# A Study on Impact of Highway Gradients on Capacity of National Highways

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***Abstract-*** *For the present study gradients are selected as the main parameter to study the variation of Capacity. The different magnitudes of gradients such as 1.985, 2.47, 2.81, 3.324 and 4.02 percent were chosen for the study on national highway 206. Capacity of stretch is calculated on each section by using linear regression equation obtained by plotting the speed flow relations. Setting linear regression equation for variation of capacity with respect to gradient.*

***Keywords***- Capacity, Passenger car unit, gradients

## I. INTRODUCTION

The designing, planning and Maintenance of Road requires the capacity as main factor. Highway capacity can be defined as the ability of roadway or traffic lane to allow maximum traffic movement per unit time, which is actually vehicles in a lane or roadway that can pass a given point in unit time at highest rate. The units used for this is vehicles per hour per lane or roadway. For the present study we considered the gradient as the one of main factor which impacts on highway capacity

## II. OBJECTIVES OF STUDY

To determine the capacity on both upgrades and downgrades using speed-flow relations. To find linear regression equations for variation of capacity with respect to gradients

## III. REVIEW OF LITERATURE

"Effect of gradients on capacity of two lane roads "by Dr. Chandra and Nitesh Kumar Goyal [2001], central road research center new delhi-110020. This topic has the objectives such as to find variation of PCU values on different upgrades and downgrades of different magnitude, free speed variations of the different class of vehicles on gradients and to draw speed volume relationship which gives linear equations on gradients and thus finding the capacity of grades. The volume corresponding to half of FFS is taken as capacity After speed studies, they concluded that PCU values increase on Upgrades and decreases on downgrades and two lane two movement road have more capacity than one way movement, each single percent of upgrade decreases capacity by 2.61% and downgrade increases capacity by 3.09% and there is linear effect of PCU on gradients.

"Effect of gradient and its length on performance of vehicles under heterogeneous traffic condition "by Shreenivas s Arkatkar and V Thamizh Arasan (2010). They developed level of service or v/c ratio for different upgrades for different grade lengths. Finally they concluded that output results of HETEROSIM replicates the heterogeneous traffic flow on upgrades. PCU values change with change of traffic volume and PCU decrease with increase in traffic volume in case of vehicles larger than passenger car and there is increase in PCU value with increase of traffic volume in case of vehicles smaller than passenger cars.

"Capacity estimation procedure for two lane road under mixed traffic condition "by Dr. Chandra s (2004), After the analysis of results they gave a conclusion that capacity decrease on upgrade and increases on downgrades, as the lane width goes on increases the capacity of road also increases and if lane width decreases capacity also decreases. Capacity decreases when the roughness of road increases and vice versa and speed volume curves were drawn to estimate capacity.

Webster and Cobbe (1996) they studied capacity variations on grades and concluded that capacity increase 3 percent on downgrades and decrease same on upgrades.

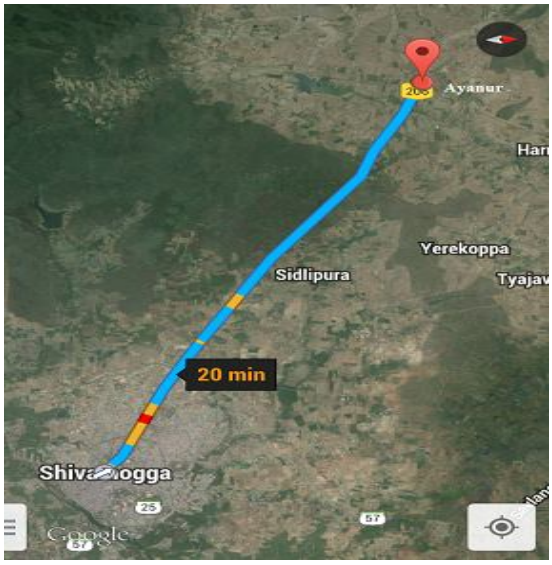
## IV. DATA COLLECTION

With respect to the objectives of the study the required data were collected in five stages as follows

- study stretch selection
- Surveying to obtain required sections
- Classified traffic volume count
- Observation and collection of speed of traffic stream
- Dimension of different class of vehicles.

For the present study National Highway- 206 is selected which connects the cities such as the Tumkur and Honnavara. About 17 km stretch is selected for the study

which is from Shimoga to Ayanur. The satellite view of stretch is shown below.




National Highway 206 Shimoga to Ayanur

For the stretch of 17 kms we surveyed road profile using total station for the availability of gradients and we got about 15 gradients of different magnitude, chosen 5 gradients for observation.

| Section number | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Chainage (Km) | 222.2 | 224 | 217.8 | 227.2 | 228 |
| Carriageway width(m) | 7+1.5m paved shoulder on both side | 7+1.5m paved shoulder on both side | 7+1.5m paved shoulder on both side | 7+1.5m paved shoulder on both side | 7+1.5m paved shoulder on both side |
| Gradient (%) | 1.985 | 2.47 | 2.81 | 3.324 | 4.02 |
| Remarks | 1.985% up movement & -1.985% down movement | 2.47% up movement & -2.47% down movement | 2.81% up movement & -2.81% down movement | 3.324%up movement & -3.324 down movement | 4.02%up movement & -4.04% down movement |

A level stretch is selected at the Chainage of 225.6 km which has same carriage width as shown on table for the comparison with other grades. The gradient magnitude is finding out by taking the levels at the toe of grade and at top of grade, the difference of levels at toe and the top gives level difference. The ratio of level difference to the horizontal distance between the head and toe of grade gives the magnitude of gradient. Suppose a gradient having the level of 101.2 at toe and 109.4 at the top, horizontal distance is 200m. Then the grade magnitude can be found by dividing level difference of 8.2m by 200m gives 4.1 percent as grade magnitude. Manual method is used for the traffic volume count. For each upgrades and downgrades, separate volume counts have been done. We took the data of 12 hours morning 6 to evening 6 for the period of 6 days for each section. Speeds of different class of vehicles were collected in each section. At each section a stretch length of 50m is marked. Time taken by a vehicle to cross that stretch is noted, and then ratio of distance to time gives the speed of individual vehicles. Two flags were planted on both ends of stretch for indication. There are two types of speed space mean speed and time mean speed. For the present study we calculated time mean speed. Speeds were measured for every hour. Speed data were collected because of two purposes such as to determine the PCU values of vehicles on different magnitudes of gradients. To determine mean stream speed of vehicles at different traffic volumes on different gradients. To determine PCU values at different gradients, at each section or gradients each class of vehicles speed is noted. About 25 to 30 vehicles of each category speeds were noted. For determining the stream mean speed, the speed of more than 70 percent of vehicles in the stream per hour are noted.

## V. DATA ANALYSIS AND DISCUSSION OF RESULTS

### DETERMINATION OF CAPACITY

The capacity of road at gradients can be determined by using the speed-volume relations. Speed calculated is mean stream speed at different volumes. 12 hours volume data is collected, corresponding to those data speed also noted. Then by plotting volume to mean stream speed we will get a linear regression equation. The example of equation is given below.

$$Y = AX + B$$

Y = Speed

X = Volume in PCU/hr.

B is free flow speed and A is constant

After we get equation, we can get capacity of stretch by substituting the half of free flow speed in equation, the corresponding volume is Capacity under consideration which took from literature (Chandra & Goyal 2001). Free flow speed is speed at low volumes and speed at capacity is optimum speed. The capacities of up gradients and down gradients are calculated below. And capacity of level stretch is calculated for comparison. The mean stream speed is calculated by using expression below.

$$Vm = \sum_{i=1}^{k} n_i V_i \Big/ \sum_{i=1}^{k} n_i$$

Where

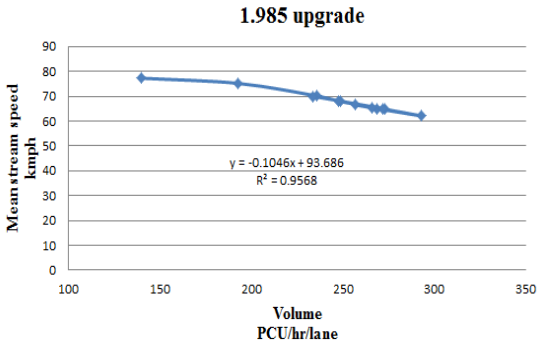
$V_m$ = Stream mean speed (kmph)

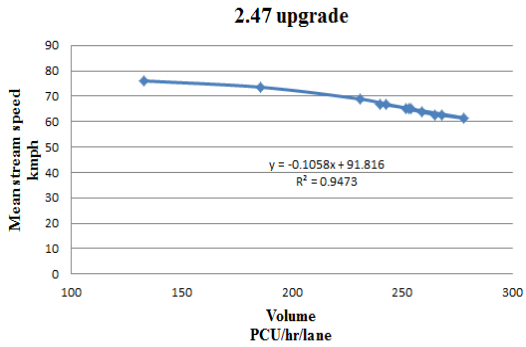
K = Total category of vehicles in stream

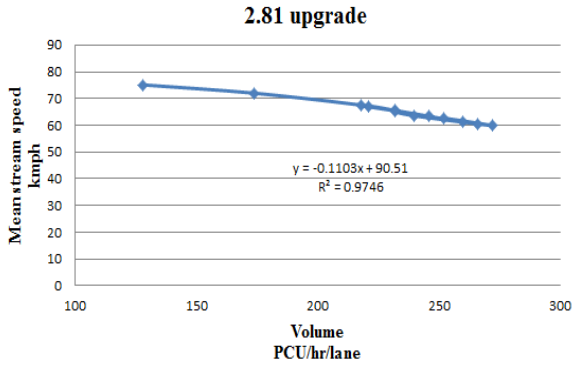
$V_i$ = i category vehicles speed (kmph)

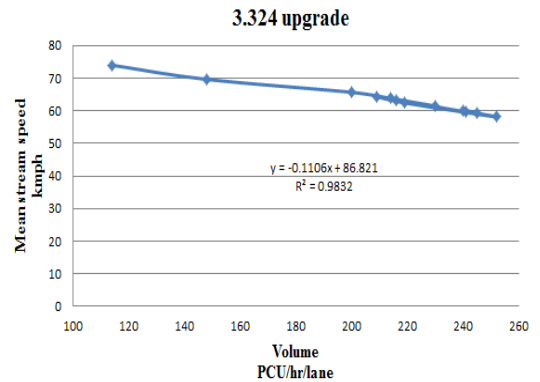
$n_i$ = Total number of i vehicle category in stream.

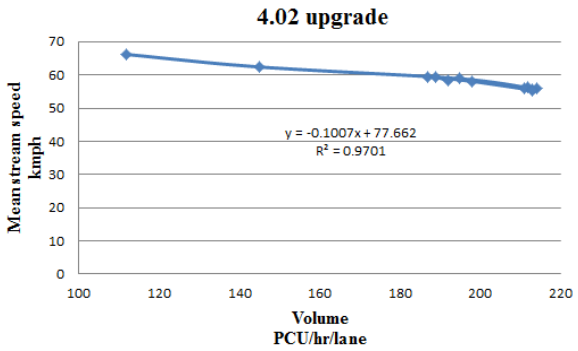
## VI. ANALYSIS

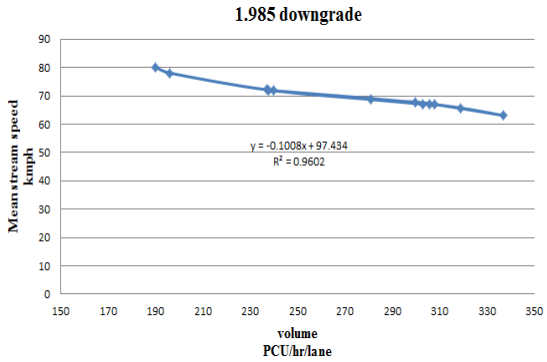


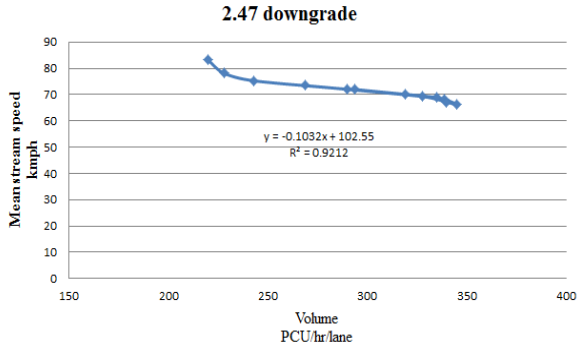



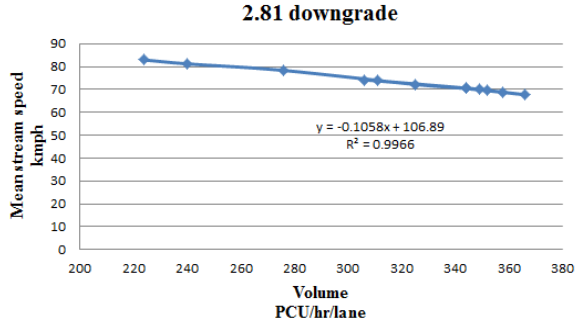



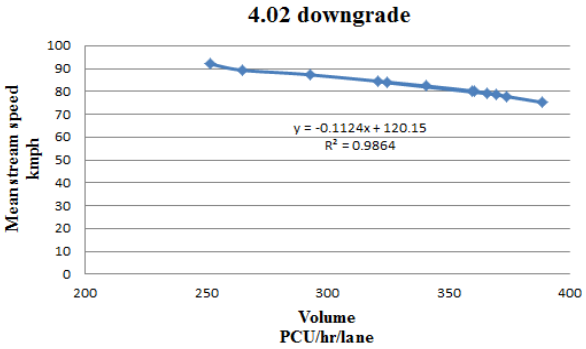



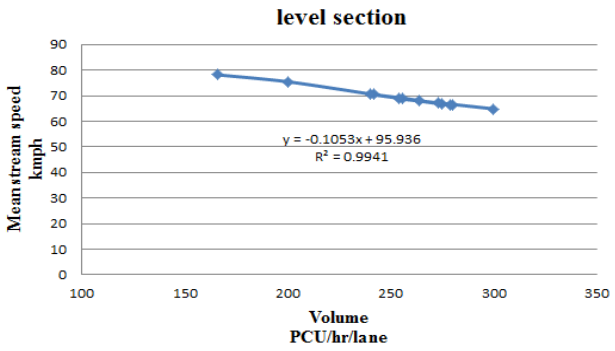



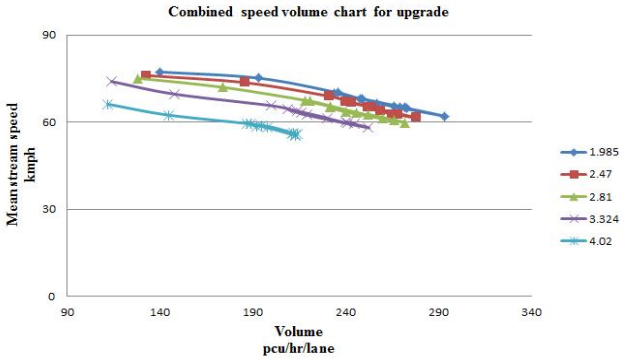



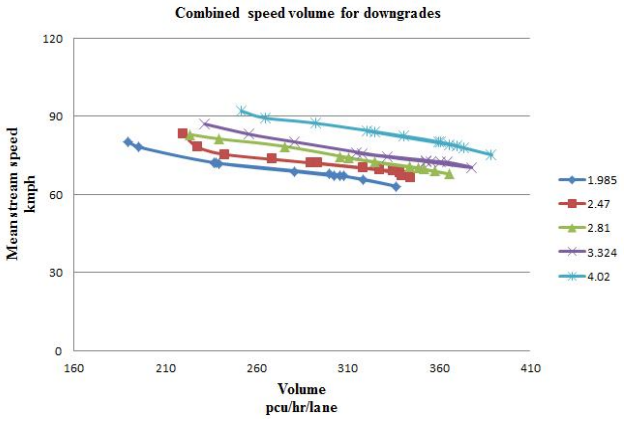



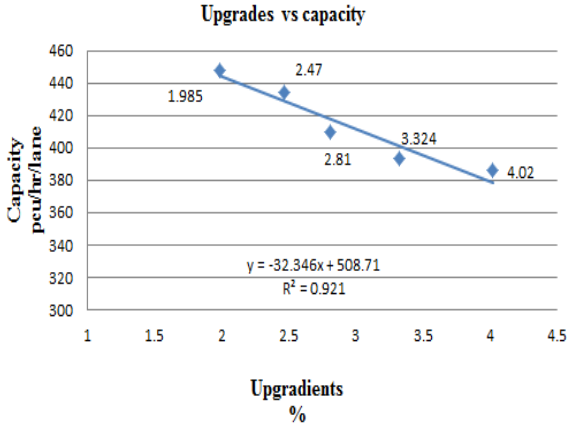


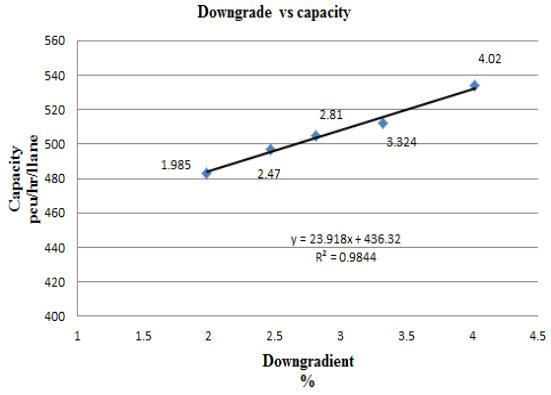




## VII. RESULTS

| Gradient (%) | Linear regression equation | $R^2$ value | Optimum speed (kmph) | Capacity (pcu/hr/lane) | Percent change of capacity w.r.t level |
|---|---|---|---|---|---|
| 1.985 | Y = -0.1046X + 93.686 | 0.9568 | 46.843 | 448 | 1.75 |
| 2.47 | Y = -0.1058X + 91.816 | 0.9473 | 45.91 | 434 | 4.82 |
| 2.81 | Y = -0.1103X + 90.51 | 0.9746 | 45.25 | 410 | 10.08 |
| 3.324 | Y = -0.1106X + 86.821 | 0.9832 | 43.41 | 393 | 13.8 |
| 4.02 | Y = -0.1007X + 77.662 | 0.9701 | 38.83 | 386 | 15.35 |
| Level | Y = -0.1053X + 95.936 | 0.9941 | 47.97 | 456 | 0 |
| -1.985 | Y = -0.1008X + 97.434 | 0.9602 | 48.72 | 483 | 5.92 |
| -2.47 | Y = -0.1032X + 102.55 | 0.9212 | 51.28 | 497 | 8.99 |
| -2.81 | Y = -0.1058X + 106.89 | 0.9966 | 53.45 | 505 | 10.7 |
| -3.324 | Y = -0.1083X + 110.96 | 0.9828 | 55.48 | 512 | 12.28 |
| -4.02 | Y = -0.1124X + 120.15 | 0.9864 | 60.07 | 534 | 17.1 |



## VIII. CONCLUSION

- The decrease of capacity at an average rate of 14 pcu/hr/lane or 2.87 percent for every successive increase of upgrade magnitude.
- There is increase of capacity at the rate of 17 pcu/hr/lane or 3.68 percent for every unit increase of down grade magnitude.
- Linear equation for capacity variation on upgrades is Y = -32.346X + 508.71 & For downgrades Y = 23.918X + 436.32
- There is linear variation of capacity and optimum speed on both upgrades and downgrades.

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