Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Impact of Car Restrictive Policies: A Case Study of Srinagar City in J&K State India

Adnan Pasha [a,*], Rajat Rastogi [a], M. S. Mir [b]

[a] *Department of Civil Engineering, Indian Institute of Technology Roorkee, UK 247667, India*
[b] *Department of Civil Engineering, National Institute of Technology Srinagar, JK 190006, India*

Abstract

Urbanization and economic development in developing countries has led to an exponential increase in the ownership and usage of private vehicles in the past decades. Such growths have made city roads choked with congestion. Srinagar city in India is not different wherein the volume to capacity (v/c) ratio of 22 arterial roads was found to be more than 1.0 and associated level of service (LOS) on these links varied between E and F. In addition to this, the city has inadequate public transport and on-street parking is predominant. This case study aims at easing out the traffic situation in Srinagar city by analyzing the impact of car restrictive policy options like Odd-Even road-space rationing, revamping public transportation including inland waterways and prohibiting on-street parking.

Household personal interview survey is conducted in 390 households among various Traffic Analysis Zones across the city. The information on existing travel mode used and perceived usage of private vehicles under proposed car restrictive policies are collected. The results indicate that the commuters cover an average distance of 9.89 km with an average speed of 15.40 km/h. The average delay estimated for this distance came out to be 16.03 minutes. 77% of cars and 62% of 2-wheelers comply with Bharat Stage III (Euro 3) emission standards which when compared with the car and 2-wheeler registration in the city reveal that CO and HC+NOx emissions are 8.58 and 4.03 tonnes per day, respectively. When addressed, 57% of the respondents favoured the implementation of Odd-Even policy and 75% of the respondents stated that they will not buy another vehicle if the policy is implemented. Around 64% of the respondents with origin or destination along the river and lake side showed interest in using inland waterways if implemented. All respondents complied with the prohibition of on-street parking provided there are adequate parking facilities available.

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY.

Keywords: Transport Policy; Congestion; Odd-Even Scheme; On-Street Parking; Inland Waterways.

* Corresponding author. Tel.: +91-700-641-6950,
E-mail address: apasha@ce.iitr.ac.in

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY

1. Introduction

Worldwide vehicle population is increasing at a faster rate and has already crossed 1-billion-unit mark in the year 2010. It is estimated to reach 2 billion by 2020, with cars constituting more than 50% of all vehicles (Sperling and Gordon, 2009). Car ownership in India is increasing exponentially, having an average annual growth rate of 10.8% between 1990 and 2014, which is second highest after China and much higher than global growth rate of 2.9%. At this rate, the number of cars in India will go up from 27.2 million in 2014 to more than 50 million by 2020. Still it is one of the world's most attractive auto markets as motorization rate in 2014 was only 30.8 vehicles per 1000 inhabitants (Davis et al., 2016).

The increasing ownership and use of private vehicles have created numerous social, economic and environmental problems in different big and small cities in the country. Social problems involve the degradation of the quality of urban life due to noise, annoyance, traffic accidents, air pollution and less space availability for cycling and walking. Economic problems include less accessibility of economically important destinations and loss of gross domestic product (GDP) due to traffic congestion. Environmental problems involve the emissions of harmful and toxic substances which contribute to global warming, acid precipitation and smog. These problems might be tackled by technological innovations, new road infrastructure, stimulating people to use more sustainable modes and implementation of certain policies which restrict private vehicle use.

Private vehicle restrictive policies are those policies which are aimed at limiting and controlling the ownership and usage of private motorized vehicles for commuting and encouraging greater usage of more sustainable travel modes like public transport through promotion, subsidies or improvements with primary aim to reduce traffic congestion and air pollution. Various such restrictive policies have been used at global level to tackle traffic related problems, to mention few are congestion pricing, credit-based congestion pricing, distance-based charging, road space rationing, auto-restricted zones, vehicle quota system and vehicle lottery system. Under congestion pricing road users are charged a fee to ply on designated roads. Distance based charges are levied on road users based on the distance travelled by the vehicle during a certain time period. Road space rationing is a vehicle rationing system wherein vehicles with license plates ending in certain digits are restricted to ply on roads during certain days of the week. E.g. Odd-Even policy, car free days etc. Auto-restricted zones are the zones which in one way or other restrict vehicular traffic. They include low emission zones, pedestrian malls and parking controls. Vehicle quota system is an auction system wherein limited number of new vehicles are allowed to register and the individuals have to bid for a certificate of entitlement (COE) to own a vehicle. Vehicle lottery system restricts ownership through publicly held lottery system. (de Palma and Lindsey, 2011; Gulipalli et al., 2004; Han et al., 2010; Litman, 1999; Seik, 1998; Yang et al., 2014)

One such experiment was done in the capital city of New Delhi, India, which was experiencing high level of air pollution and low vehicular speeds. The Government of Delhi implemented Odd-Even policy in two phases of 15 days each to examine its effect and response of vehicle users. The policy reduced the number of private cars on the road by 35%, doubled the average journey speed, increased the respective bus and metro ridership by 8% and 7%, increased the occupancy in personal cars from 1.4 to 2.1, decreased the respective petrol and diesel sales by 4.7% and 7.8% and substantially reduced both particulate and nitrogen oxide load from cars by as much as 40%. However, certain cases of multiple car acquisition were reported and around 24% of wrong numbered cars were on the roads probably due to exemptions and partly due to non-compliance (Centre for Science and Environment, 2016; Goel and Pant, 2016; Goel et al., 2016).

The experience gained through Delhi experiment stimulated other metro cities to look for similar exercises to curb the growing traffic problems due to higher reliance on private vehicle travel. During academic interaction between the two institutions (of authors) it was observed that Srinagar city is facing traffic problems on count of various reasons (geographical, social and settlement pattern based) and hence is a fit case of carrying out a study with mentioned perspective. Srinagar city of Jammu and Kashmir State, India is the capital of the state. The city has been described as 'Heaven on Earth' and is a major tourist destination. The physiography of the region includes mountains, wetlands and water bodies, which restricts the space needed for the circulation of traffic. According to RITES (2012), the volume to capacity ratio (v/c) on major road links in the city was found between 0.15 and 3.89. Out of 35 locations on 24 road links, 17 locations had v/c ratio more than 1. Similar results were reported by Janwari et al. (2014) for 22 arterial roads. Level of service (LOS) was reported varying between E and F. Minibus and Sumo (8-10 seat shared jeep) were reported as the only public transport modes available in the city. Parking demand outstripped supply, parking indices neared 1

at many parking locations and on-street parking restricted the smooth flow of traffic. Based on the documentary study and first-hand information available to the authors as a resident of the city, it was decided to examine the possible changes in travel patterns and the use of sustainable travel modes in the city due to implementation of Odd-Even road-space rationing policy, revamping of public transportation including inland waterways and prohibition of on-street parking.

The paper in this direction first defines the study area and methodology adopted, then it speaks of sample characteristics and travel characteristics, and finally examines the impact of implementation of car restrictive policies.

Next section now presents details of study area and the methodology adopted to achieve the goals.

2. Study Area and Methodology

Srinagar is the largest city and the summer capital of Jammu and Kashmir State in India, located at 34º0´-34º20´N latitude, 74º40´-75º05´E longitude and 5200 feet above mean sea level. The area within the municipal limits of city is 294 km^2. There are many settlements just adjacent to the municipality, which when included makes Srinagar Urban Agglomeration (UA) which covers an area of 416 km^2. Population of the city is 1.18 million with a density of 4919 persons per km^2 and decadal growth of 25.44% during 2001-2011 (Census of India, 2011). The study area (Srinagar UA) is shown in Figure 1. The city is known for its tourism attraction and experiences influx of people during summers and after peak winters. It is also a gateway for snow clad peaks and ranges, to strategic outposts of military and to certain destinations of pilgrimage value. During these periods the population of the city increases substantially which further puts pressure on the un-sustainable public transportation and intra-city travel infrastructure. It is also a place to purchase saffron, dry fruits, pashmina, silverware products, handicrafts and Papier-Mâché products.

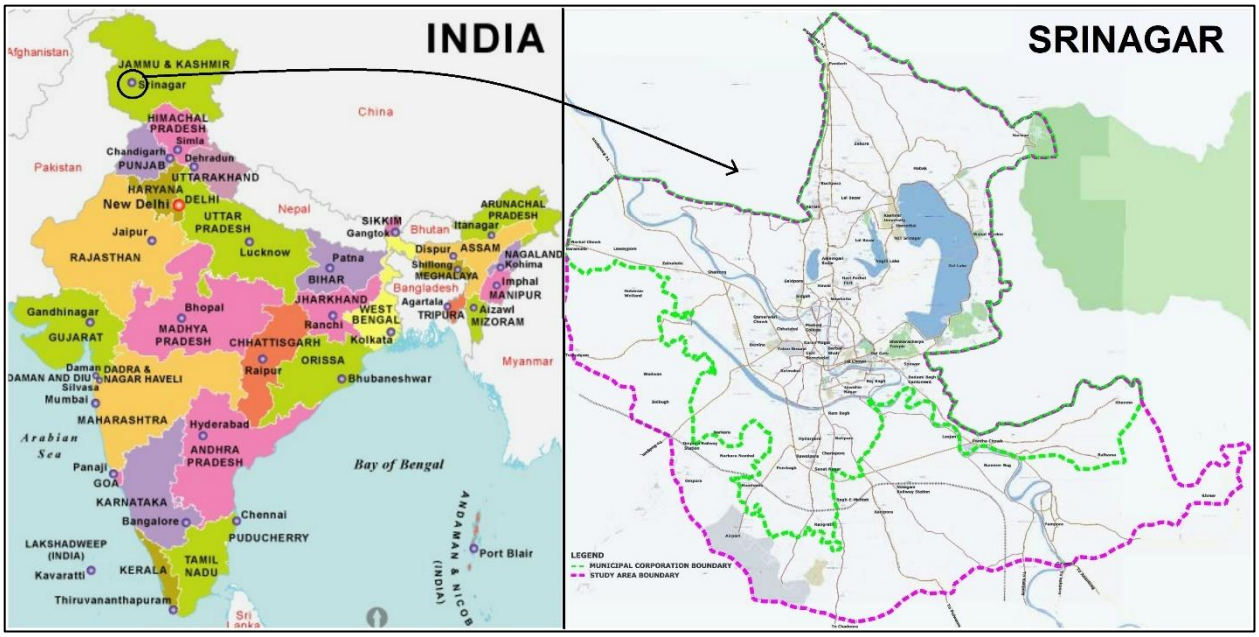


Fig. 1. Study Area. Source: RITES (2012).

The city has grown over the years, from a small downtown with area around 5 km^2 to today's expense all around covering an area of 294 km^2. Same is true for the vehicle ownership. The growth of vehicles in Srinagar district in the last decade is shown in Table 1. The increase in number of cars and motorized 2-wheelers between 2007 and 2017 is found to be 3 times and 2 times, respectively. They constitute 36% and 43% respectively of total registered vehicles (RTO Kashmir, 2017). According to the study conducted by RITES (2012), the share of Minibus out of total traffic volume is only 8% but it carries 60% of the total person trips. On 60% of the roads, the right of way is less than 10m

and carriageway width is less than 6.5m. Around 134 locations are identified in that study which experienced delay. On majority of the locations the delay exceeded 5 minutes. Average journey speed during peak period is 13 km/h. Most of the locations exhibit predominance of fast-moving passenger traffic, though operationally going slow. Average vehicle occupancy for cars, two wheelers, auto rickshaws, Sumos and Minibuses is 2.7, 1.6, 2.6, 6.3 and 13, respectively. As per the assessment made by city authorities regarding the parking problem, only 29 parking areas are identified in the city. Parking Demand is 7188 ECS, supply is 1937 ECS (SMC, 2017). Looking at the statistics of registered vehicles and the notion that for almost 80% of the time a vehicle is in parking, this capacity looks to be highly inadequate to tackle the situation.

Table 1. Growth of registered vehicles in Srinagar district, J&K State (2007 – 2017). Source: RTO Kashmir (2017)

Vehicle Type	Number of Registered Vehicles											Average Annual Growth Rate
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
Car/Jeep	37027	41359	46064	52058	59108	65998	73572	80260	88366	98222	106023	11.10%
2-wheeler	63674	66622	69332	72712	78815	86598	97285	101951	106893	116916	126514	7.14%
3-wheeler	12685	13426	14091	14548	15218	15885	16569	17223	17972	18846	19872	4.59%
Taxi	4333	4832	5306	5638	6099	7103	8119	8737	9173	9474	9492	8.26%
Bus	3130	3186	3256	3282	3298	3315	3349	3394	3473	3509	3513	1.16%
Minibus	3155	3286	3334	3380	3454	3543	3640	3754	3861	4005	4065	2.57%
Trucks	9389	9994	10304	10910	11302	11547	11738	11868	12015	12172	12336	2.78%
Others	5030	5070	5304	5435	5817	7352	8239	8605	8727	9326	9697	7.01%
Total	138423	147775	156991	167963	183111	201341	222511	235792	250480	272470	291512	7.74%

The traffic condition in the city indicates that congestion is primarily due to private vehicles and unorganized movement of mass transport modes like Sumos and Minibuses. It gets compounded due to lack of parking spaces at prominent destinations. But this condition is more prevalent in the downtown and central business district areas and less in outskirts. The condition prevailing in the affected areas of the city prompted to use different traffic management related policies which are listed here:

- Odd-Even registration number policy in a cordoned area (Figure 2 & 3) which confines the most congested areas of the city. This need to be supplemented with a regulated on-street parking policy and provision of off-street parking lots.
- A policy is required to manage and operate the Minibuses on different routes in the city. This is a major carrier and provides service to poor and middle-class population. Therefore, along with optimizing, routing, scheduling and synchronizing the Minibus services, it is proposed to implement a stop-based service to decrease travel time and increase the speed and frequency of the minibus transit.
- Another possibility which can be tapped is the inland water transport. Srinagar has interconnected water bodies namely Jhelum river, Dal Lake, Nigeen Lake, Anchar Lake and Khusal Sar. Inland water transport would help in reducing congestion on many road links and in generating new avenues of employment. The inland waterway routes identified and proposed are shown in Figure 2.

Having considered the possible implementation of the above-mentioned policies the main aim of the study focused on the potential of these policies in bringing a change in the existing travel pattern in the city which is having quite higher use of private motorized modes. The possible shift to more sustainable travel options will be the final output of the analysis.

Keeping in view the aim of the study it is decided to conduct a household interview survey using face-to-face interview technique. Data needs are identified which related to existing travel pattern of the respondents and the response of the respondent when confronted with the choices among available travel modes, when given a travel scenario. So, it is decided to collect data related to household characteristics, respondents' personal characteristics, and existing travel characteristics (travel mode, time of travel, destination, trip purpose, travel time, travel cost, delays experienced, etc.). This constituted a Revealed Preference (RP) survey set. Another set is created to evaluate the existing travel mode of the respondent with respect to the operational characteristics of the alternative being proposed. These alternatives are related to the policy which are enumerated before. The travel attributes compared are travel time, travel cost, comfort, etc. which are presented to the respondent in a choice set format. This constituted the Stated

Preference (SP) survey set. A bi-lingual paper-based questionnaire was created in English and Urdu keeping in view the population demographics and to collect the desired RP and SP based information. Eligibility for participation in the survey is kept as follows:

- Age of the respondent shall be 15 years or above,
- The purpose of the trip shall be work or education,
- The respondent is either using the private motorized vehicle or has an option to use them for trips, and
- The origin or destination of the trip falls within the cordoned area.

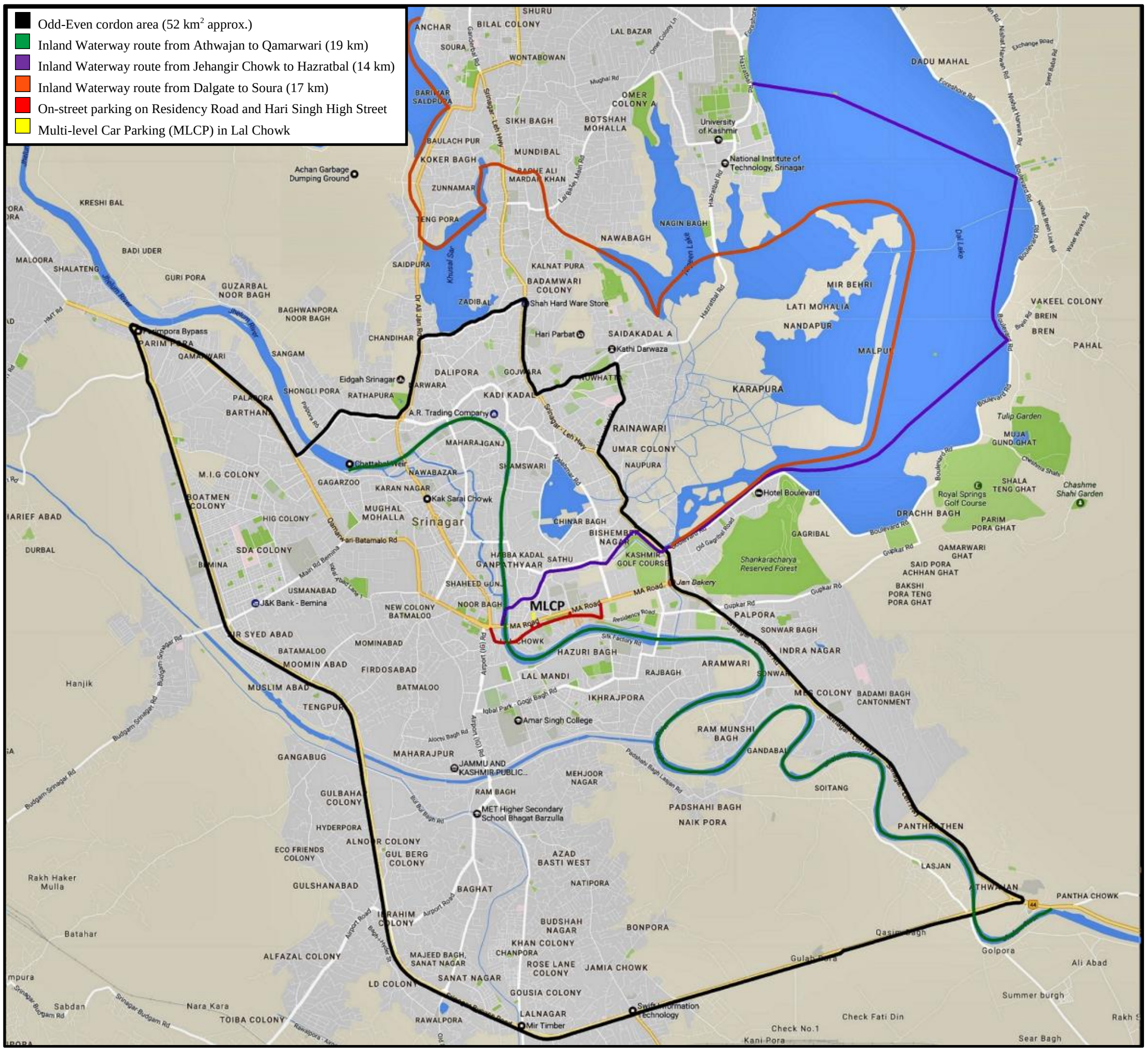
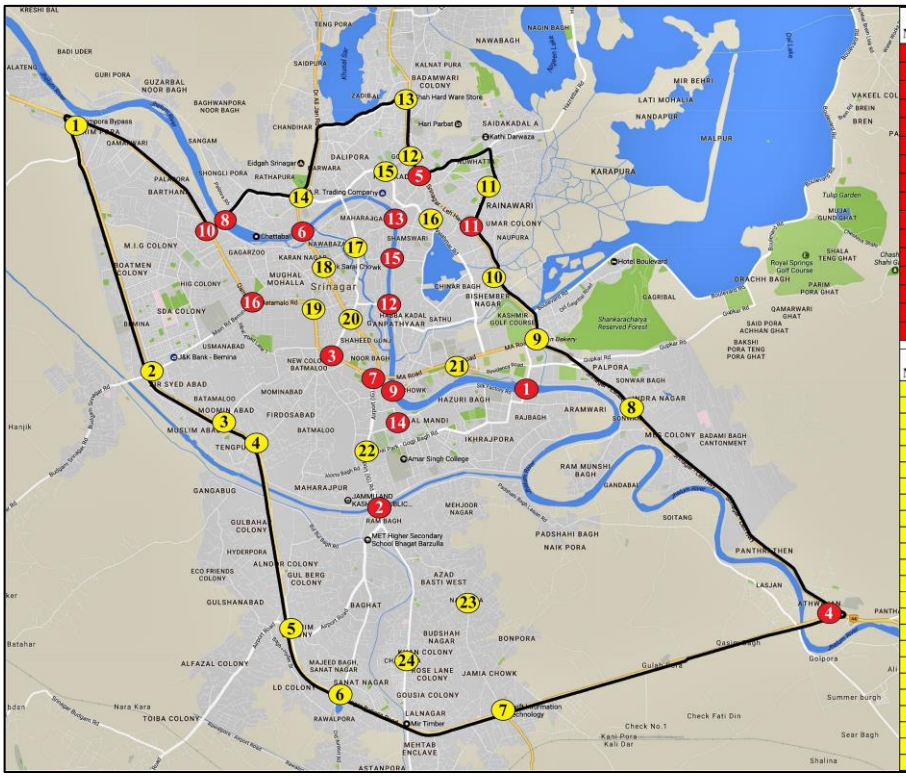


Fig. 2. Odd Even zone, Inland waterway routes and parking scenario in Srinagar.

For the consideration of Odd-Even Registration Number policy, the desired information was the identification of segments or locations which are facing traffic congestion. Based on the documentary search and reconnaissance survey conducted in the city in the month of December 2016, the locations are identified and are shown in Figure 3. It is decided that all the major areas experiencing congestion shall come within the cordon to be marked on the map of the city. The Odd-Even Cordon area considered in this study is shown in Figure 2 & 3. As far as possible, natural geographic and physical features are considered in defining the cordon area. The cordon line was marked by Srinagar Bypass along south and west direction and by Srinagar–Leh highway along east direction. The cordon line along north direction is marked based on extent of locations facing traffic congestion in the area.



S. No.	Congested locations based on RITES (2012)	v/c ratio
1	Abdullah Bridge	3.89
2	Rambagh Bridge	2.16
3	Batmaloo Fire Station	1.96
4	Pantha Chowk	1.94
5	Nowhatta Chowk	1.72
6	Safa Kadal	1.61
7	Jehangir Chowk	1.51
8	Cement Kadal	1.49
9	Amira Kadal	1.24
10	Qamarwari Chowk	1.20
11	Khanyar Chowk	1.04
12	New Habba Kadal	1.02
13	New Zaina Kadal	1.02
14	Wazir Bagh	1.01
15	Fateh Kadal	0.93
16	Bemina Mode	0.85

S. No.	Congested locations based on reconnaissance survey
1	Parimpora Crossing
2	Bemina Crossing
3	Batmaloo Crossing
4	Tengpura Chowk
5	Hyderpora Chowk
6	Sanat Nagar Chowk
7	Nowgam Chowk
8	Sonwar
9	Dalgate
10	Naupura
11	Rainawari
12	Gojwara
13	Hawal Chowk
14	Sekidafar
15	Rajouri Kadal
16	Khanyar Police Station
17	Nawabazar
18	Kak Sarai Chowk
19	Tatoo Ground
20	Landmark Karan Nagar
21	Residency Road
22	Iqbal Park
23	Natipora
24	Chanapora

Fig. 3. Congested locations in the city and Odd Even cordon area.

Once the cordon area is marked, the next step was to identify the locations which may either have origin or the destination of the trip being made. It is decided to use the Traffic Analysis Zones (TAZs) for this purpose which are created in RITES (2012) study. It used 108 TAZs in Srinagar city and around. In the present study 8 TAZs are selected within cordon area and outside cordon area, each. Number of households in the selected TAZs are calculated by dividing the population of the respective TAZs with average household size, i.e. 5.5 as reported for the city (Census of India, 2011). 1% sample of households is taken from each of the selected TAZs and a total sample size of 390 households is obtained.

The survey was conducted in the 16 TAZs according to their respective sample sizes. The TAZ boundaries were obtained by superimposing the TAZ map onto Google Earth. Households were selected randomly in such a way that whole TAZ was covered.

Training is given to enumerators who are mostly graduates in engineering discipline and belonged to the city. They had knowledge of both the languages. Being residents of the city, they were comfortable in approaching the respondents and in conversation with them. This helped in reducing the non-response to an item or a questionnaire. Measures were taken during the training so as to minimize the entry of enumerator's bias. Pilot survey is conducted to reduce the possible problems with respect to the collection of data or data item. Once finalized, the final household personal interview survey is conducted in the month of January 2017 for a period of 25 days. The households are contacted during weekends or at time suitable to the respondent (as communicated by them on contact) so that a male member is present in the house at the time of data collection and interaction.

Once the data are collected, their usability and completeness is examined by entering them in the excel formats. Based on different logical tests among data items (say income v/s vehicle ownership or house ownership) the final RP data set of 326 respondents and SP data set of 408/480/416/312/832 respondents is used for the analysis of choices between Car vs Minibus, Car vs Ferry, Bike/Scooter vs Minibus, Bike/Scooter vs Ferry and Sumo vs Minibus, respectively.

The next section now presents the sample characteristics observed in the RP data set.

3. Sample Characteristics

The characteristics of sampled households with private vehicles and members making trip(s) to cordoned area are summarized in Table 2.

Table 2. Household sample characteristics.

S. No.	Characteristics	Average	Standard Deviation
1	Average Household size	5.62	2.28
2	Household income (monthly, INR)	44216	24537
3	Number of cars owned	1.00	0.67
4	Number of motorized 2-wheelers owned	0.61	0.68
5	Number of working members in household	1.63	0.84
6	Number of non-working members in household	4.06	1.92
7	Number of students in household	1.66	1.15

Examination of the average household size with the census data indicates that the sample represents the population of the city. The dependency factor per household is 2.5 (= non-working members per earning member in a household). Every household is observed to have a car, which is indicative of the good economic status of the households in the city. This is also reflected from the monthly household income. The car ownership at national level is 0.465 per household (Census of India, 2011). Around one-third of the population belongs to education sector, which also is as per the norms and statistics.

Comparison is also made with RITES (2012) data which provides the information on the changes that might have occurred during the gap of 5 years between the two studies. It is interesting to see that the bigger sized households (with members 7 or more) have increased in numbers during the period. Big change has been observed in the household size less than 5.

A reduction is observed in the single car ownership households, as well as, single 2-wheeler ownership households. This reduction is high in car category as compared to 2-wheeler category. The households with car ownership have increased marginally but the number of households with 2-wheeler only have halved. The households having both the vehicles have doubled during the study periods. (Refer Figure 4). Vehicle ownership, especially car ownership, is highly correlated with household income. 2-wheeler ownership is almost 1 in households having monthly income upto INR 25000, after which it fluctuates around 0.50. Households owning 2 cars are present. This is in the households having high monthly income and more earning members.

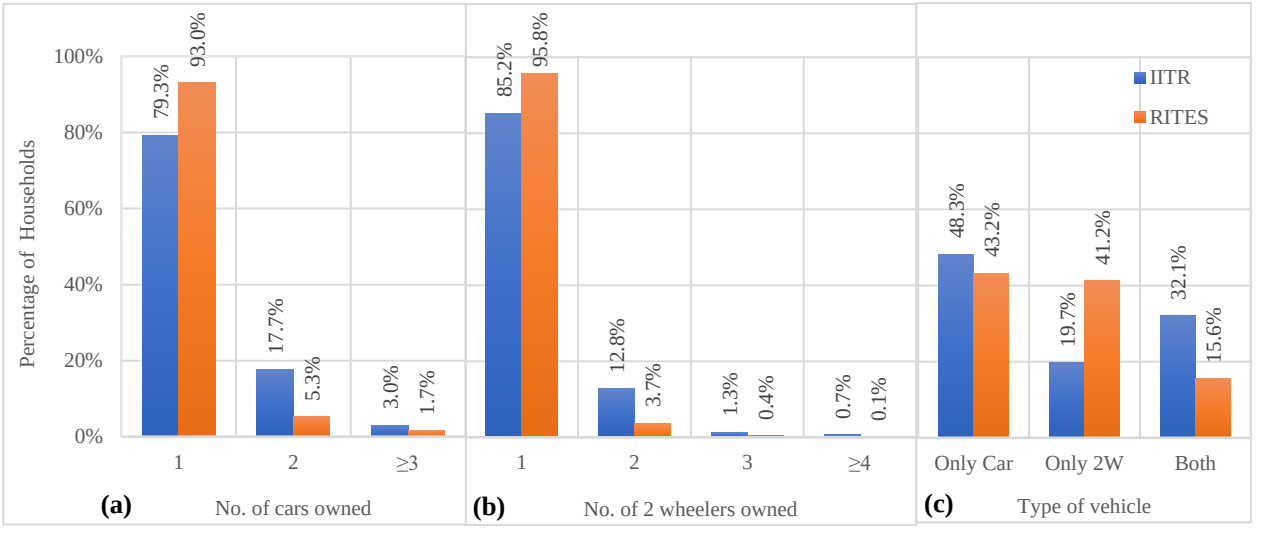


Fig. 4. Distribution of households by (a) Car ownership; (b) 2-wheeler ownership; (c) Type of vehicle

The dependency ratio is observed to be 1:3.5 which is more than the reported ratio by Census of India (2011), i.e. 1:3.08. Increase in dependency ratio may indicate towards possible rise in unemployment in the city or higher population growth.

The examination of personal characteristics of trip makers revealed that majority of them (81.3%) are within the age group of more than 25 and upto 60 years. Around 14.5% of the trips are observed in the age group of 15 to 25 years, out of which 81% are education oriented. Of the total trips captured, 88% were work trips. 71% trip makers reported of parking on driveways and only 16% in garages. Rest of the trip makers parked on-street. 50% of the respondents are observed to be either graduate or above. Around 68% trip makers drove small cars, 6% drove Sport Utility vehicles, 15% drove motor-bikes and 11% drove scooters. Around 18% of the private vehicles were diesel fueled vehicles.

The travel characteristics of the respondents are now presented in the next section.

4. Travel Characteristics

The RP data set is analyzed to examine the travel attributes like travel time, travel cost, trip length, travel speed, delay, etc. First of all, the trips are examined with respect to the time in the day when they start or end. The related profile is shown in Figure 5. The times of start and finish of trips are plotted to get an idea of the peak periods. Morning peak hour is observed between 9 AM and 10 AM and evening peak period is varying between 4 PM and 6 PM. Similar characteristics are observed for work trips. For education trips morning peak period is found varying between 8 AM and 10 AM and the evening peak period spanned from 3 PM to 5 PM. It is evident that morning peak is more severe than evening peak. Further, the deviation in the start and end of trip plot indicates that travel time is higher between 8.30 and 9.30 AM and between 3.00 and 5.00 PM.

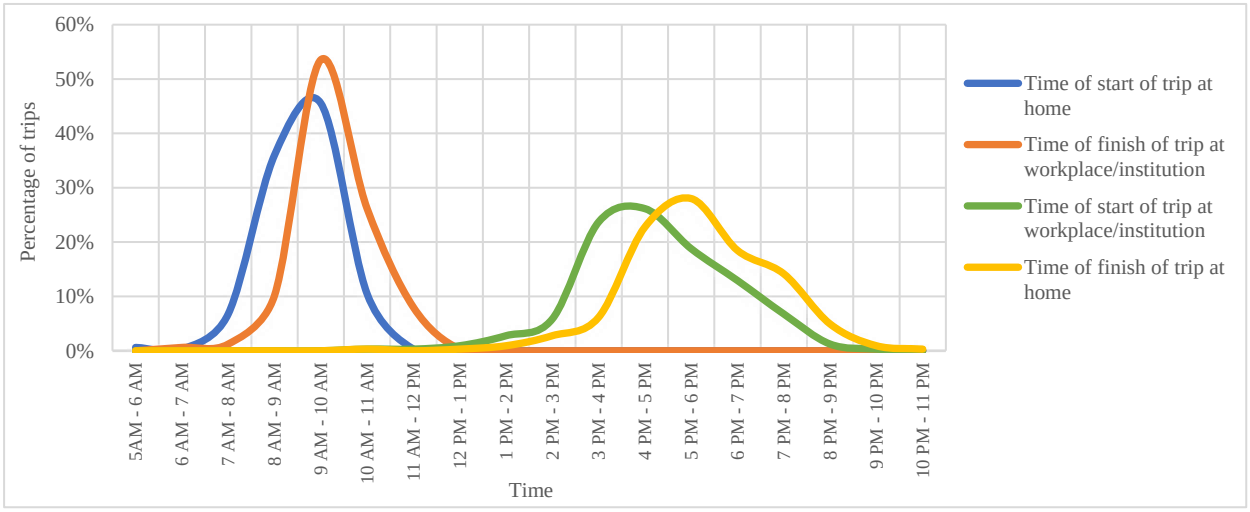


Fig. 5. Peak periods with respect to start and end of trips.

It is to be noted here that the above trip start or end profile does not consider the tourists who visit the city and move as per their own comfort and programme. Consideration of that along with public transport like 8-10 seat vehicles (Sumos etc.) will impact the peak periods which at present looks to be either an hour or two.

Further, the distribution of trips by trip length, travel speed and travel time is illustrated in Figures 6a, 6b and 6c, respectively. It can be observed that majority of trips are made in the distance range of 6 to 10 km. 75% of the trips are made within 10 km distance and 90% within 15 km distance. Travel distance segments provide an opportunity to look at the hierarchical use of travel modes in the city. Routes may be created for Sumos which may be used for distances more than 10 km. Minibuses can be the option in the distance range of 1 to 10 km and this may be accessed through either non-motorized modes or small but efficient vehicles used in shared condition. These travel modes can also be the mode of travel within 5 km range.

The scenario of the travel speed is not good either. Only 16% of the trips are reported to have achieved a journey speed of 20 km/h or more. Based on the urban road hierarchy, this speed is not even acceptable for local streets, for which it should be 30 km/h (IRC 86 1983). Travel time is one of the efficiency measures for any network in a city. Presenting pure travel time will be indicative only of the amount of time spent by trip makers in travelling between origin and destination. That way it can be noted that only 9% of the trip makers are able to reach their destination within 15 minutes of travel. Marginally lower than 50% of the trip makers have to travel for more than 30 minutes. This cannot be admired looking at the extent of the city in length (29 km) and breadth (27 km). To get better feeling or an idea of travel situation it would be better to discuss it in terms of travel time per km distance or unit travel time. The distribution with respect to the unit travel time is shown in Figure 6d. Majority of the trips (40%) have a unit travel time of 2 to 4 minutes per km. Only 5% of trips are covered with less than 2 minutes per km. Around 90% of trips have a unit travel time between 2 to 8 minutes per km.

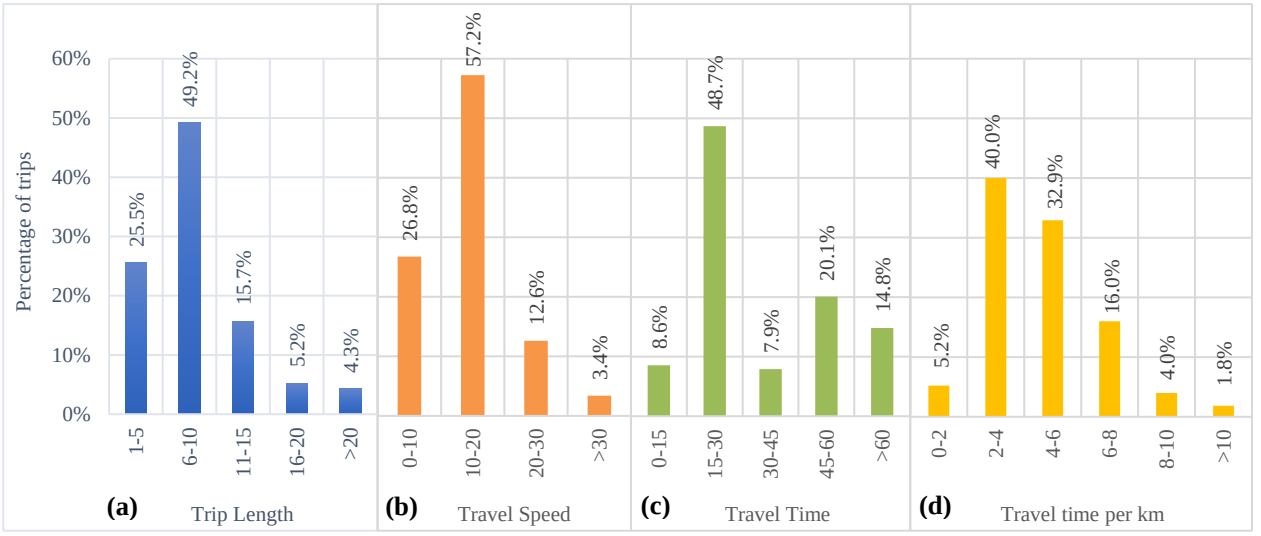


Fig. 6. Distribution of trips by (a) Trip length; (b) Travel Speed; (c) Travel time; (d) Unit travel time.

Average value, standard deviation and 85th percentile values for various travel characteristics are shown in Table 3. The data indicates that students have to travel longer distances, around 110% of the distance travelled on an average by work force. In the case of 85th percentile values this variation increases to 125%. Compared to 2-wheelers, cars are used for longer distances. Travel speeds provide interesting information. Trips within cordon area (generated and completed) are facing higher friction which is indicated by lower speed. In comparison to this the trips which are made across the cordon line have faced lower friction as symbolized by the travel speed. As one travels outside the cordon area the speeds increase. In terms of travel mode, the speed efficiency of car and 2-wheeler is found to be almost same. This indicates that there is no mode utility in the present scenario.

Travel time is indicative of the performance measure of a road or a network. It is obvious that the average travel time when using car is higher than the travel time by 2-wheeler. This is because of the higher distances being travelled by car owners as compared to 2-wheeler owners. But when it is looked in terms of unit travel time it can be noted that car is taking marginally lesser time as compared to 2-wheeler in covering 1 km distance. The average Unit travel time is as high as 5 minutes per km. The congested condition on a section is better known in terms of delays being observed at that section. It is observed that the delay is quite high on the road network in the city. Travel cost of the trip for education purpose is quite lower than the cost incurred on work trip. This may be due to use of public transport more for education trip as compared to work trip which may be by car or 2-wheeler. The cost of travel by car is 3 times higher than that spent on travelling by 2-wheeler.

The variation in delay due to congestion with respect to travel time is shown in Figure 7. The steep rise in delay with increase in travel time shows the gravity of traffic problem in the city. The overall average delay for a trip length of 9.89 km was estimated as 16.03 minutes.

Table 3. Statistics related to Travel Characteristics.

Type of trips	85th Percentile	Average	Standard deviation
Trip length (km)			
Work trips	13.00	9.79	9.08
Education trips	16.20	10.60	5.32
Trips by car	15.00	10.41	9.75
Trips by 2-wheeler	12.00	8.43	4.40
Overall trips	15.00	9.89	8.70
Travel speed (km/h)			
Trips within cordon area	16.70	12.49	5.81
Trips generated within cordon area	20.00	14.27	7.08
Trips generated outside cordon area	21.00	16.73	7.88
Trips by car	20.00	15.14	7.87
Trips by 2-wheeler	21.08	16.13	6.56
Overall trips	21.00	15.40	7.55
Travel time (minutes)			
Trips by car	60.00	41.57	20.16
Trips by 2-wheeler	50.63	33.98	20.41
Overall trips	60.00	39.56	20.47
Unit travel time (minutes/km)			
Overall trips	7.03	4.85	5.39
Delay per travel time (%)			
Overall trips	55.55	40.53	15.45
Travel cost (INR)			
Work trips	68.52	50.53	53.26
Education trips	85.65	35.56	30.95
Trips by car	85.65	59.44	55.70
Trips by 2-wheeler	26.76	18.80	9.80
Overall trips	70.80	48.69	51.25

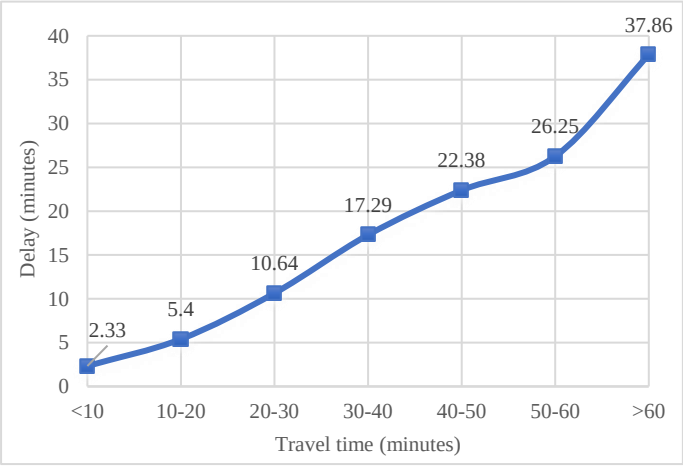


Fig. 7. Delay v/s Travel time.

5. Policy Implementation

The origin and destinations of work and education trip makers are available for trips generated within and outside the cordon area. On the whole, 20% of work trips, 18% of trips generated within cordon area and 19% of trips generated outside cordon area are directed towards Lal Chowk which is the CBD area of Srinagar. Majority of education trips (27.5%) are directed towards Hazratbal where the major educational institutions like University of Kashmir and National Institute of Technology Srinagar are situated. The Desire Line diagram is presented in Figure 8.

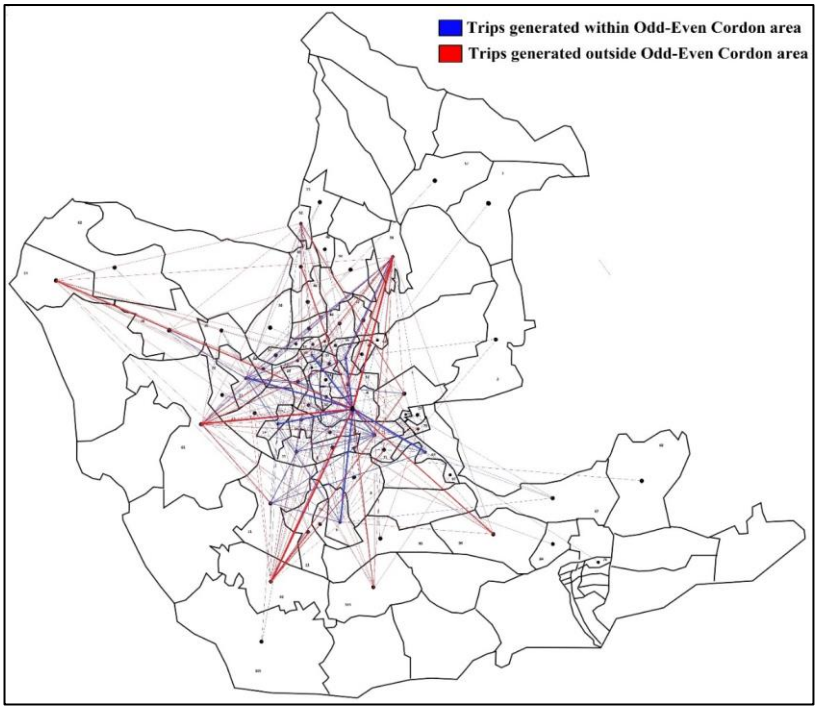


Fig. 8. Desire line diagram.

Figure 9 shows the congested locations in Srinagar as per the respondents' perception. The graph roughly follows a negative exponential distribution and it can be implied that the locations towards the left of the point where the curvature increases abruptly need to be tackled urgently. The locations in the descending order of their severity are identified as Jehangir Chowk, Rambagh Bridge, Batmaloo Fire Station, Dalgate, Abdullah Bridge, Qamarwari Chowk and Pantha Chowk. RITES (2012) reported the effective v/c ratio at these locations as 1.51, 2.16, 1.96, NA, 3.89, 1.20 and 1.94, respectively. Another important condition to be noted is the higher flow of trips towards these 7 locations. Around 40% of the trips are made to these locations which itself speak of the gravity of the situation.

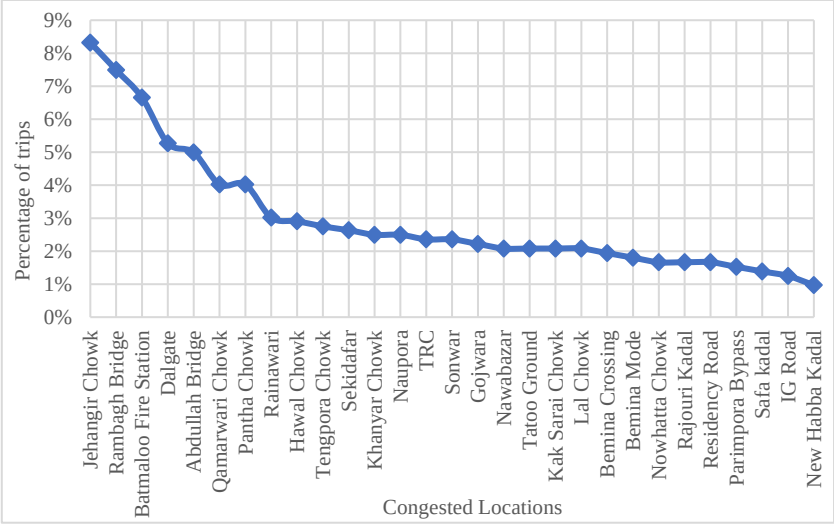


Fig. 9. Congested locations as per respondents' perception

While looking at the parking problem in these congested areas it is noticed that 62% of the trip makers parked in office/institute parking. Only 6% used parking lots including multi-level car parking in Lal chowk area (Refer Figure 2). Rest is on-street. This indicates towards deficient parking system in Srinagar. The percentage of on-street parking is 6% in Lal Chowk (CBD) (Refer Figure 2) and 9% in Downtown Srinagar, while 17% in rest of the city. Again, it can be noted that these two areas are congested, and Lal chowk is commercially active. Downtown is a densely populated area. The above percent of on-street parking is more than sufficient to cause blocks and traffic congestion in these areas. 100% of the respondents who parked on-street responded that they will comply with on-street parking prohibition subjective there are adequate off-street or multi-storied parking facilities available in the areas.

Another issue that gets prominent is the level of air pollution and its loading in the atmosphere that increases due to lower speeds, congestion and idling of vehicles. For each vehicle category and their average round trip lengths, the sample percentage of vehicles falling in different environment control category of vehicle classification is used with respect to the total vehicle registrations in the city. The emission factors for each stage are obtained from CPCB (2017) to calculate the total emissions caused by cars and 2-wheelers in Srinagar city. Table 4 illustrates the process by which the emissions are calculated. The Carbon Monoxide emissions (CO) are determined as 8.58 tonnes/day while the Hydrocarbons and Oxides of Nitrogen (HC+NOx) emissions are found out to be 4.03 tonnes/day. This calculation is based on the assumption that all the registered cars and 2-wheelers are plying on the roads.

Table 4. TAZ map and Sampling of households.

Stage	Sample %	Emission Factors (g/km/veh/day)		Emissions (tonnes/day)	
		CO	HC+NOx	CO	HC+NOx
Cars (Total registrations=106023, Average round trip length=20.82 kms)					
Bharat Stage III (Euro 3)	76.99%	2.30	0.35	3.91	0.59
Bharat Stage II (Euro 2)	17.99%	2.20	0.50	0.87	0.20
India Stage I (Euro 1)	4.60%	2.72	0.97	0.28	0.10
1998	0.42%	4.34	1.50	0.04	0.01
2-wheelers (Total registrations=126514, Average round trip length=16.86 kms)					
Bharat Stage III (Euro 3)	61.63%	1.00	1.00	1.31	1.31
Bharat Stage II (Euro 2)	17.44%	1.50	1.50	0.56	0.56
India Stage I (Euro 1)	15.12%	2.00	2.00	0.65	0.65
1996	4.65%	4.50	3.60	0.45	0.36
1991	1.16%	21.00	10.00	0.52	0.25
Total Emissions				8.58	4.03

Before presenting the Odd-Even registration number policy it was needed to know the travel times in the present scenario and to get an estimate of reduction in travel time if this policy is implemented. This was required to be told to the respondents at the time of interview before they took any decision related to the policy. Travel time by car and motorized 2-wheeler is measured by Average Car method or Average Speed method wherein the test vehicle travels at a speed that is judged as the representative of the speed of all traffic at that time and the travel time is reported as the average of back and forth travel times. Travel time is measured during both peak and off-peak periods using car and bike as test vehicles along four directional routes within the Odd-Even cordon area and the possible reduction in travel time due to implementation of Odd-Even policy is reported as the difference between the travel time in peak and off-peak periods.

Majority of the respondents (81.37%) are already aware of the Odd-Even policy implementation in New Delhi. Only 16.15% of the trip makers owned and used vehicles with both odd and even registration plate numbers by themselves. Interview of these individuals is terminated at this point. The responses of other trip makers are considered in the analysis of Odd-Even policy.

The support for the implementation of Odd-Even Policy based on gender, age, education and household income is demonstrated in Figure 10. Females are found to be more supportive than males. Similarly, trip makers in upper age group are found more supportive than those in lower age groups. Support for the policy in different education groups fluctuated around 55%. Interestingly, the higher income groups showed much more support for the odd-even policy as compared to trip makers in lower income groups. The support was found to be as high as 82.4%. Such positive response from the high-income groups suggests that there will be less multiple car acquisition if the policy is implemented.

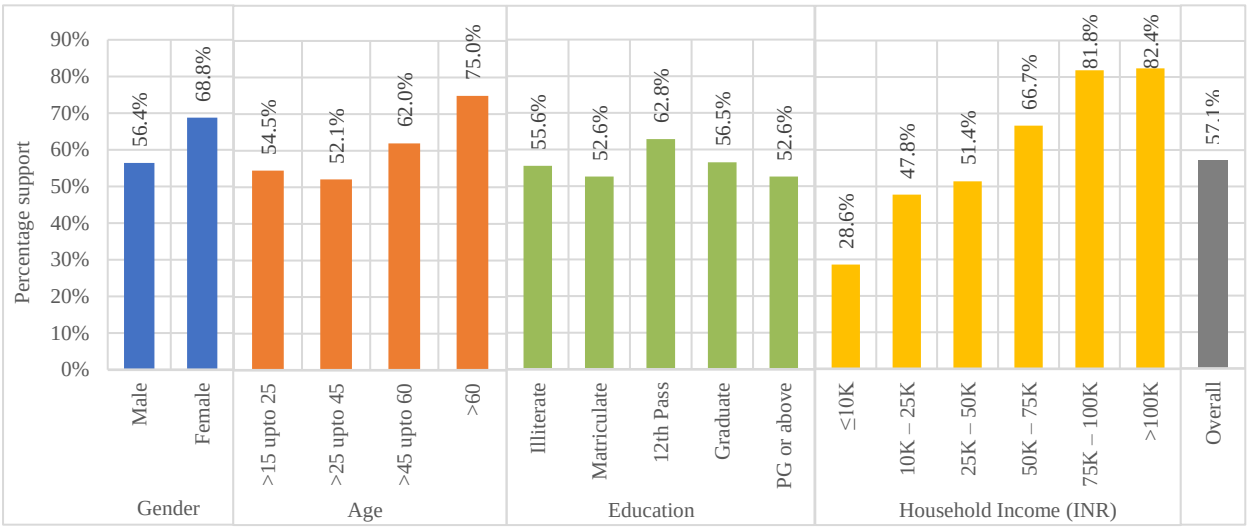


Fig. 10. Support for implementation of Odd-Even policy across population groups.

On the whole around 57% respondents supported the implementation of Odd-Even policy for the city. 19% trip makers remained neutral and around one-quarter of the trip makers did not favoured the policy. Additionally, three-quarter of the respondents stated that they will not purchase another vehicle with counter registration plate number of the vehicle if the policy is implemented. Though the literature (Couture and Dooley, 1981) speaks that positive responses to the un-experienced situations are not fully reliable, it at least indicates towards the positive public opinion regarding the policy and their understanding of the problems which the city is facing due to high level of traffic congestion. Therefore, it can be inferred that the people of Srinagar are saying "Yes for a change" and at the same time they are not trying to nullify the effects of the policy by acquiring another vehicle. If at least 35% of the trip makers using private vehicles shift to alternate travel opportunities under the implementation of Odd-Even policy, then the pollution load due to cars and 2-wheelers is expected to reduce by around one third of the present load. CO emissions will reduce by 3 tonnes/day and HC+NOx emissions by 1.54 tonnes/day. The expected reductions in v/c ratio are shown in Table 5.

Table 5. Expected reductions in v/c ratio under implementation of odd-even policy.

S. No.	Congested location	Present v/c ratio	Expected v/c ratio
1	Abdullah Bridge	3.89	3.17
2	Rambagh Bridge	2.16	1.73
3	Batmaloo Fire Station	1.96	1.61
4	Pantha Chowk	1.94	1.65
5	Nowhatta Chowk	1.72	1.32
6	Safa Kadal	1.61	1.30
7	Jehangir Chowk	1.51	1.28
8	Cement Kadal	1.49	1.25
9	Amira Kadal	1.24	1.07
10	Qamarwari Chowk	1.20	0.97
11	Khanyar Chowk	1.04	0.87
12	New Habba Kadal	1.02	0.83
13	New Zaina Kadal	1.02	0.87
14	Wazir Bagh	1.01	0.82
15	Fateh Kadal	0.93	0.74
16	Bemina Mode	0.85	0.69

The probable modal shifts are presented in Figure 11.

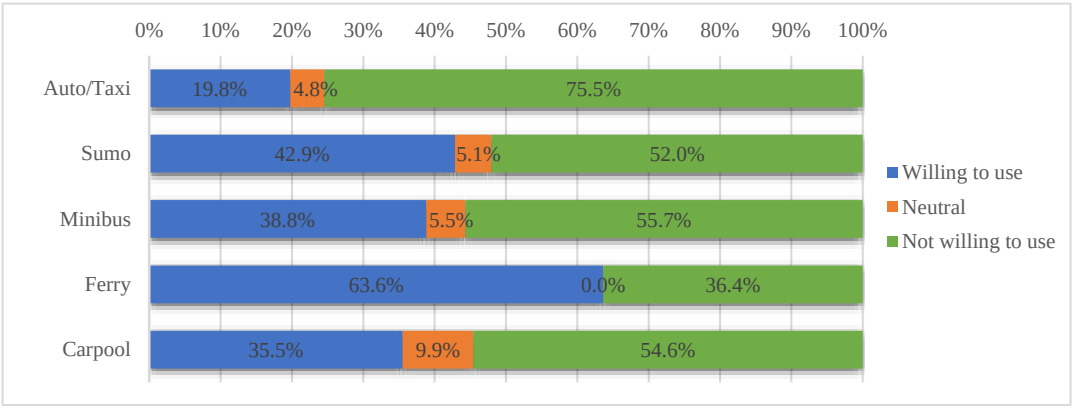


Fig. 11. Probable modal shifts under implementation of odd-even policy.

The low willingness to use Auto/Taxi (19.8%) is understandable owing to the high cost of these alternatives. 52% of the respondents are not willing to use Sumo as an alternative. The low willingness to use it is due to the fact that out of these trip makers, majority (83.8%) are found travelling for a distance of upto 10 km. Further, Sumos are meant for larger distances and they have a fixed fare. Only 38.8% of respondents are willing to use Minibus as an alternative. This is obvious because the current condition of Minibuses is far from worse. Travel times are higher, speeds are extremely low and comfort condition is detestable.

Inland waterways and use of ferry is proposed in the areas which are aligned along the river or provide connectivity across water bodies (lakes here). These are discussed before. The design of ferry is considered such that vehicles can also be taken in it across the water bodies. The willingness to use Ferry is determined for those trips which have origin or destination along the river or lake side. 63.6% of overall and 83.3% of 2-wheeler trip makers showed interest in using Ferry as an alternative, if implemented. This indicates a good potential for the implementation of Inland waterway transport is Srinagar.

Only 35.5% of overall trip makers showed willing to use carpool. Carpooling is taken positively by education trip makers wherein 56.8% showed their willingness. In such conditions the load of traffic on the roads will reduce which will improve the travel speeds and travel times across the locations.

The expected reductions in v/c ratios and emission loadings under these policy impacts are presented in Tables 6 and 7, respectively.

Table 6. Base and expected v/c ratios under various policy impacts.

S. No.	Congested location	Present v/c ratio	Expected v/c ratio due to policy impacts				
			Auto/Taxi	Sumo	Minibus	Ferry	Carpool
1	Abdullah Bridge	3.89	3.50	3.04	3.03	3.01	3.16
2	Rambagh Bridge	2.16	1.92	1.64	1.67	1.64	1.72
3	Batmaloo Fire Station	1.96	1.77	1.55	1.54	1.53	1.61
4	Pantha Chowk	1.94	1.76	1.55	1.66	1.60	1.64
5	Nowhatta Chowk	1.72	1.52	1.28	1.20	1.22	1.32
6	Safa Kadal	1.61	1.46	1.28	1.20	1.23	1.30
7	Jehangir Chowk	1.51	1.39	1.24	1.24	1.23	1.28
8	Cement Kadal	1.49	1.36	1.22	1.18	1.19	1.25
9	Amira Kadal	1.24	1.16	1.07	1.01	1.03	1.07
10	Qamarwari Chowk	1.20	1.09	0.96	0.88	0.91	0.97
11	Khanyar Chowk	1.04	0.96	0.86	0.80	0.82	0.87
12	New Habba Kadal	1.02	0.93	0.83	0.76	0.78	0.83
13	New Zaina Kadal	1.02	0.95	0.86	0.81	0.83	0.87
14	Wazir Bagh	1.01	0.91	0.79	0.78	0.78	0.82
15	Fateh Kadal	0.93	0.84	0.72	0.69	0.70	0.74
16	Bemina Mode	0.85	0.77	0.67	0.66	0.66	0.69

Table 7. Base and expected emission loadings under various policy impacts.

Policy Impacts	Base Emission Loadings (tonnes/day)		Expected Emission Loadings (tonnes/day)	
	CO	HC+NOx	CO	HC+NOx
Auto/Taxi	8.58	4.03	7.00	3.47
Sumo			5.13	2.77
Minibus			4.92	1.76
Ferry			4.90	2.18
Carpool			5.55	2.63

A significance analysis of various factors is carried out and a correlation matrix is developed, on the basis of which, it is observed that household income, age, trip length/distance and delay per travel time are the factors which influence the decisions regarding the support for Odd-Even policy. Income, age and delay per travel time have a positive effect on the response while the trip length/distance have a negative effect. These are shown in Tables 8 and Figure 13.

Table 8. Correlation matrix of support for odd-even policy.

	HHSize	Working	Students	Income	WE	Gender	Age	Edu	Distance	Mode	TSH	TFWE	TSWE	TFH	Time	Speed	Delay	DelayTT	DelhiOE	Support
HHSize	1																			
Working	0.605	1																		
Students	0.752	0.314	1																	
Income	0.265	0.370	0.232	1																
WE	-0.039	-0.078	-0.022	0.103	1															
Gender	-0.018	0.029	-0.058	0.038	0.220	1														
Age	0.010	-0.048	0.097	0.003	-0.624	-0.192	1													
Edu	-0.125	-0.055	-0.072	0.181	-0.012	0.141	-0.162	1												
Distance	-0.035	0.106	-0.093	0.142	0.020	-0.034	-0.042	0.110	1											
Mode	-0.003	0.125	-0.072	-0.181	0.363	0.119	-0.323	-0.193	-0.124	1										
TSH	-0.007	0.005	0.068	0.024	-0.150	0.018	0.122	0.042	-0.292	-0.215	1									
TFWE	-0.017	-0.024	0.039	0.091	-0.151	-0.007	0.118	0.069	-0.008	-0.283	0.894	1								
TSWE	0.053	-0.017	0.069	-0.086	-0.292	-0.177	0.206	-0.239	0.004	-0.271	0.156	0.145	1							
TFH	0.048	-0.016	0.047	-0.068	-0.288	-0.174	0.200	-0.210	0.155	-0.296	0.091	0.161	0.971	1						
Time	0.005	-0.007	-0.058	0.121	-0.009	-0.036	0.001	0.075	0.692	-0.166	-0.201	0.194	-0.040	0.181	1					
Speed	-0.099	0.048	-0.096	-0.025	0.026	-0.019	0.001	0.025	0.626	0.033	-0.270	-0.248	0.053	0.053	0.007	1				
Delay	0.055	-0.014	0.011	0.154	-0.007	0.018	0.015	0.095	0.488	-0.181	-0.077	0.246	-0.041	0.149	0.841	-0.168	1			
DelayTT	0.096	-0.005	0.065	0.093	0.046	0.131	-0.023	0.071	-0.068	-0.096	0.149	0.193	-0.082	-0.035	0.177	-0.371	0.623	1		
DelhiOE	0.007	0.005	0.017	-0.144	-0.151	-0.051	0.164	-0.332	-0.094	0.150	0.006	-0.025	0.096	0.079	-0.066	-0.025	-0.121	-0.118	1	
Support	0.032	0.019	0.101	**0.202**	-0.015	0.034	**0.136**	0.013	**-0.157**	-0.062	0.107	0.042	-0.044	-0.056	-0.081	-0.179	0.039	**0.173**	0.003	1

6. Conclusions and Recommendations

The socio-economic status of the people in Srinagar city is improving as is depicted by the increase in the number of private vehicles in the household when compared with the study of RITES (2012). Majority of private vehicle trips are work oriented and made by males within the age group of 25 to 60 years, the driving license holding being 96%. The average travel time is more and average speed is less within the cordon area when compared with outside the cordon area, which clearly suggests that the proposed Odd-Even cordon area has congestion problems. The 85th percentile delay per travel time and unit travel time is as high as 56% and 7.03 minutes, respectively. The most congested locations as obtained from the survey have a v/c ratio of more than 1 when compared with RITES (2012). On-street parking is predominant in CBD (Lal Chowk) and Downtown areas of the city. All respondents replied to comply with the prohibition of On-street parking provided there are adequate parking facilities available. The prospects for Odd-Even Policy in Srinagar are good with over 57% of the respondents in favour and 19% being neutral. Moreover 76% stated that they won't nullify the policy by acquiring a vehicle with counter registration plate number. Around 64% of the respondents with origin or destination along the river and lake side showed interest in using inland waterways which indicates a good potential for its implementation in Srinagar city. Majority of education trip makers (57%) are ready to carpool which is a good sign. Use of ferry and minibus under implementation of Odd-Even Policy gave best results in terms of v/c ratio and pollution reduction.

The traffic congestion at Jehangir Chowk, Rambagh Bridge, Batmaloo, Dalgate, Abdullah Bridge, Qamarwari Chowk and Pantha Chowk needs to be tackled urgently. Odd-Even policy should be implemented within the proposed cordon area to reduce congestion and air pollution in the city. Considerable effort is needed to improve the overall conditions of minibus to arrest the shift towards private vehicles. Additionally, a stop-based service should be put into effect to decrease travel time, and increase the speed and frequency of the minibus transit. The water bodies in Srinagar, i.e. Jhelum river, Dal lake, Nigeen lake, Khusal Sar and Anchar lake should be utilized for inland water transport which will reduce traffic congestion on the roads and also generate new avenues of employment. On-street parking should be prohibited in CBD and Downtown areas especially on the Residency Road, Hari Singh High Street, Nallamar Road and KZP Road. Moreover, there is a need for construction of more parking lots to address the exorbitant parking demand in CBD and Downtown areas. Additionally, the parking charges should be increased to discourage private vehicle trips. These should also be levied on on-street parking and should be quite high as compared to the off-street car park cost. The parking charges for on-street parking shall be implemented at least within 1000 m of the multi-level car park in the Lal chowk area of the city.

It is envisaged that if the proposed measures are implemented in the city then the traffic generated problem will come under control for coming years. This time shall be used to give a rethinking and to plan for future set of policies which may be needed due to expansion of city and increase in population and vehicle ownership in the city.

Acknowledgements

Authors are thankful to postgraduate students of NIT Srinagar namely Molvi Abrar Hussain, Tufail Hussain Khan, Abdul Rashid, Mohammad Shafi, Tawseef Ahmad and Irfan Amin Bhat for constant support during data collection.

References

Census of India (2011). District Census Handbook Srinagar, Srinagar: Directorate of Census Operations Jammu & Kashmir.

Centre for Science and Environment (2016). Status of air pollution during winter of 2015-16 and the impact of odd-even car rationing scheme on air quality. New Delhi: Centre for Science and Environment Fact Sheets, pp. 1-14.

Couture and Dooley, (1981). Stated Preference methods and travel demand forecasting: An examination of the scale factor problem. Transportation Research Part A, Vol. 25 (2-3), pp. 79-89.

CPCB (2017). Vehicular Exhaust. New Delhi: Central Pollution Control Board. Available at: http://cpcb.nic.in/vehicular-exhaust/ [Accessed 12 Jun. 2018].

Davis, S.C., Diegel, S.W. and Boundy, R.G. (2016). Transportation Energy Data Book: Edition 35. Oak Ridge: Oak Ridge National Laboratory.

de Palma, A. and Lindsey, R. (2011). Traffic congestion pricing methodologies and technologies. Transportation Research Part C: Emerging Technologies, 19(6), pp. 1377-1399.

Goel, R. and Pant, P. (2016). Vehicular Pollution Mitigation Policies in Delhi. Economic & Political Weekly, 51(9), pp. 41-45.

Goel, R., Tiwari, G. and Mohan, D. (2016). Evaluation of the Effects of the 15-day Odd-Even Scheme in Delhi: A Preliminary Report. New Delhi: Transportation Research & Injury Prevention Programme, Indian Institute of Technology Delhi.

Gulipalli, P.K., Kalmanje, S. and Kockelman, K. (2011). Credit-based congestion pricing: expert expectations and guidelines for application. Journal of the Transportation Research Forum 47(2), pp. 5-19.

Han, D., Yang, H. and Wang, X. (2010). Efficiency of the plate-number-based traffic rationing in general networks. Transportation Research Part E: Logistics and Transportation Review, 46(6), pp. 1095-1110.

IRC: 86 (1983). Geometric Design Standards for Urban Roads in Plains. New Delhi: Indian Roads Congress.

Janwari, M.M., Tiwari, G., Popli, S.K. and Mir, M.S. (2016). Traffic Analysis of Srinagar City. Transportation Research Procedia, 17, pp. 3-15.

Litman, T., (1999). Distance-based charges; a practical strategy for more optimal vehicle pricing. Victoria: Victoria Transport Policy Institute.

RITES (2012). Comprehensive Mobility Plan for Srinagar. Srinagar: Rail India Technical and Economic Service Limited, for Planning and Development Department, Government of Jammu and Kashmir.

RTO Kashmir (2017). District wise/ Category wise number of vehicles registered in Kashmir Division since inception upto ending 31-03-2017. Srinagar: Regional Transport Office Kashmir.

Seik, F.T. (1998). A unique demand management instrument in urban transport: the vehicle quota system in Singapore. Cities, 15(1), pp. 27-39.

SMC (2016). Srinagar Smart City: Citywide concept plan. Srinagar: Srinagar Municipal Corporation.

Sperling, D. and Gordon, D. (2009). Two billion cars: driving toward sustainability. Oxford: Oxford University Press.

Yang, J., Liu, Y., Qin, P. and Liu, A. A. (2014). A review of Beijing's vehicle registration lottery: Short-term effects on vehicle growth and fuel consumption. Energy Policy, 75, pp. 157-166.