Level of Service of Urban and Rural Roads- A Case study in Bhimavaram

Pala Gireesh Kumar¹, Sathya Ranjan Samal², L. Prasanthi³, V. Bhavitha⁴, J. Mounika Devi⁵

¹Associate Professor, Department of Civil Engineering, Shri Vishnu Engineering College for Women (Autonomous), Vishnupur, Bhimavaram-534202, West Godavari Dist., India
²Associate Professor, School of Civil Engineering, KIIT Deemed to be University, Bhuvaneswar, India
³,⁴,⁵ U.G Students, Department of Civil Engineering, Shri Vishnu Engineering College for Women (Autonomous), Vishnupur, Bhimavaram-534202, West Godavari Dist., India

E-mail: bhavithavetukuri@gmail.com; palagireeshk@gmail.com; prasanthilokam277@gmail.com

Abstract. With rapid growth of population in urban and rural areas, purchase of motorized vehicles is also grown and the demand for proper transportation network which can give good compatibility to the road users has become a major challenge in India. Level of Service (LOS) is one such parameter in terms of compatibility that gives a quality measure for the operational conditions within a traffic stream, i.e., generally in terms of service that is provided by the road to the user. This paper investigates on the existing level of service models for urban and rural roads given by researchers globally. To determine the Level of service of a particular road section, there are few commonly used methods like, Cluster Analysis, Genetic Algorithm, Fuzzy Set Theory and Neural Network etc., which are used, were discussed and reported in this paper. A new approach for finding level of service was introduced, i.e., using volume to capacity ratio (v/c), average speed of the vehicles, percentage speed reduction is also discussed and presented. This paper brings out the collective information on LOS and its findings using analytical models which can estimate/predict compatibility levels of various road users in heterogeneous traffic conditions in urban environment. The objective of this project is to study Los for various selected roads were obtained and discussed. Research work was carried in Bhimavaram (India) town, Ramayanpuram, Jaganadhapuram villages. Both study area-1,3 was observed to have LOS-D grade whereas study area-2,4 was observed to have LOS-E grade. Some of the remedial measures were given in order to increase its Los grades towards better satisfaction of traffic conditions.

1. Introduction

Over the past decade, use of motorized vehicles has been significantly increased with rapid growth of urbanization in India. This robust increase in population has given a challenge for the development of modern society which has turned into a major concern in metropolitan cities in developing countries like India. At present, the world population crosses seven billion and population residing at urban areas are nearly half of seven billion counts which is expected to raise up to 60 % over worlds entire population by the end of 2025 [5]. Indian cities are well connected with urban roads and rural roads everywhere but, there exists poor transportation network/connectivity with negligible intra and intercity facilities [5]. Hence, traffic flow in heterogeneous conditions is highly complex and is difficult to predict the flow behaviour on urban roads. Driver’s comfort, convenience, traffic volume, lane width, grade type, geometric design,
travel delay and safety are the major concerns on Indian urban roads which are to be taken care. Monitoring traffic volume and level of service which represents quality transport has become indispensable [13].

In recent years, traffic congestion and decreasing level of service has become major issues in most of the metropolitan cities and results its impact on urban economy and its environment [1], [9], [11]. Good transportation facilities are needed to be provided as it plays a major role in growing India’s economy [4], [13] [14], [15]. From past studies, it was found that, obtained traffic volume plays a vital role in determining the existing conditions and even possible to predict the future traffic volume conditions [9], [11]. There are certain factors which are responsible for decreasing level of service and traffic congestion i.e., speed and travel time, traffic interruptions and restrictions. This downfall of level of service has become a serious threat as it creates difficulty for vehicle manoeuvring. Similarly, traffic congestion also creates air pollution and noise pollution which is caused by the delays in traffic jams. This traffic congestion and poor level of service on Indian roads have huge impact on its economic growth [1], [9]. There are few commonly used methods like, Cluster Analysis, Genetic Algorithm, Fuzzy Set Theory and Neural Network etc., which are used to determine the Level of service of a particular road section.

This paper aims to develop sound understanding of Level of Service (LOS) on urban and rural roads in Indian conditions from the previous studies conducted. The detailed information on various parameters that are used to define LOS are also reported and presented. The classifications of LOS grades along with its operating characteristics are also provided.

2. State of the art and methodology
This section gives sound knowledge on level of service concept under heterogeneous traffic conditions on Indian urban roads. A detail literature study was carried out and presented an outline of various researchers’ findings.

2.1. Literature review
B Robin et al (2016) carried at research work on finding level of service for urban areas under free flow conditions, load factor, peak hour factor and volume to capacity ratio respectively. The classification of LOS and its operating characteristics were presented in this paper which is mostly based on run time and delay time. Concludes that, LOS for urban roads are unlike similar to that of rural roads [5].

S Biswas et al (2016) field studies were carried out using video graphic technique to observe and collect traffic flow characteristics on urban arterials in Kolkata metropolises city. Companion has been made among the collected data like, mean speed, standard deviation and coefficient of variation with standard values. Kolmogorov -Simonov (K-S) test was performed to check compatibility of the modelled distribution curves. Clustering algorithm was used to classify PSR into number of sub groups. Study concludes that, the metropolitan's study operational conditions on roads falls under LOS F; which indicates necessity of improvement on LOS with immediate effect [16].

F M John and Al Werner (1990) an attempt has been made to investigate the traffic performs slow moving vehicles rather concentrating on speed to measure the traffic performances. Supply and demand were considerate to determine overtaking ratios which is a measure of LOS and to compare it with 1985 (HCM). Concludes that, effect of passing lanes on the level of service can be measured with the help of over-ratio concept [12].

C R Patel and G J Joshi (2012) this paper aims to study the behaviour of heterogeneous traffic speed and flow rate at signalized intersections in urban article roads of Gujarat state. Data was collected manually and using video graphic technique for six lane divided road segments in Surat, Gujarat state of India, multi regime speed flow relation was developed with the data from field survey and obtained LOS based on v/c ratio on cluster analysis approach. Concludes that, road way section capacity would be calculated based on traffic, control and road way conditions. LOS with
respect to capacity and volume measures the traffic quality which can help further to improve long and short-term infrastructure facilities for the existing scenario by conditions [8].

B Someshwar Rao et al (2017) focused on estimating the critical gap using various methods like Wu harder, Raff’s and sum of the proposed methods (by IIT Rookie). The study area comprises three places in Vishakhapatnam and peak hour traffic data, traffic volume vehicle entry time, vehicle exit time, was collected with video graphic technique. Conclude that harder method gives higher critical gap values when compared with the other method adopted [6].

S Chatterjee et al (2017) platoon parameters such as follower rate; follower density, percentage follower and platoon rate were used to study the level of service for multi lane highway in India. K-means clustering technique is used to classify traffic flow, i.e. free flow, stable flow and constrain flow. Stream parameters like flow rate, density, v/c ratio were examined the all six sections which was considered for the study taking time head way into count as a parameter to define platoon criteria. A new approach has been adopted which is based on platoon parameters in order to predict LOS further in the research [17].

B Prasanta Kumar Bhuyan and K V Krishna Rao (2011) conducted survey corridors of Kolkata city and data like average travel speed was collected using GPS were fitted on mobile velocity. The probe vehicle was fitted with tremble Geo-xt GPS receiver, capable of collecting speed data information continuously using HIC methodology [2]. Concludes speed ranges on urban streets in Indian contexts are different from corresponding values mentioned in HCM (2000).

C. K. Haritha et al (2017) a relation between flow and speed have been developed and it can be used to estimate capacity of road way. Video graphic method is adopted to collect the data such as density and speed averages of vehicles which are used to measure LOS. Results concludes that, the obtain capacity value by static PLU method is 11% higher than the recommended value by IRC and decrease in carriageway width results increase in level of service [7].

D V Jitendra Bhai et al (2016) spot speed and traffic volume studies were carried out traffic data and they’re by providing recommendation towards congestion mitigation that ultimately results in improving existing level of service [10].

B R Marwah and Bhuvanesh Sigh (2000) conducted studies using simulation models for urban roads under heterogeneous traffic conditions in Kanpur metropolitan city. Calibration and validation have been carried out for traffic system. Road section lengths and roadway characteristics were used to design simulation experiments. Results conclude that, level of service is classified into four groups which can be used to identify deficiencies and helps to plan for alternative improvement measures [3].

A Patel and K Bhatt (2017) level of service on different road segments in urban areas are well investigated and presented a critical review from the previous studies. This paper highlights the basis for LOS and different categories which are given by HCM. The various definitions, congestion parameters, factors affecting LOS and factors affecting capacity and congestion affecting LOS are well addressed. The study concludes that, level of service various from country to country and have different methodologies to measure it [1].

S Raji and A Jagannatham (2017) correlation between level of service and capacity is well addressed in this paper. Level of service concept and its classification from ‘A’ to ‘F’ has been explained along with graphical representation. Some of the inputs like evolution in level of service, LOS and safety, road traffic influences, heterogeneous traffic conditions, LOS and road user’s data were used [18].

D B Qadr et al (2019) conducted video graphic surveys on 60-M ring-road in Erbil city, Iraq to collect data for traffic volume and spot speed of vehicles. Results shows that, average vehicle speed is about 19 km/hr which is less than the designed speed of 60 km/hr that leads LOS for that particular road segment is at ‘F’ category. Peak hour factor is also calculated and obtained 0.97 which exceeds the range of typical values that are given for urban areas. Concludes PHF can be improved with LOS and by solving traffic congestion issue which would be a result of design and construction of bridge ramps [9].
E N Joseph and M S Nagakumar (2014) different parameter types like LOS, capacity, vehicle to capacity ratio, average delay time, peak hour, average journey time were studied and are well addressed in this paper. Reconnaissance survey is carried out on road segments along with field surveys for traffic volume and for spot speed of vehicles [11].

Sanjay Kumar Singh (2012) mainly focused on urban transportation problems like pollution, traffic, accidents and congestion etc. the challenges in India over urban transportation such as transport availability, vehicular growth in metropolitan cities, number of restricted motor vehicles and private vehicles in India has been briefly reported. Information about vehicular emission, road safety and its effect on health as well as policy measures for urban transportation were provided [19].

2.2. Study corridors and Objectives
Four different study corridors in and around Bhimavaram, Andhra Pradesh, India were chosen to define LOS for different types of roads. In which two corridors come under urban roads categories (Refer Fig. 1, Fig. 2) and two corridors comes under Rural roads categories (Refer Fig. 3, Fig. 4). Bhimavaram is densely populated town with different type of transport network. After the result is obtained it is easy to know how LOS will be vary for urban and rural roads. Section length of 21 meters was considered.

The objectives of this project are to find volume of vehicle in each corridor, to find difference in composition in peak hour and non-peak hour, to determine Average speed of vehicles in each corridor, to find difference in LOS grades for urban and Rural areas.

**Table: 1 Road Characteristics**

| S.No | Name of Road          | Class of Road | Lane Characteristics | Length of Road (m) |
|------|-----------------------|---------------|----------------------|-------------------|
| 1.   | Vishnu college road   | Sub Arterial  | 2 Lanes (Two Lane)   | 2900              |
| 2.   | Undi Bypass road      | Sub Arterial  | 2 Lanes (Two Lane)   | 2200              |
| 3.   | Ramayanapura m        | Sub Arterial  | 2 Lanes (Two Lane)   | 1300              |
| 4.   | Jaganadhapuram        | Sub Arterial  | 2 Lanes (Two Lane)   | 1500              |

**Fig. 1** Vishnu College Road (Corridor-1)  
**Fig. 2** Undi Bypass Road (Corridor- 2)
2.3. Methodology
The vehicles were classified into four categories: motorized two wheelers, cars/Autos, heavy vehicles, pedestrian. In this project LOS grades were defined mainly by using V/C ratio and Average speed method which were possible in selected corridors. There are many methods like cluster analysis, Percentage speed reduction, Fuzzy set theory and many more to define LOS of roads but these two methods were common and best methods to define LOS in suburban and rural areas. All four corridors were free from pedestrian activities, bus stop, vehicles parking.

3. Level of service (LOS) concept
The term level-of-service has been introduced by Highway capacity Manual (HCM) which represents the level of facility a user can experience from a road under various operating characteristics and traffic volumes. The Highway capacity manual is a publication National Academics of Science which contains concepts, guidelines and procedures for knowing capacity and quality of service of highway facilities. Capacity gives a quantitative measure of traffic, whereas Level of service gives a Qualitative measure. Capacity of the road could be constant whereas the actual flow rate will be different for different days, times in a day itself. Depending upon v/c ratio and travel speed, HCM has defined six Level of Services i.e. A to F (Refer from Fig. 5 to Fig. 10). A represents the best operating conditions and F represents worst condition.

i) LOS A: This grade represents best operating conditions for a user with free flow of traffic and with an average speed of vehicles obtaining 90% of its free flow speed. Volume to capacity ratio for this grade is less than 0.125.

ii) LOS B: This grade indicates stable flow of traffic and users can go in their desired speed. The volume to capacity ratio for this grade lies between 0.125 and 0.276 and the average speed is 70 % to 80 % of free flow speed.

iii) LOS C: This grade also indicates stable flow of traffic. The average speed varies from 50 % to 60 % leads to gradual decrease in level of comfort. The volume to capacity ratio for this grade is between 0.276 and 0.479.

iv) LOS D: This grade indicates nearly an unstable flow of traffic with high density of vehicles. The average speed of vehicles is about 40 % 50 % and the drivers are restricted to go in their desired speed. The volume to capacity ratio for this grade lies between 0.479 and 0.715 that indicates poor level of comfort.
v) **LOS E:** This grade cannot allow drivers to go with their desired speed as it indicates high density of vehicles with average speed of vehicle dropped to 30% to 40%. The volume to capacity ratio for this grade lies between 0.715 and 1.0 which gives extremely poor comfort and convenience to passengers.

vi) **LOS F:** This grade indicates the amount of traffic is very high and the average speed is dropped to 25 percent to 35 percent indicating the driver’s comfort, patience and convenience as very poor. The volume to capacity ratio is greater than 1.000 for this grade.
3.1 Level of service based on volume to capacity (v/c) ratio and passenger speed reduction (PSR)

This study emphasis on the level of service for urban and rural roads under heterogeneous traffic conditions in India. Critical findings of Level of service based on Characteristics for urban and suburban arterials, Average speed, volume to capacity ratio and percentage speed reduction are well addressed and the various ranges and their LOS are given (Refer Table 2 to Table 5) respectively. Methods to find parameters required for LOS determination are also discussed.

**Table 2** LOS Characteristics for urban and suburban Arterials

| S. No. | LOS | Operating Characteristics |
|--------|-----|---------------------------|
| 1      | A   | ✓ Average overall travel speed is 50 kmph or more  
✓ Free flow  
✓ v/c ratio is 0.6 or less and factor at intersections is 0.0  
✓ Peak Hour Factor is 0.7 or less. |
| 2      | B   | ✓ Average overall travel speed is 40 kmph or more  
✓ Stable flow but negligible delays  
✓ v/c ratio is 0.7 or less and load factor at intersections is 0.11 or less  
✓ Peak Hour Factor is 0.8 or less. |
| 3      | C   | ✓ Average overall travel speed is 30 kmph or more  
✓ Stable flow and acceptable delays  
✓ v/c ratio is 0.8 or less and load factor at intersections is 0.3 or less  
✓ Peak Hour Factor is 0.85 or less. |
| 4      | D   | ✓ Average overall travel speed is 25 kmph or more  
✓ Unstable flow and tolerable delays  
✓ v/c ratio is 0.9 or less and load factor at intersections is 0.7 or less  
✓ Peak Hour Factor is 0.9 or less. |
| 5      | E   | ✓ Average overall travel speed is 25 kmph or more  
✓ Unstable flow & intolerable delays  
✓ Congestion and load factor at intersections is 1.0 or less  
✓ Peak Hour Factor is 0.95 or less. |
| 6      | F   | ✓ Average overall travel speed is 15 kmph or less  
✓ Forced flow & Jammed conditions  
✓ v/c ratio exceeds 1.0 and overloaded intersections |

**Table 3**: LOS based on Average travel speed of vehicles on urban roads

| S. No. | Urban street class | 1    | 2     | 3     | 4    |
|--------|--------------------|------|-------|-------|------|
| 1      | LOS A              | >72  | >59   | >50   | >41  |
| 2      | LOS B              | >56-72 | >46-59 | >39-50 | >32-41 |
| 3      | LOS C              | >40-56 | >33-46 | >28-39 | >23-32 |
| 4      | LOS D              | >32-40 | >26-33 | >22-28 | >18-23 |
| 5      | LOS E              | >26-32 | >21-26 | >17-22 | >14-18 |
| 6      | LOS F              | <26  | <21   | <17   | <14  |
3.2 Theoretical capacity
Capacity is maximum no. Of vehicles that can pass a point in lane in one hour. The formula for theoretical capacity is given below,

\[ \text{Theoretical capacity} (C) = 1760 \times V/I \]

Where \( V \) = constant vehicular speed expressed in miles per hour
\( I \) = intra vehicular lead expressed in yards

4. Results and discussions
Field studies were carried out manually i.e. for volumetric survey no.of vehicles passed through that corridor in specific time was counted and noted.
4.1. Volume study in peak hour and non-peak hour

Both peak hour and non-peak hour traffic composition for selected four corridors were shown below in the form pie charts. Traffic composition was taken by manual method. In all four corridor's maximum vehicle composition is occupied by Bikes above 50% whereas non-motorized vehicles such as bicycles and pedestrian occupy less composition below 7% (Refer Fig. 11 to Fig. 14).

Fig. 11 (a) During peak hour
Fig. 11 (b) During Non-peak hour

**Fig: 11** Traffic volume at Vishnu college road

Fig. 12 (a) During peak hour
Fig. 12 (b) During Non- peak hour

**Fig: 12** Traffic volume at Undi Bypass road

Fig. 13 (a) During peak hour
Fig. 13 (b) During Non-peak hour

**Fig: 13** Traffic volume at Ramayanapuram road
Average speed studies

Average speed studies were carried out along a selected study Corridor by manual method i.e. using stop watch method. These studies were conducted in both peak and non-peak hour. Average speeds for all selected four corridors were obtained from speed distribution curves (Speed vs Frequency). In Corridor-1 maximum no. of vehicles travelled at the speed of 45-50 kmph (Refer Fig. 15). In Corridor-2,3,4 the maximum vehicles travelled at a speed of 25-30 kmph (Refer Fig. 16 to Fig. 18).

Fig. 14 Traffic volume at Jaganadhapuram road

Fig. 15 (a) Average speed of vehicles at corridor-1 in peak hour
Fig. 15 (b) Average speed of vehicles at corridor-1 in non-peak hour

Average speed of vehicles travelled in corridor-1 was 31.65 kmph. Speed of vehicles travelled in Corridor-1 was higher than remaining selected study corridors.

Fig. 16 (a) Average speed of vehicles at corridor-2 in Peak hour
Fig. 16 (b) Average speed of vehicles at corridor-2 in Non-Peak hour

Average speed of vehicles travelled in corridor-2 was 24.46 kmph. The Average speed of vehicles travelled in this Corridor was less than remaining selected corridors.

Fig. 17 (a) Average speed of vehicles at corridor-3 in Peak hour
Fig. 17 (b) Average speed of vehicles at corridor-3 in Non-Peak hour

Average speed of vehicles travelled in corridor-3 was 28.51kmph.

Fig. 18 (a) Average speed of vehicles at corridor-4 in Peak hour
Fig. 18 (b) Average speed of vehicles at corridor-4 in Non-peak hour

Average speed of vehicles travelled in corridor-4 was 25.81kmph.

4.3 LOS based on Average speed and V/C ratio

Above observations were calibrated and values were compared to standard values which is given in HCM 2000 (Refer Table-2, Table-4). The final LOS grades of selected four corridors were given in below table.

Table:7 LOS of selected corridors based on V/C ratio and Average speed

| S.No  | Speed (kmph) | V/C Ratio | LOS Grades |
|-------|--------------|-----------|------------|
| Corridor-1 | 31.65        | 0.48      | D          |
| Corridor-2 | 24.46        | 0.96      | E          |
| Corridor-3 | 28.51        | 0.48      | D          |
| Corridor-4 | 25.84        | 0.73      | E          |

5. Conclusion

LOS criterion based on various factors are discussed and presented in detail. A keen insight into level of service concept for urban and rural roads was given and methods to define compatibility level of urban roads under heterogeneous traffic were addressed based on the literature survey study. Volume to capacity ratio is found to be the easiest method to determine LOS from the various methods which are available. Level of service characteristics for urban and sub-urban arterials roads were also summarized for 6 categories (Refer Table 1). LOS based on average travel speed, v/c ratio and percentage speed reduction (PSR) are discussed and presented (Refer Table 2 to Table 5). It is observed that LOS grades for Vishnu college road (corridor-1) and Ramayanapuram village (corridor-3) was LOS-D and Undi bypass road (corridor-2) and Jaganadhapuram village (corridor-4) were LOS-E grade. Corridors-2, Corridor-4 was observed to
have poor LOS grades because the road conditions were not up to the mark. The limitation of our study is that we need to consider more no. of vehicles in order to obtain better results.

Acknowledgement
We thank our mentor and guide Dr Pala Gireesh Kumar for the kind support and encouragement given for doing this present work. We would like to thank the management of Shri Vishnu Engineering College for Women (Autonomous) for their acceptance to support to implement the project in Bhimavaram, West Godavari District, Andhra Pradesh.

References
[1] A Patel and K Bhatt 2017 Level of service on different segment road: Review Int. Jr. Scientific Research in Science, Engineering and Technology vol. 3 pp. 451-454.
[2] B Prasanta Kumar and K V Krishna Rao 2011 Defining level of service criteria of urban streets in Indian context European Transport vol. 49 pp. 38-52.
[3] B R Marwah and Bhuvanesh Singh 2000 Level of service classification for Urban Heterogeneous traffic a case study of Kanpur Metropolis Transportation Research Circular E-C018: 4th Int. Symp. on Highway Capacity pp. 271-286.
[4] B Rabeya et. al. 2014 Changing modes of transportation: A case study of Rajshahi city corporation.
[5] B Robin, S Viranta and K D Ajay 2016 Level of service concept in urban roads Int. Jr. of Engineering Science Innovation research and Development vol. 3 pp. 1-5.
[6] B Someswara Rao, T Rambabu and G Venkata Rao 2017 Analysis of capacity and level of service at uncontrolled intersections under heterogeneous traffic conditions Int. Jr. of Civil Engineering and Technology vol. 8 pp. 181-190.
[7] C K Haritha, N P Bindiya and V S Ravindra 2017 Estimation of capacity and LOS for urban arterial road – A case study of Rajkot city Int. Jr. of Innovative Research in Science vol. 6 pp. 9377 – 9383.
[8] C R Patel and G J Joshi 2012 Capacity and LOS for urban arterial road in Indian mixed traffic conditions Procedia – Social and Behavioral Sciences vol. 48 pp. 527-534.
[9] D B Qadr et. al. 2019 Improving the level of service of a portion of 60-M ring road in Erbil city Cihan University- Erbil Scientific Journal vol. 3 pp. 12-17.
[10] D V Jitendra Bhai et. al. 2016 Estimation of LOS through congestion on urban road - A case study of Verundavan cross road Int. Re. Jr. of Engineering and Technology vol. 3 pp. 317-320.
[11] E N Joseph and M S Nagakumar 2014 Evaluation of capacity and level of service of urban roads Int. Jr. Emerging Tech. and Eng. pp. 1-7.
[12] F M John and Al Werner 1990 Measuring level of service of two-lane highways by overtaking Transportation Research Board pp. 62-69.
[13] K Abdulla-Al et. al. 2018 Estimating traffic volume to identify the level of service in majorier intersections of Rajshahi, Bangladesh Trends in Civil Engineering and its Architecture vol. 2 pp. 292-309.
[14] M A A Imran, B Ahmed and M K Bhuiyan 2014 Investigation of highway geometric problems and remedial measures in Rajshahi City Corporation area, Bangladesh International Journal of Advanced Structures and Geotechnical Engineering vol. 3 pp. 126-133.
[15] S Ashish Kumer, B A Moir Rahaman and T Tasnim Nahar 2013 Analysis of traffic congestion and remedial measures at traffic mor in Pabna City, Bangladesh International journal of recent development in engineering and technology vol. 1 pp. 23-26.
[16] S Biswas, Bhupendra Singh and S Arpita 2016 Assessment of LOS on urban arterials case study in Kolkata metropolis Int. Jr. for Traffic and Transport Engineering vol. 6 pp. 303-312.
[17] S Chatterjee et. al. 2017 Level of service criteria on Indian multilane highways based on platoon characteristics Transportation Research Board pp. 1-3.
[18] S Raji and A Jagannatham 2017 Evolution and application of level of service concept – A literature study Int. Jr. of Informative and Futuristic Research vol. 4 pp. 8450-8474.
[19] Sanjay Kumar Singh 2012 Urban transport in India: Issues, challenges, and the way forward European Transport vol. 5 pp. 1-26.