ESTIMATION OF BICYCLE LEVEL OF SERVICE FOR URBAN INDIAN ROADS

PIYUSH AGARWAL

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

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ESTIMATION OF BICYCLE LEVEL OF SERVICE FOR URBAN INDIAN ROADS

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By

Piyush Agarwal

Roll no.-109CE0432

Under guidance of

Prof. P.K Bhuyan

DEPARMENT OF CIVIL ENGINEERING

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CERTIFICATE

This is to certify that project entitled “**Estimation of Bicycle Level of Service for Urban Indian Roads**” submitted by ***Piyush Agarwal*** in partial fulfillment of the requirements for the award of **Bachelor Of Technology** Degree in **Civil Engineering** at National Institute of Technology, Rourkela is an authentic work carried out by him under my personal supervision and guidance. To the best of my knowledge the matter embodied in this project review report has not been submitted in any college/institute for awarding degree or diploma.

Prof. P.K Bhuyan

Department of civil engineering

National Institute of Technology

Rourkela -769008

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PIYUSH AGARWAL

109CE0432

DEPARTMENT OF CIVIL ENGINEERING

NIT ROURKELA

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ABSTRACT

Bicycle level of service (BLOS) methodologies have been developed for suburban and urban as well as for rural road segments. Although, today, the utilitarian bicyclist requires access to suburban, urban, and rural environments to safely travel between home and work. In order to complement BLOS methodologies which incorporate mental stressors along road segments, this study develops a methodology by which BLOS and Bicycle compatibility Index (BCI) can be found out by qualitative analysis.

Qualitative analysis deals with real-time human perceptions taking into account the satisfaction level of bicyclists while riding along a road. The satisfaction level of the bicyclist or the compatibility of the road for bicyclists is derived from a survey where bicyclist are asked questions based on their perception about safely, visibility and convenience. The survey is conducted on numerous bicyclists and their view are taken down in the form of ratings. These rating can be represented in a graphical form so as to give a clear picture of satisfaction level of bicyclists with respect to the road compatibility. BCI is computed using inverse variance method and finally BLOS, ranging from LOS-A to LOS-F, is found out.

Qualitative analysis though differs from quantitative analysis in terms of its surveyed data, the result of both will differ to a much extent. The BCI identifies which intersection approaches have the maximum priority for bicycle safety improvements within a particular jurisdiction. The model provides traffic planners and others the capability to rate roadways with respect to bicyclists' level of satisfaction, and can be used in the process of evaluating existing roads, redesigning existing roads or designing new roads.

CHAPTER-1

1.1 GENERAL

Bicycling is a fundamental form of transportation that is at times overlooked in this age of high-tech motorized travel. Higher levels of bicycle based transportation would eventually result in significant benefits in terms of the environment, health and physical fitness and transportation-related effects.

To develop roadways for shared use by the two modes of transportation i.e. bicycle and motor vehicles, one must begin by evaluating existing roadways and determine what can be considered user-friendly from the perspective of a bicyclist. Currently, there is no methodology that can be widely accepted by planners, engineers or bicycle coordinators that will allow them to determine how much compatible a roadway can be for allowing efficient accommodation of bicycles and motor vehicles together. Determination of how existing traffic operations and geometric conditions affect a bicyclist's decision whether to use or not use a specific roadway is the first step in determination of the bicycle compatibility of that roadway.

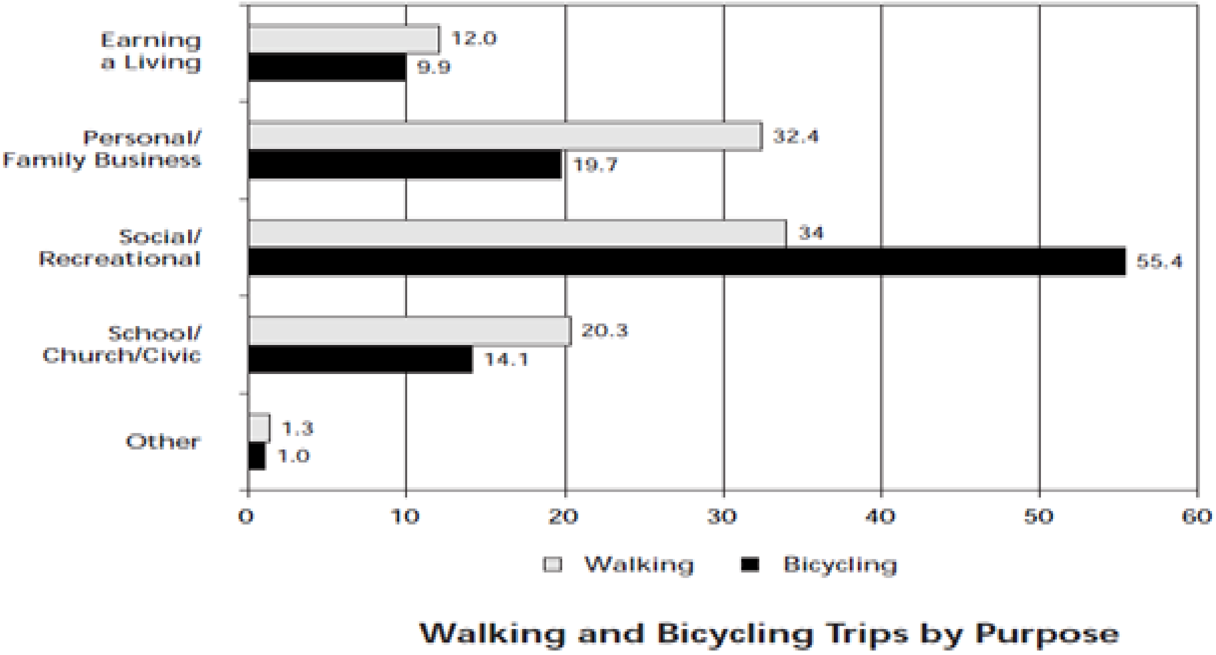


Fig. 1

In past few years, numerous studies have been done to develop some systematic means of measuring the operational condition for bicycling of roadways. These efforts include:

- Development of models based on the geometrics of intersections and roadway segments
- Pavement conditions
- Traffic volumes
- Speed limits, and other variables.

The missing element in these studies is the lack of recognition of the perspectives of bicyclists'. As these are the ones who will eventually decide whether a roadway meets their personal level of satisfaction for riding in the presence or absence of motorized vehicle traffic.

The (QOS) Quality of service and other related methodologies can function as tools to help communities to plan multimodal transportation options. Since QOS literature for transit focuses on work by a few researchers only, the dominance of the transit level of service technique is clearly apparent in the literature. While a good amount of attempts at pedestrian methodologies exist, they have not yet produced any validated models for the bicycle mode. Therefore, the literature in this area is not as plentiful.

Since for bicycles, LOS criteria is not defined in the Highway Capacity Manual, discussions on bicycles are primarily limited to the impact of bicycles on motor vehicles LOS. By definition of LOS, there are a very few on-street facilities where LOS criteria would be needed simply because of low bicycle volumes. For a bicyclist, the qualitative terms comfort and convenience and freedom to manoeuvre are critical factors with respect to determining their quality of service on a given facility. By definition of LOS, the perception of the user of the operational conditions is an important element with respect to assigning an LOS designation.

The bicycle stress level concept incorporates the bicyclists' perception to assess the bicycle compatibility of roadways on a five-point scale. Each point on the scale can be thought of as representing a different LOS for bicyclists. For instance, a roadway with a considerably very low stress level would be considered to offer a high degree of comfort by bicyclists, which would be represented by the LOS-A designation. Currently study of the *bicycle compatibility index* (BCI) reflects comfort and satisfaction levels of bicyclists based on observed geometric and operational conditions of a wide variety of roadways and correlation of these comfort levels with the conditions of the roadway in the development of the BCI model helps the user in determining bicycle levels of service for roadway segments by incorporating the geometric and operational characteristics into the current model.

1.2 OBJECTIVES AND SCOPE OF STUDY

The main objective of this thesis is to develop a methodology for deriving a bicycle compatibility index (BCI) that could be easily used by traffic engineers, bicycle coordinators, transportation planners, and others to evaluate the capability of specific roadways to accommodate both modes of transport i.e. bicyclists and motor vehicular traffic in urban areas.

A BCI can be determined using a combination of pictures and video, and surveys of bicyclists of different abilities. It gives the advantage of surveying multiple bicyclists at once, irrespective of weather and is much less time consuming than inventorying entire corridors, highways or regions. Video capture can be quickly executed and preserved for a long time before performing a survey and eventually analyzing.

Though needed less often, one of the pressing needs for a quality-of-service model is to overcome the current barriers in developing a sequential bicycle travel-demand simulation and forecasting model for urban-area utilitarian bicycling. Though annual numbers of cycling fatalities and injuries, data on the frequency and the severity of bicycle-motor vehicle collisions is not currently used to determine the suitability of particular routes in road networks for utilitarian cycling trips despite being readily available.

It is therefore important to find out:

(*a*) What types of cyclists that are most likely to be involved in severe bicycle-motor vehicle collisions?

(b) What are the types of physical stressors that have the greatest effect on the frequency and the severity of bicycle-motor vehicle collisions in a road network of a region so as to improve level of service for utilitarian cycling?

A bicycle-route selection in an urban setting for utilitarian trip purposes is influenced by several additional factors, including the perceived hazard of sharing the roadway with motor vehicles, the roadway surface condition, grade, and scenery. The first two factors can be combined into a single mathematical function and the resulting quality of- service function can be used as a travel impedance in both assignment algorithms of system-level travel simulation models and the trip-distribution.

Operational measures of effectiveness taken into consideration in evaluating the various types of facilities should significantly reflect relative risk to the bicyclist and the motorist. The risk to the bicyclist when being passed by a motor vehicle is either in being struck or in being run off the road and to the motorist when passing a bicyclist is in being struck by the bicyclist or in weaving into the adjacent left lane and striking another vehicle (head-on collision on a rear-end, two-lane road or sideswipe, or angle collision on a multilane facility).

BLOS and BCI evaluation may be useful in the following ways:

- A map can be produced for the public to guide them to proper selection of the bicycle route.

- To identify the most appropriate route for inclusion in the community bicycle network.
- Possible weak links in the network can be determined, and improvements needed in the sites can be prioritized.
- Alternatives for treatments for improving bike-friendliness of a roadway can be evaluated.
- Road project selection formulas that can include a Bicycle Level of Service or Bicycle Compatibility Index term to encourage implementation of bike planning goals.

CHAPTER-2

C0NCEPT OF LEVEL OF SERVICE

3.1 General

The Highway Capacity Manual has defined levels of service (LOS) as "qualitative measures that characterize operational conditions within a traffic stream and their perception by motorists and passengers." LOS (designated as A through F, with LOS F being the least desirable) includes speed, travel time, freedom to manoeuvre, interruptions in traffic, comfort and convenience. The LOS concept was introduced to qualify the characteristics associated with various levels of vehicles and people passing a given point during specified time periods. Hence, LOS has been a qualifier of conditions relating to vehicle or person throughout rather than a qualifier of conditions relating to individual comfort level.

The Bicycle LOS Model is like a "supply-side" criterion. It is an evaluation of safety as perceived by bicyclists with respect to the motor vehicle traffic. Bicycle level of service can be defined as the assessment of the suitability of a road segment to accommodate motor vehicle and bicycle traffic safely. Nowadays, methodologies to assess bicycle level of service do so by the perceived comfort report on specific road segments by cyclists. Assessment metrics of cyclist comfort now are available for road segments for urban and suburban areas as well as those found in rural areas. To date the research for developing a level of service methodology for road networks and not only road segments, in urban and suburban as well as in rural areas is not clearly evident in the literature. BLOS helps to identify the quality of service for bicyclists that currently exists within the roadway environment

The bicycle LOS levels are defined as follows:

LOS A: The roadways are highly bicycle oriented & will tend to encourage bicycle trips. The roadways will be characterized by low speed or low-volume motor-vehicle traffic, bicycle friendly intersection designs, sufficient pavement space, and bountiful facilities (e.g., benches, shade, and so forth). The roadway features will be planned at human scale for maximum bicycle comfort. Roadways with this level of bicycle accommodation may be expected in college campus locations, central-city and tourist. Bicycles can expect a low level of interaction with motor vehicles.

LOS B: These roadways provide many bicyclists safety and comfort features that will draw bicycle trips .These roadways would have multiple features of an LOS A bicycle facility, but there may be fewer facilities or bicycle-friendly design rudiments. Bicyclists can expect a low to moderate level of interaction with motor vehicles.

LOS C: These roadways are sufficient for bicycle use, but may not necessarily attract bicycle trips. These roadways will likely have some faults in maintenance or intersection design and may be situated on roadways with high volume motor-vehicle traffic, high-speed etc. Bicyclists can expect moderate interaction with motor vehicles on these roadways.

LOS D: These roadways are sufficient for bicycle use, but will not draw the attention of bicyclists. These roadways will have more deficiencies in bicyclist safety and comfort features and may infringe requirements for width and clearance. Intersection crossings are most likely to be harder and frequent. Bicyclists can anticipate moderate to high levels of interaction with motor vehicles.

LOS E: These roadways are not suitable for bicycle use. These roadways do not provide a bicycle facility. These roadways will not meet the requirements and will have frequent deficiencies in road width, continuity, clearance, and intersection design. The roadways in this category that do not provide a bicycle facility may be characterized as rural roadway sections with moderate motor-vehicle traffic. Bicyclists can anticipate a high level of interaction with motor vehicles.

LOS F: These roadways hardly provide any uninterrupted bicycle facilities and are characterized by high levels of motor vehicle use and traffic. These roadways are primarily designed for high-volume motor-vehicle traffic with frequent turning conflicts and high speeds.

3.2 Factors affecting Bicycle Level of Service

The factors affecting level of service are as follows:

1. *Traffic volume*: It is observed that as the traffic volume increases the BLOS consequently tends to decrease. One can observe that during heavy traffic the bicyclists are more apprehensive of their safety than any other time.
2. *On street parking*: This factor influences BLOS positively as it acts as a buffer in between the bicyclist and the traffic hence providing a sense of security. Since people perceive that they are safe, it results in higher LOS.
3. *Roadway width*: Increase in width of the road makes it difficult for the bicyclist to cross the road from one end to another thus decreasing the BLOS.
4. *Speed limits*: The speed limit for the road surveyed was 40 km/hr. With increase in speed there is a drastic decrease in the bicycle level of service. It is due to the fact that at higher speeds the bicyclists perceive higher threat levels to their life hence resulting in a decrease in BLOS.

CHAPTER-3

LITERATURE REVIEW

<u>Landis et al.'s (2003)</u>- A recent work derived a model to predict the perceived hazard of bicyclists riding through intersections as a function of vehicle volume, motor width of the outside lane and the crossing distance of the intersection.

<u>Sorton and Walsh's (1994)</u> – They considered the percentage of heavy vehicles moving along a roadway segment and to focus on traffic volumes at peak hour as further refinements to modeling stress levels of bicyclists. They did this by relating traffic curb lane width, speed of traffic and volume per lane to surveyed stress levels of survey participants.

<u>Crider (1999)</u> - Set up a system of determining "point" level of service. According to him it was useful because many of the problems that a bicyclist usually encounters are small, in terms of geography. There may be a bus stop that does not allow bicyclists on board, a narrow road under a bridge, one particularly dangerous intersection or lack of bicycle parking; all of which will certainly tarnish a bicycling experience.

<u>Landis et al. (1996)</u> - Past assessments have often focused on factors such as overcrowding of facilities and, transit vehicle performance or the quality of supply of multimodal facilities. Supply-side assessments do not predict or estimate future demand but, they are invaluable in providing information for decision making regarding investments in improved or new multimodal facilities. They are indicators of the quality and benefits to users—information that can be used to guide or justify provision of additional facilities.

<u>Evans et al. (1997)</u> - A "Transit Friendliness Factor" was developed for the Triangle Transit Authority, North Carolina to predict automobile versus transit choice. Four elements rated on a scale of one to five were: street crossings, sidewalks, proximity to destinations, and transit amenities. Including the transit friendliness factors greatly improved the model's ability to predict automobile versus transit trip selection. The transit friendliness factors are directly related to pedestrian and bicycle mode planning as they are interrelated and support each other.

Turner et al. (1998) - Some travel demand methods are enhanced by incorporating pedestrian environment analysis. By merging "supply" with demand analysis to provide a more complete analysis of issues for bicycle, pedestrian and transit facilities, cities are able to implement a more holistic or integrated approach to transportation planning.

Harkey et al. validated a video-based methodology using a stationary camera. They concluded that the video-based methodology to be a valid technique for obtaining realistic perspectives of bicyclists. But, they didn't calibrate their video-based findings to bicyclists riding on the roadways. They only validated viewpoints from still standing respondents without obtaining realistic perspectives of the bicyclists.

Kroll and Ramey examined how the presence of a bicycle lane affects driver and bicyclist behavior by observing a confederate cyclist riding on 10 streets with bicycle lanes and 10 streets without bicycle lanes. The results indicated that the mean separation distance between bicycles and cars was largely a function of the motorist's available travel space (the distance between the bicyclist and the center line) rather than the presence or absence of a bicycle lane.

The McHenry and Wallace study was conducted with an objective of determining how adequate varying wide curb lanes were for shared use by motor vehicles and bicycles. The research method consisted of collecting and analyzing the differences in lateral positioning data for bicyclists and motorists interacting on multilane roadways.

Shafizadeh and Niemeier concluded that some cyclists may travel further distances on separate paths, compared to cycling on streets with vehicles.

Botma proposed level of service methodologies for bicycle paths and bicycle pedestrian paths. Both defined level of service in terms of events. An event occurs when one user passes another user traveling in the same direction, or when one user encounters another user traveling in the opposite direction. The level of service deteriorates from A to F as events become more and more frequent.

Hunter et al. studied the differences between wide curb lanes and bike lanes. They observed videotapes of about 4,600 bicyclists and evaluated operational characteristics and interactions between bicyclists and motorists. They concluded that the type of bicycle facility had much less impact on safety and operations than other site characteristics and recommended that both wide curb lanes and bike lanes be used to improve riding conditions for bicyclists.

Harkey et al. developed a Bicycle Compatibility Index (BCI) for suburban and urban roadways at midblock locations. The BCI was developed from bicyclists watching a videotape of various roadway segments and giving ratings of how comfortable they would feel riding on every segment. Examples of these variables are volume of traffic, curb lane width and speeds of vehicle. The BCI values were then translated into bicycle level of service. LOS A (corresponding to a BCI < 1.50) indicated that a roadway is extremely compatible for an average adult bicyclist. On the other hand, LOS F (corresponding to a BCI > 5.30) indicated that a roadway is extremely incompatible for an average adult bicyclist.

CHAPTER-4

METHODOLOGY

4.1 General

Qualitative analysis is used to find the Bicycle Compatibility Index of the intersection for urban streets. Qualitative analysis depends on real time human perceptions towards bicycle riding. Hence a survey should comprise of detailed questions relating human perceptions. The *Model* will be responsive to the factors that are statistically significant in particular.

The study is a stated preference survey, where roadway segment is rated on a fixed scale. Bicycling and walking functionally are not different from other modes of transportation. The same basic assumptions can be applied to bicycling and walking that allow planners to predict the outcome of transport decisions for other modes.

The measures of effectiveness thought to be related to the risks for bicyclists and motorists that were collected and further analyzed are:

- Lateral placement of the bicyclist,
- Lateral placement of the motor vehicle,
- Separation distance between the motor vehicle and bicycle,
- Encroachments by the bicyclist or motorist during the passing maneuver.

- Other than these, study of intersection is also important which includes:
    - Safety
    - Visibility
    - Crossing

4.2 Questionnaire

NAME –

AGE –

SEX –

TIME –

a) BICYCLE

- Is the width of road sufficient for you? (Yes/No)
- Would you prefer a specific bicycle lane? (Yes/No)
- How would you rate the surrounding and cleanliness of the area? (Rate 1-5)
- How would you rate the pedestrian traffic on the road? (Rate 1-5)
- How would you rate the motor vehicle traffic on the road? (Rate 1-5)
- Is there proper lighting during night to have a clear view of road? (Rate 1-5)

b) ROAD

- How would you rate the vehicular traffic speed? (Rate 1-5)
- Is median present? (Yes/No)
- In terms of safety how would you rate the width of road? (Rate 1-5)
- Do you think specifying a speed limit for the road will make it safer? (Yes/No)
- How comfortable do you feel when the following vehicles approach while crossing (please provide ratings) -:

  i. When a heavy vehicle like bus/truck is approaching. (Rate 1-5)

  ii. When lighter vehicle like car approaches. (Rate 1-5)

  iii. When a bicycle/bike approaches. (Rate 1-5)

c) CROSSINGS/INTERSECTION

- Do the vehicles pose a threat for you while turning? (Rate 1-5)
- While crossing or turning are you able to clearly see the approaching vehicles? (Yes/No)
- Are there speed bumps before crossings? (Yes/No)
- Are the turnings at intersections sharp /curved and rate it. (Rate 1-5)
- How dangerous do you feel the crossing is? (Rate 1-5)

d) TRANSIT AREA

- Can you view the bus stop clearly? (Yes/No)
- Is the sight distance to bus stop adequate for you? (Yes/No)

e) SAFETY

- According to you do you feel that drivers are following driving rules and regulations? (Yes/No)
- Rate the space between pavement and vehicular traffic in terms of how comfortable you feel. (Rate 1-5)
- In terms of accident frequency, rate the road. (Rate 1-5)

4.3 Development of Bicycle Compatibility Index:

The questionnaire was designed in such that it could easily understood by majority of the public. All questions were either a simple Yes/No answers or rating based, where rating was done on a scale of 1-5:

1- Very Poor

2- Poor

3- Normal/Ok

4- Good

5- Excellent

On the basis of this, the weights of different quantities are taken against their ratings and compatibility index is found. The statistically calibrated mathematical equation entitled the Bicycle Level of Service can be used for the evaluation of bicycling conditions. The weights are calculated by using inverse variance method (from Bicyclist Intersection Safety Index by Daniel L. Carter) according to which the weights or constants are equal to inverse of the variance of the surveyed parameters. The question are divided in five different groups starting from a) bicycle to e) safety. These five groups are used as parameters to calculate BCI.

BICYCLE COMPATIBILITY INDEX (y) = $aX_1 + bX_2 + cX_3 + dX_4 + eX_5$

Where:

- **a, b, c, d and e** are constants calculated by finding the inverse variance of their respective observations.
- X_1, **X2**, X_3, X_4, **and X5** are the mean of their respective observations.

Variance = $\sum(x - \tilde{x})^2/(n-1)$

The Bicycle LOS score resulting from the final equation is pre-stratified into service categories “A, B, C, D, E, and F”, according to the ranges shown in Table , reflecting users’ perception of the road segments level of service for bicycle travel. The Model is particularly responsive to the factors that are statistically significant.

The final result will give a similar table as below but with different values.

LOS	BCI Range	Compatibility Level
A	≤ 1.50	Extremely High
B	1.51 - 2.30	Very High
C	2.31 - 3.40	Moderately High
D	3.41 - 4.40	Moderately Low
E	4.41 - 5.30	Very Low
F	> 5.30	Extremely Low

(Note: For calculation purposes Yes/No are replaced by 1 and 0 respectively)

CHAPTER-5

STUDY AREA AND DATA COLLECTION:

5.1 Study Area

The survey was carried out at sector-2, Rourkela (Odisha), India. The location is a 4-way intersection with a bus-stop at one end and without traffic lights. The following picture shows a satellite view of the study area with the dots representing regions of survey.

5.2 DATA COLLECTION

S no.	Reading No. / Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	Is the width of road sufficient for you? (Y/N)	1	1	0	1	0	1	1	1	1	1	1	0	0	1	1	1	0	0	0	0	0	0	0	1	1
2	Would you prefer a specific bicycle lane?(Y/N)	1	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1	0	1	1	1
3	How would you rate the surrounding and cleanliness of the area?	2	4	3	1	5	5	4	4	3	3	3	2	1	1	3	2	2	4	4	2	4	3	5	2	2
4	How would you rate the pedestrian traffic on the road?	1	5	3	5	5	4	1	5	3	5	2	3	1	4	2	4	1	3	3	2	3	3	2	3	5
5	How would you rate the motor vehicle traffic on the road?	1	4	4	1	5	3	1	3	4	4	4	4	1	3	4	4	2	4	4	3	5	2	4	1	2
6	Is there proper lighting during night to have a clear view of road?	2	5	3	5	1	4	5	4	3	5	3	5	1	4	4	4	3	3	4	2	2	2	1	3	2
7	How would you rate the vehicular traffic speed?	3	3	3	5	1	3	4	2	4	4	3	3	2	1	3	4	2	3	3	3	4	3	3	3	2
8	Is median present?(Y/N)	1	1	0	1	1	1	1	1	1	0	0	1	0	1	1	0	1	1	1	1	0	0	1	0	0
9	In terms of safety how would you rate the width of road?	2	4	3	5	5	3	4	5	4	4	4	2	1	5	5	2	2	4	4	2	4	3	2	2	2
10	Do you think specifying a speed limit for the road will make it safer?(Y/N)	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	1
11	How comfortable do you feel when the following vehicles approach while crossing :																									
	i. When a heavy vehicle like bus/truck is approaching.	3	3	4	1	1	3	3	3	1	4	2	3	1	3	3	4	3	3	3	1	3	2	4	1	2
	ii. When lighter vehicle like car approaches.	1	4	2	5	3	4	3	4	3	3	4	4	2	3	3	4	4	3	3	2	2	5	3	2	2
	iii. When a bicycle/bike approaches.	1	5	2	5	5	3	2	5	5	4	3	2	1	5	5	2	2	4	4	3	5	3	5	3	3
12	Do the vehicles pose a threat for you while turning?	5	4	3	5	1	3	4	3	3	4	2	3	2	3	2	3	1	2	2	3	2	3	1	2	2
13	While crossing or turning are you able to clearly see the approaching vehicles? (Y/N)	1	1	0	1	1	1	1	1	0	1	1	0	0	1	1	0	1	1	1	0	1	0	0	0	1
14	Are there speed bumps before crossings? (Y/N)	1	1	1	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	1
15	Are the turnings at intersections sharp /curved and rate it?	3	3	4	1	1	4	3	4	4	4	4	4	1	4	4	1	2	3	3	2	2	4	2	3	2
16	How dangerous do you feel the crossing is?	5	5	2	1	5	3	2	3	3	4	1	4	4	3	3	3	3	5	5	3	3	2	5	2	3
17	Can you view the bus stop clearly? (Y/N)	0	0	0	1	0	1	1	1	0	1	1	1	0	1	1	0	0	0	0	1	1	0	1	0	0
18	Is the sight distance to bus stop adequate for you?(Y/N)	1	0	0	1	1	0	1	1	0	0	1	0	0	1	1	0	1	0	0	1	1	0	0	1	1
19	According to you do you feel that drivers are following driving rules and regulations?(Y/N)	1	0	0	1	1	1	1	1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	1	1	1
20	Rate the space between pavement and vehicular traffic in terms of how comfortable you feel.	5	2	3	5	3	4	3	4	4	4	3	3	1	3	3	4	2	3	3	4	2	3	2	2	3
21	In terms of accident frequency, rate the road.	5	4	2	5	2	3	2	3	4	3	1	1	5	2	3	5	2	2	2	4	3	3	5	4	2

Table. 1 - Actual Survey Data

	Reading No.	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
S no.	Question																									
1	Is the width of road sufficient for you? (Y/N)	1	1	1	1	1	0	0	0	0	1	0	1	0	0	1	0	1	0	1	0	0	1	1	1	0
2	Would you prefer a specific bicycle lane?(Y/N)	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	How would you rate the surrounding and cleanliness of the area?	2	3	3	3	3	3	3	3	4	4	3	2	3	4	5	3	3	2	1	3	5	5	5	4	4
4	How would you rate the pedestrian traffic on the road?	3	3	2	4	4	3	2	5	5	3	4	4	4	3	2	3	3	1	3	4	2	2	2	3	3
5	How would you rate the motor vehicle traffic on the road?	4	2	4	3	2	3	2	5	4	3	3	4	3	1	2	2	2	2	2	3	3	3	3	3	1
6	Is there proper lighting during night to have a clear view of road?	5	4	1	5	5	3	3	2	2	5	3	5	2	3	2	3	4	2	2	2	2	3	3	5	3
7	How would you rate the vehicular traffic speed?	3	2	2	4	3	2	3	0	5	2	2	5	3	3	1	3	4	3	1	3	5	5	5	5	3
8	Is median present?(Y/N)	0	0	1	0	0	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0
9	In terms of safety how would you rate the width of road?	3	2	3	4	3	0	0	1	1	0	0	5	2	3	5	3	4	2	5	2	5	5	5	5	3
10	Do you think specifying a speed limit for the road will make it safer?(Y/N)	1	1	0	1	0	1	1	0	0	0	1	0	1	1	1	1	1	1	1	1	0	1	0	0	1
11	How comfortable do you feel when the following vehicles approach while crossing :																									
	i. When a heavy vehicle like bus/truck is approaching.	2	2	5	2	4	2	2	1	4	3	3	1	1	1	4	2	4	1	2	2	2	5	5	3	1
	ii. When lighter vehicle like car approaches.	3	2	3	5	2	2	3	1	5	2	2	1	3	2	4	3	2	5	3	2	4	5	5	2	2
	iii. When a bicycle/bike approaches.	4	4	4	5	2	1	2	1	5	5	2	1	4	4	4	4	1	5	5	4	5	4	4	5	4
12	Do the vehicles pose a threat for you while turning?	3	3	5	2	2	2	2	4	3	4	2	4	3	2	4	4	2	2	4	3	4	4	4	4	2
13	While crossing or turning are you able to clearly see the approaching vehicles? (Y/N)	1	0	1	0	0	0	0	0	0	1	0	0	0	1	1	1	0	1	1	1	1	1	0	0	0
14	Are there speed bumps before crossings? (Y/N)	1	1	0	1	1	1	0	1	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0
15	Are the turnings at intersections sharp /curved and rate it?	3	3	2	4	3	4	2	3	4	5	2	3	3	3	3	4	4	3	4	3	2	2	3	5	2
16	How dangerous do you feel the crossing is?	4	5	3	3	4	2	3	3	4	5	4	5	4	2	5	4	2	2	1	3	3	3	4	5	2
17	Can you view the bus stop clearly? (Y/N)	1	0	0	1	1	1	0	0	1	1	1	1	0	0	1	1	1	0	1	1	0	1	1	1	0
18	Is the sight distance to bus stop adequate for you?(Y/N)	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1	0	1	0	1	1	0
19	According to you do you feel that drivers are following driving rules and regulations?(Y/N)	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0
20	Rate the space between pavement and vehicular traffic in terms of how comfortable you feel.	3	2	3	4	5	3	2	3	3	5	3	3	3	4	3	3	4	2	3	3	3	5	5	5	4
21	In terms of accident frequency, rate the road.	4	4	5	4	3	2	3	4	2	5	3	1	3	3	1	3	3	3	5	4	3	2	2	5	3

Table 2 - Actual Survey Data

Table-3 – Data for Most Compatible Road for Bicyclists

S no.	Question / Reading No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
1	Is the width of road sufficient for you? (Y/N)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	Would you prefer a specific bicycle lane?(Y/N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	How would you rate the surrounding and cleanliness of the area?	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
4	How would you rate the pedestrian traffic on the road?	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	How would you rate the motor vehicle traffic on the road?	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
6	Is there proper lighting during night to have a clear view of road?	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
7	How would you rate the vehicular traffic speed?	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
8	Is median present?(Y/N)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	In terms of safety how would you rate the width of road?	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
10	Do you think specifying a speed limit for the road will make it safer?(Y/N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	i. When a heavy vehicle like bus/truck is approachin	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	ii. When lighter vehicle like car approaches.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	iii. When a bicycle/bike approaches.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
12	Do the vehicles pose a threat for you while turning?	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
13	While crossing or turning are you able to clearly see	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	Are there speed bumps before crossings? (Y/N)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	Are the turnings at intersections sharp /curved and rate it?	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
16	How dangerous do you feel the crossing is?	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
17	Can you view the bus stop clearly? (Y/N)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	Is the sight distance to bus stop adequate for you?(Y/N)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	According to you do you feel that drivers are following driving rules and regulations?(Y/N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	Rate the space between pavement and vehicular traffic in terms of how comfortable you feel.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
21	In terms of accident frequency, rate the road.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

Table-4 – Data for Least Compatible Road for Bicyclists

	Reading No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
S no.	Question																																																		
1	Is the width of road sufficient for you? (Y/N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Would you prefer a specific bicycle lane?(Y/N)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	How would you rate the surrounding and cleanliness of the area?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	How would you rate the pedestrian traffic on the road?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	How would you rate the motor vehicle traffic on the road?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	Is there proper lighting during night to have a clear view of road?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	How would you rate the vehicular traffic speed?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	Is median present?(Y/N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	In terms of safety how would you rate the width of road?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Do you think specifying a speed limit for the road will make it safer?(Y/N)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	i. When a heavy vehicle like bus/truck is approaching.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	ii. When lighter vehicle like car approaches.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	iii. When a bicycle/bike approaches.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	Do the vehicles pose a threat for you while turning?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	While crossing or turning are you able to clearly see the approaching vehicles? (Y/N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Are there speed bumps before crossings? (Y/N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Are the turnings at intersections sharp /curved and rate it?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	How dangerous do you feel the crossing is?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	Can you view the bus stop clearly? (Y/N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Is the sight distance to bus stop adequate for you?(Y/N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	According to you do you feel that drivers are following driving rules and regulations?(Y/N)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	Rate the space between pavement and vehicular traffic in terms of how comfortable you feel.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	In terms of accident frequency, rate the road.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

CHAPTER-6

RESULT & ANALYSIS

6.1 Analysis

A total of 50 people were surveyed and asked questions for which the analysis was done.

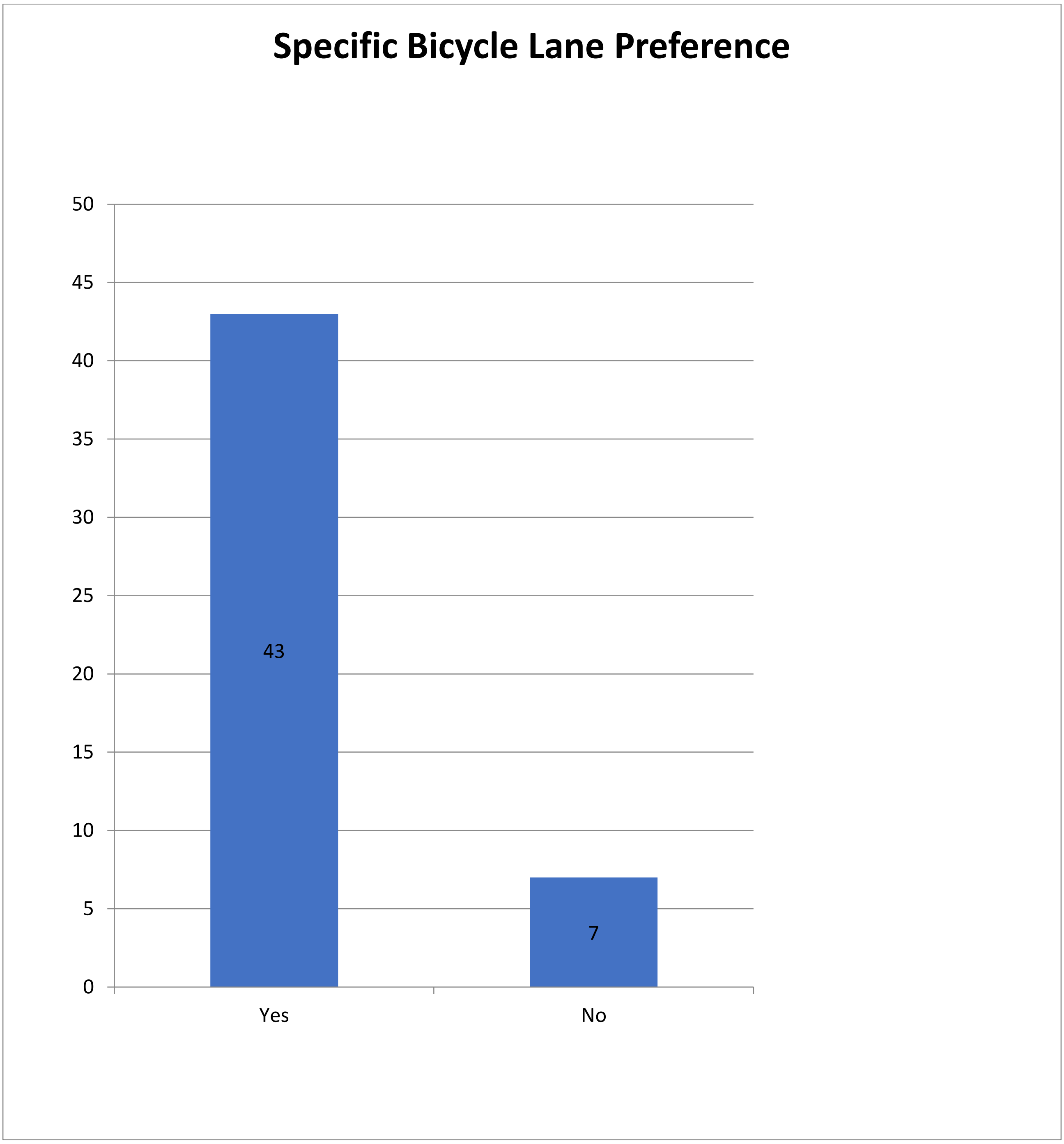


Fig. 2

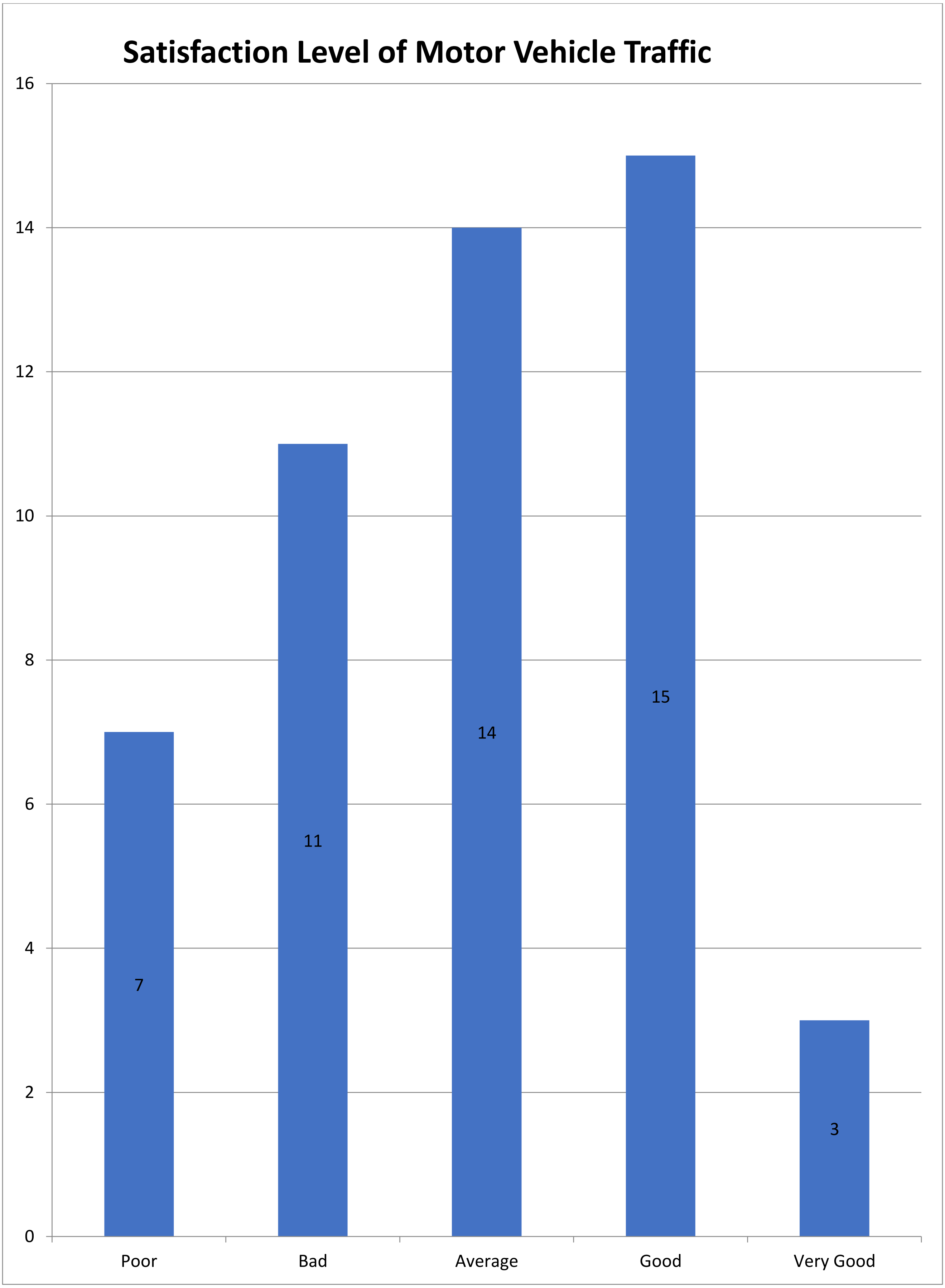

Satisfaction Level of Motor Vehicle Traffic
16
14
12
10
8
6
4
2
0
7
11
14
15
3
Poor
Bad
Average
Good
Very Good

Fig. 3

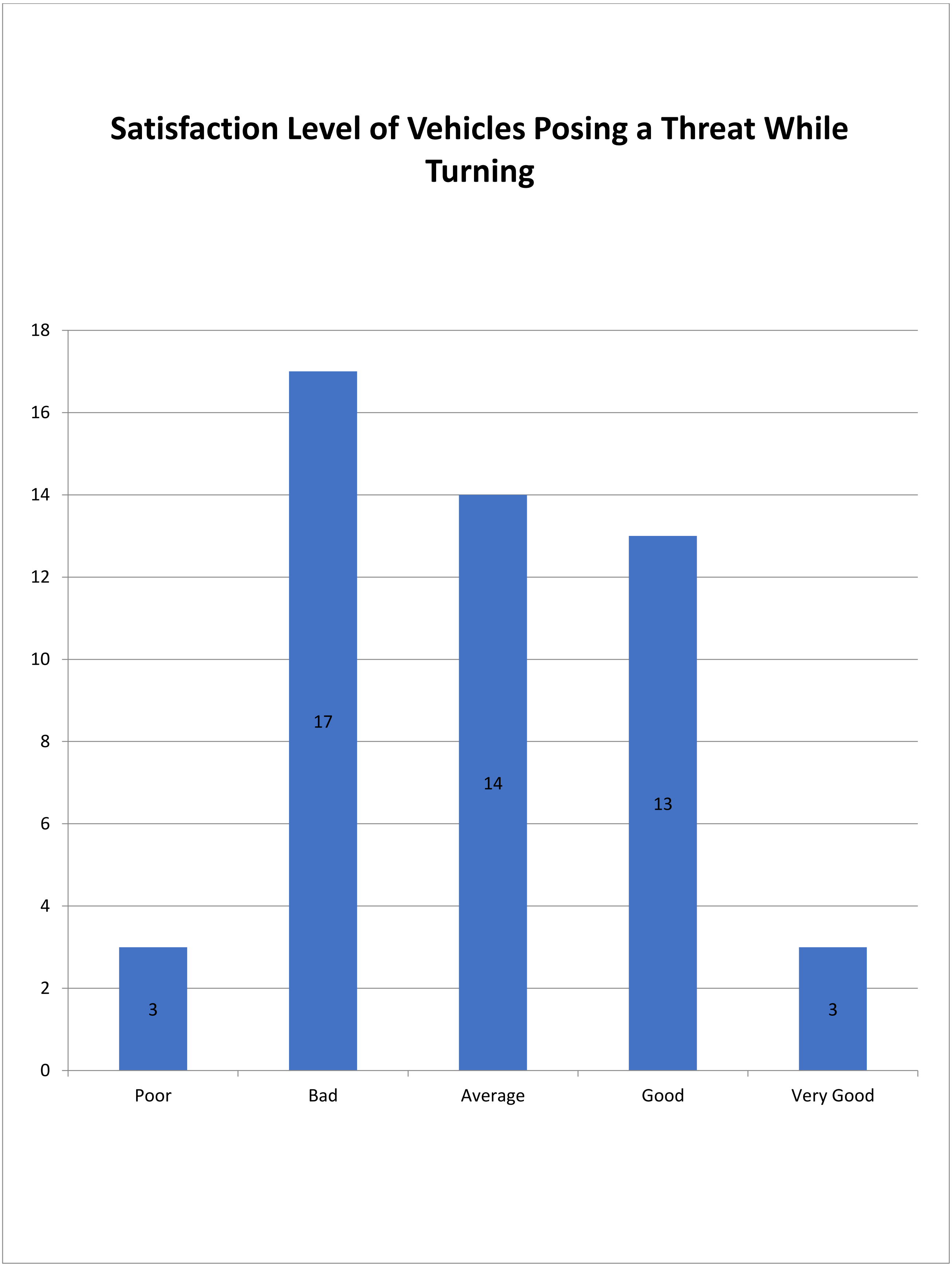
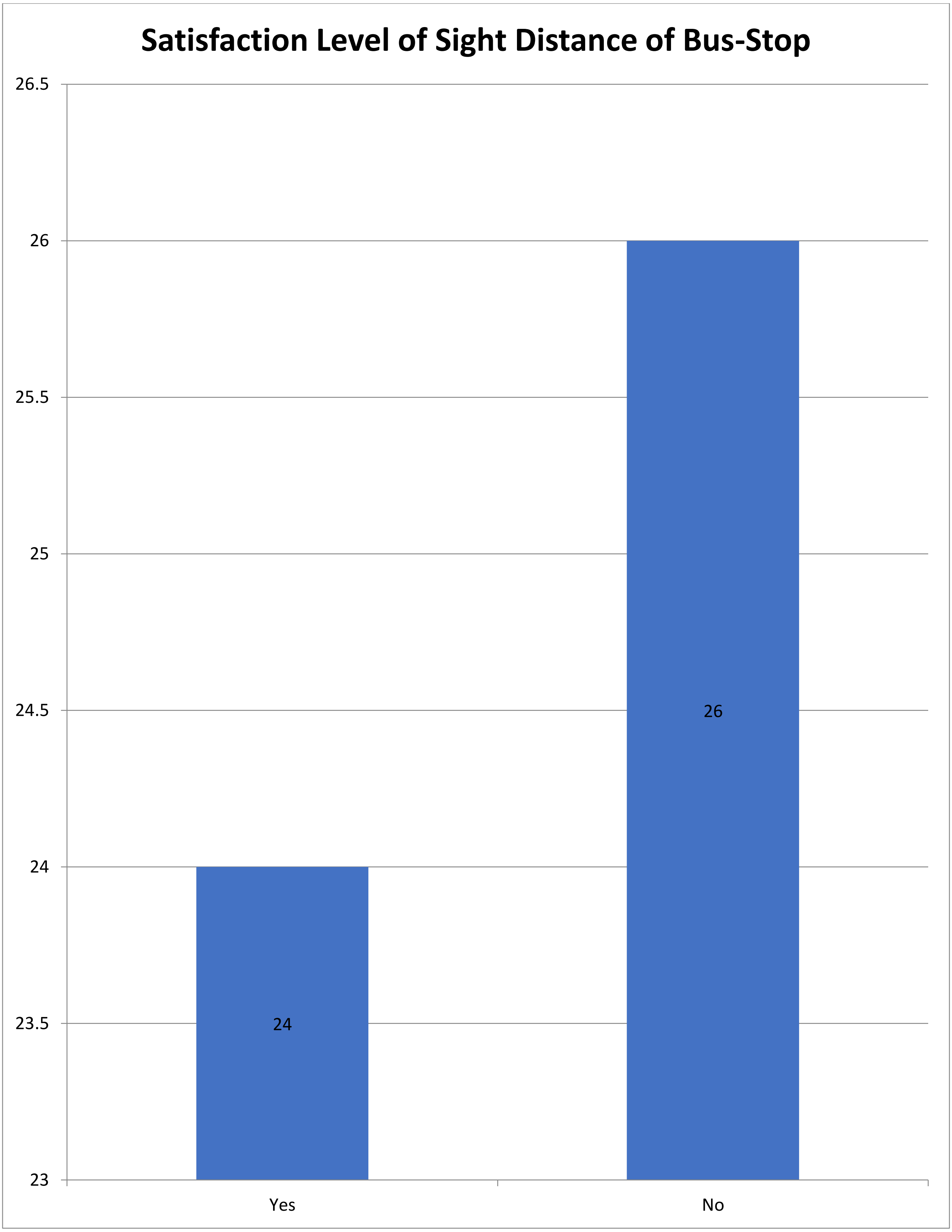

Satisfaction Level of Vehicles Posing a Threat While Turning
18
16
14
12
10
8
6
4
2
0
17
14
13
3
3
Poor
Bad
Average
Good
Very Good

Fig. 4



Satisfaction Level of Sight Distance of Bus-Stop
26.5
26
25.5
25
24.5
24
23.5
23
24
26
Yes
No

Fig. 5

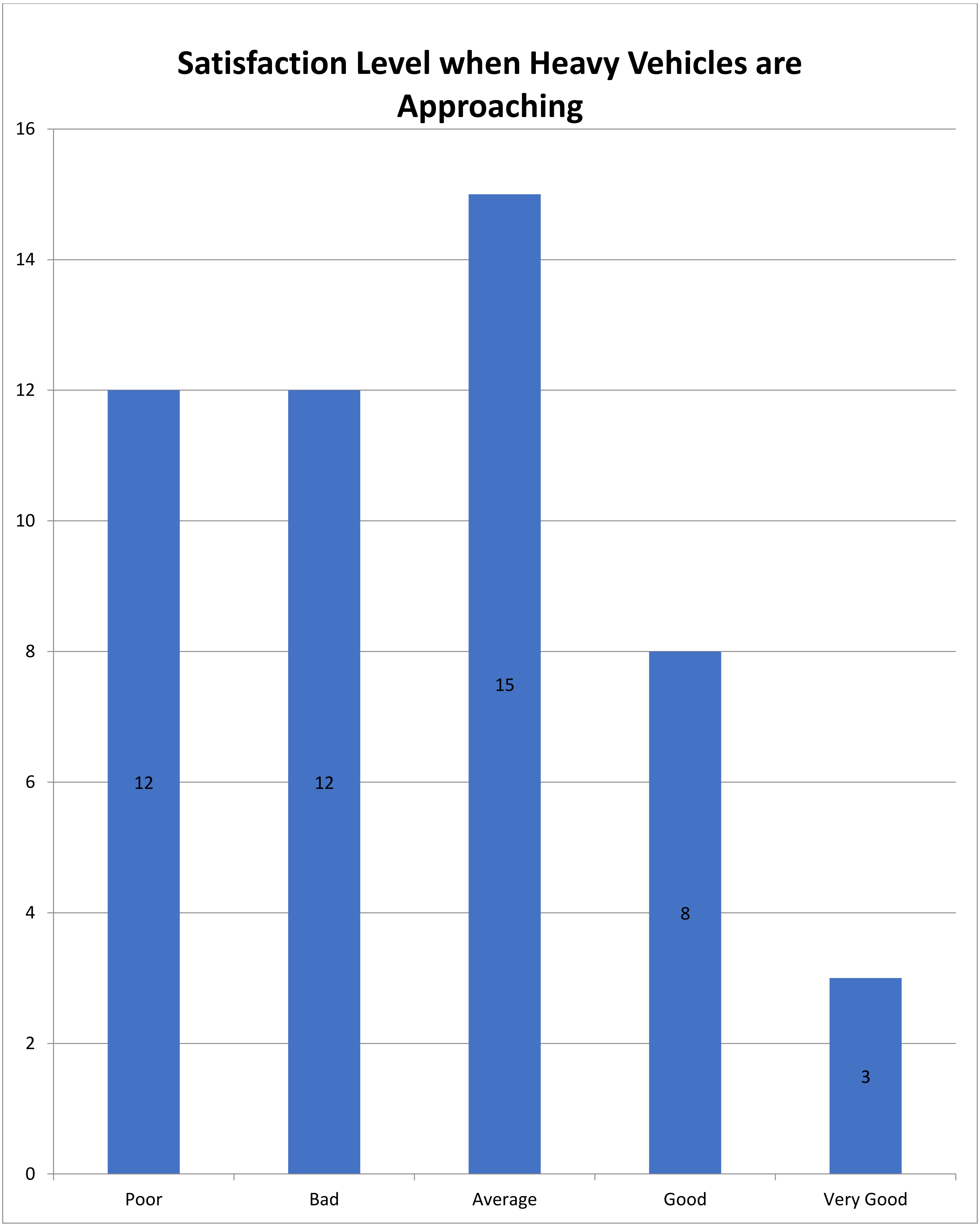

Satisfaction Level when Heavy Vehicles are Approaching
16
14
12
10
8
6
4
2
0
12
12
15
8
3
Poor
Bad
Average
Good
Very Good

Fig. 6

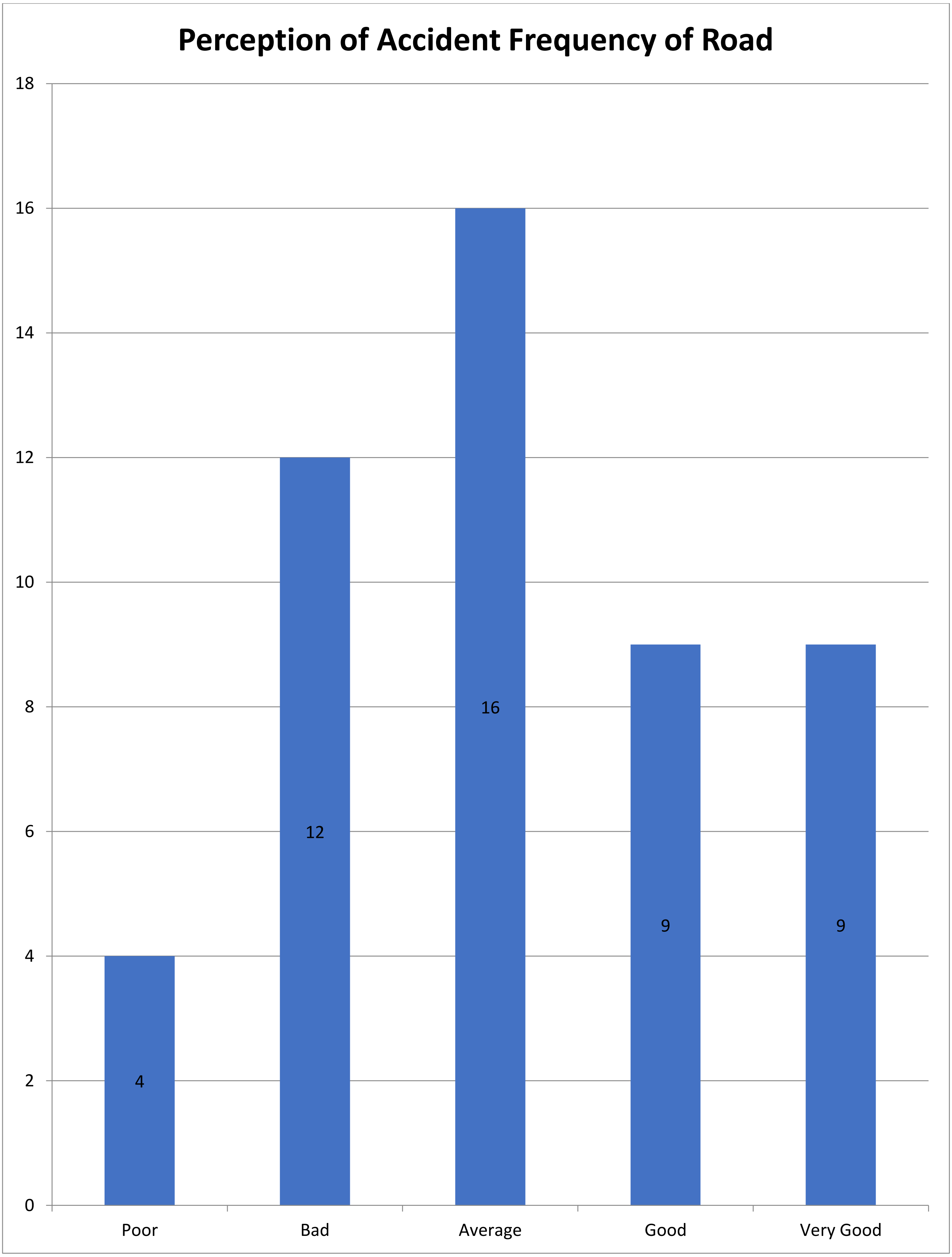

Perception of Accident Frequency of Road
18
16
14
12
10
8
6
4
2
0
4
12
16
9
9
Poor
Bad
Average
Good
Very Good

Fig. 7

6.2 Calculation of BCI:

Using: $y = aX_1 + bX_2 + cX_3 + dX_4 + eX_5$

1. **For calculating BCI (y) (for Actual Observation):**

Table-5

Const.	PARAMETERS	VARIANCE	INVERSE VARIANCE
a	BICYCLE COMPATIBILITY	2.280	0.439
b	ROAD	2.542	0.393
c	CROSSINGS/INTERSECTION	2.476	0.404
d	TRANSIT AREA	0.252	3.966
e	SAFETY	2.690	0.372

X		MEAN
X_1	=	2.29
X_2	=	2.346
X_3	=	2.044
X_4	=	0.52
X_5	=	2.26

BICYCLE COMPATIBILITY INDEX (y) = 5.66

2. **For calculating BCI ($y_{min.}$)(For Most Compatible Road):**

Table-6

Const.	PARAMETERS	VARIANCE	INVERSE VARIANCE
a	BICYCLE COMPATIBILITY	4.599	0.217
b	ROAD	4.216	0.237
c	CROSSINGS/INTERSECTION	3.855	0.259
d	TRANSIT AREA	0.000	0.000
e	SAFETY	5.593	0.179

X		MEAN
X1	=	3.5
X2	=	3.71
X3	=	3.4
X4	=	1

BICYCLE COMPATIBILITY INDEX ($y_{min.}$) = 3.120

3. **For calculating BCI ($y_{max.}$)(For Least Compatible Road):**

X5	=	3.33

Table-7

Const.	**PARAMETERS**	**VARIANCE**	**INVERSE VARIANCE**
a	BICYCLE COMPATIBILITY	0.139	7.176
b	ROAD	0.205	4.886
c	CROSSINGS/INTERSECTION	0.241	4.150
d	TRANSIT AREA	0.000	0.000
e	SAFETY	0.000	0.000

X		MEAN
X1	=	0.8333333
X2	=	0.714
X3	=	0.6
X4	=	0
X5	=	1

BICYCLE COMPATIBILITY INDEX ($y_{max.}$) = 11.960

4. **For Calculating BCI range:**

- Interval = **(y_{max} - y_{min})/6**

INTERVAL = 1.47

Table-8

LOS	BCI Range			Compatibility
A	3.12	-	4.59	Extremely High
B	**4.59**	**-**	**6.07**	**Very High**
C	6.07	-	7.54	Moderately High
D	7.54	-	9.01	Moderately Low
E	9.01	-	10.49	Very Low
F	10.49	-	11.96	Extremely Low

- The BCI lies in the LOS-B range and hence is very compatible for bicyclists.

CHAPTER 7

SUMMARY AND CONCLUSION

Qualitative Analysis of BLOS is different from Quantitative Analysis in terms of its surveyed data. While qualitative analysis takes into account real time human perceptions for calculating BCI, quantitative analysis uses mathematically calculated data from on-site observation to calculate BCI. However if both types of analysis are carried out on the same road segment, the results would not vary to a much extent.

From the survey and analysis it can be concluded that based on human perceptions the surveyed region was "very compatible" for bicyclists lying in Level of Service-B range. The Bicycle Compatibility Index using qualitative analysis was found out to be 5.66. Further the LOS can be improved to LOS-A i.e. extremely high compatibility by implementing the following changes:

1) Introducing specific bicycle lane in and around the region to achieve higher levels of satisfaction during utilitarian cycling.
2) Introducing traffic lights at the intersection to achieve higher levels of satisfaction with respective to safety.
3) Introducing street lights or some other source of light in the bus-stop region to achieve higher levels of satisfaction with respect to visibility at night.

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