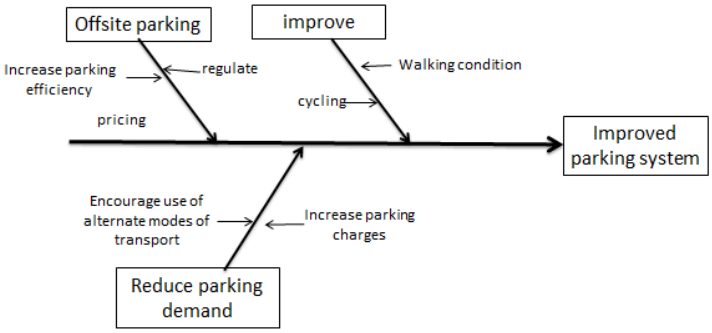

Figure 4 Cause and effect diagram for improved parking System

4.5 Control

Control process is the last step of DMAIC. It ensures that project improvements can be sustained by tracking key performance measures and CTQs on a regular basis, and taking corrective actions whenever necessary to fix the problems and bring the process back to stable performance. Individual (x-bar and R) and multivariate (*T*2 Hotelling) control charts were prepared for managing and improving the traffic congestion in Ratnagiri. The individual control chart was used to study the congestion level over time. Using upper (UCL) and lower control limits (LCL), out of control points were detected and appropriate actions were taken. *X* denotes the average congestion metric, the control limits are given by:

$$UCL = \bar{X} + 3\sigma \quad (1)$$

$$CL = \bar{X} \quad (2)$$

$$LCL = \bar{X} - 3\sigma \quad (3)$$

Using the data of Table 2 and applying equations (4.1) to (4.3), we obtain $\bar{X}$ = 2.971 σ = 0.8334, Therefore, UCL =4.221, CL =2.971, LCL = 1.721. Since LCL < 0, therefore LCL is set equal to 0. Fig. 5 shows the individual control chart for monitoring traffic congestion level in Ratnagiri. It can be seen that several points are out of control limits, therefore more actions are required to reduce congestion.

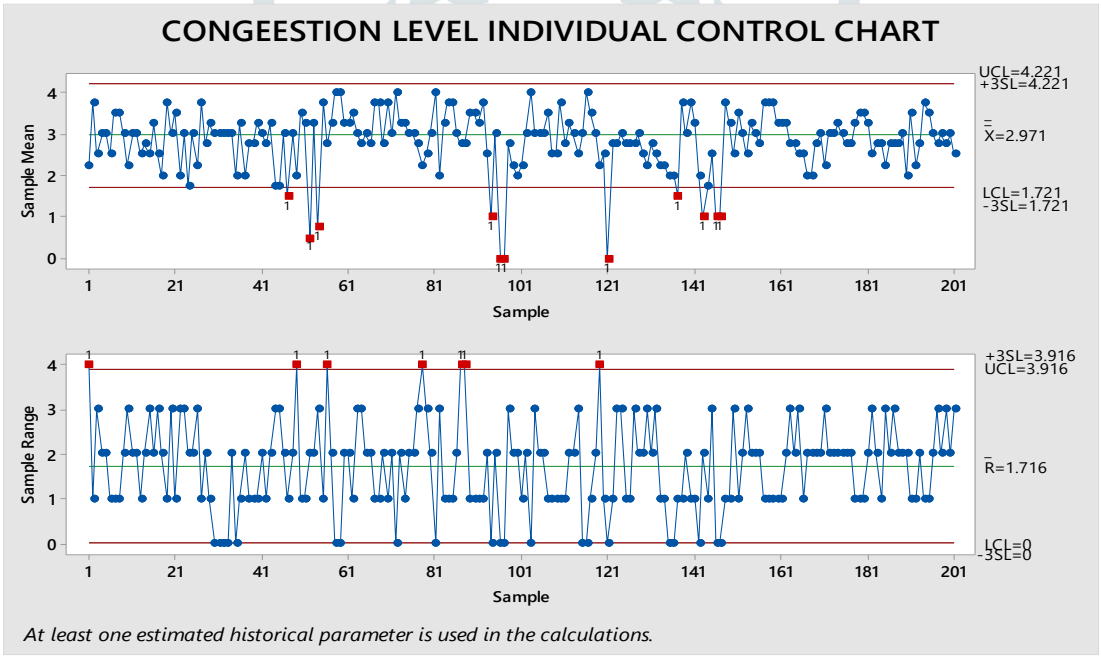

Figure 5 Individual Control Chart for congestion level

For correlated variables, we propose the use of *T*2 Hotelling control chart. For example, variables like Driving Time, Driving Distance or Waiting Time, will distort the results if considered individually.

It can be seen that three points are out of control violating upper limit. This means the data provided by these respondents cannot objectively reflect the traffic congestion in Ratnagiri. May be those respondents are under specific driving conditions or living areas. Therefore, we exclude these out-control points in Phase II and recomputed the limits. After eliminating the out of control points of Phase I, we obtain new data set. The new data will now be monitored using the control limits of Phase II. If there are still points out of control, then the reasons need to be investigated and appropriate actions required to bring the congestion situation under control.

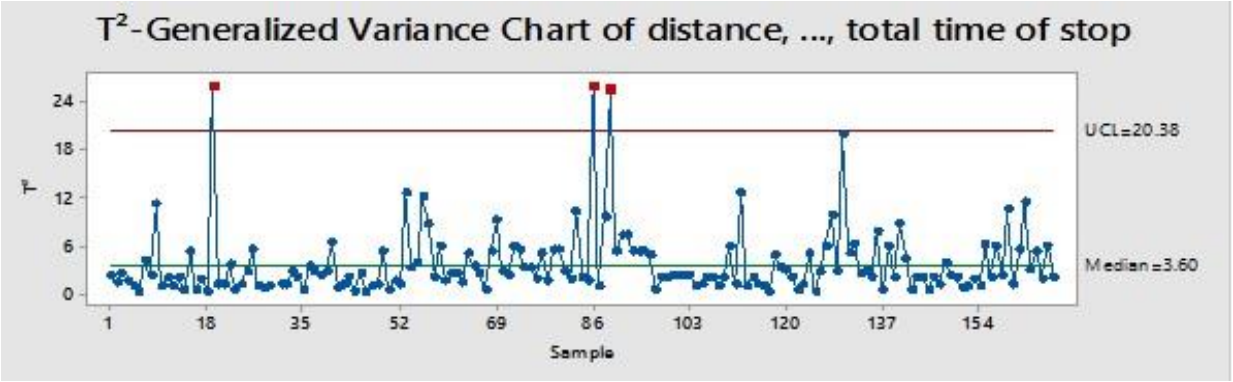

Figure 6 T^2 control chart

When asked to respondents about whether they think the problem of congestion should be intervened by some departments, majority of them replied 'Yes'. The areas that the government, public and private roads transport organizations need to focus are improving parking management, use of public transport, expansion of roads, offering flexible work schedules, etc. Fig. 7 presents the responses in favor of these suggestions.

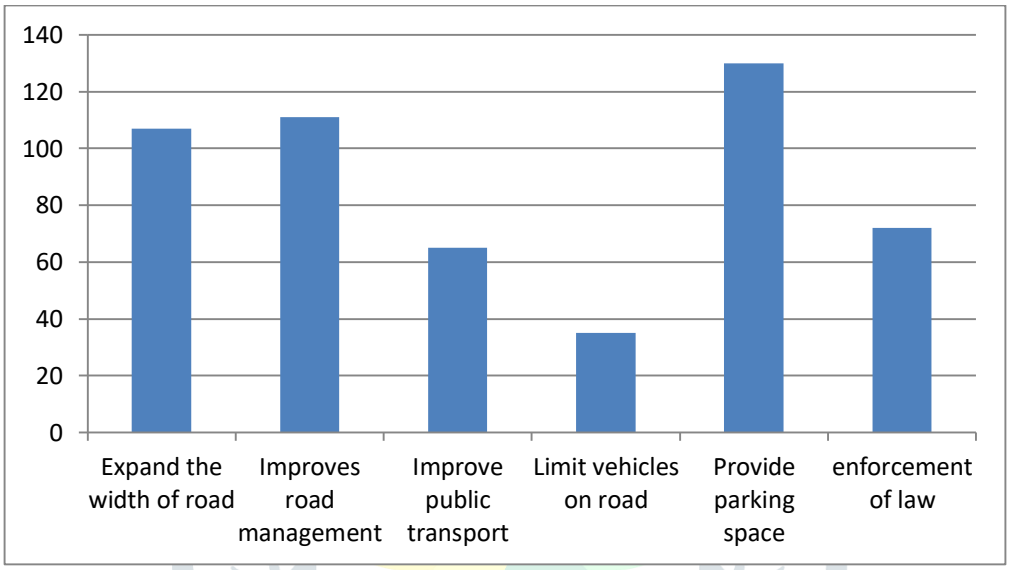

Figure 7 Respondents suggestion for managing traffic congestion

Therefore, based on the results of questionnaire survey (Fig. 7) and DMAIC (Analyze step), we can say that the two results are in agreement with each other, thereby validating the results achieved. The recommendations based on this case study to reduce congestion in Ratnagiri are better parking management, use of public transit, expanding roads and offering flexible work schedule.

V. Conclusion

The results of our study identified parking management and so many vehicles as the most significant factor influencing traffic congestion in city of Ratnagiri. The main improvement suggestions include improving parking management, improving public transportation, offering flexible work schedules, and imposing limits on vehicle movements. The limitation of this work is that majority of respondents are students which makes generalization difficult. The findings of the study will change if nature of respondents is changed.

VI. Recommendations

Parking regulation is very important for traffic management and for smooth flow of traffic in Ratnagiri. Following recommendations are made for parking management in Ratnagiri.

- Parking on road should be generally discouraged.
  Narrow roads and busy markets (Bazar peth & Ram Aali area) should be declared no parking zones.
- All no parking zones should be strictly enforced.
  Traffic cranes should be utilized to toe wrongly parked vehicles. The fines should be increased.
- The road should be painted with parking lines so that the users have choice of adhering to parking norms.
- The pay and park is suggested also with a view to use the parking place effectively, to avoid disorderly parking and to discourage unnecessary motorized journey and to encourage use of mass transport.
- Parking can be permitted on sufficiently wide roads where additional space is available after the space needed for vehicular and pedestrian traffic. A committee should be constituted to decide such locations. These should be periodically reviewed.
- All parking should be made charged parking. The charges should be decided on the basis of the principle of equity. The parking fees collected should be utilised to improve parking facilities.

- The misused parking space should be got back by removing illegal construction. The violators should be punished with legal actions including a criminal case under relevant sections of the IPC.
- The private buses should not be permitted to be parked on roads. They should be made to create their own parking lot and bus stations.
- Educational institutes should be made to use their space for parking. Their vehicles should not be permitted to be parked on streets.
- The business establishments like banks, Private firms, and tuition classes should be made to make provision for parking of vehicles of their customers.
- Parking lots should be developed both by government agencies and private developers on PPP model.

VII. ACKNOWLEDGMENT

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