A study on the effect of light in road accident prevention and promotion of pedestrian safety

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Submitted by

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This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented by **SOURAV BANERJEE (Roll No.: M6ILT19020)** in a manner satisfactory to warrant it's acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein, but, approve the thesis only for the purpose for which it has been submitted.

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All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

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Dated:…………. ………………………………

SOURAV BANERJEE

Place:……………..

Dedicated to the immortal Goddess Dipty Banerjee,

who showed me the Light of this World & Universe

and made me everything that I am.

In Eternal & Indelible Loving Memory

ABSTRACT

Road Lighting is one of the most important cogs in the wheel of the global transportation nexus. It is amongst the preeminent and pivotal aspects of the road transportation milieu, ensuring the usability and efficacy of the road network in performing it's intended functions and objectives, preventing road crashes and incidences of crime and nefarious activities in the road environs and fostering the overall safety and security of the streets, roads and highways. While perusing the extant and pertinent contemporary literature, we had encountered at many junctures the indication of a strong correlation between the presence of proper, adequate and efficient road lighting and the reduction in the incidences of road crashes and mishaps as well as criminal activities. The concepts of safety and security have both a tangible physical dimension as well as a more intangible dimension to them, as perceived by the road users. To verify, validate and gain greater comprehension about the role of road lighting in promoting safety and security, in-depth road crash data spanning over a decade was collected from several Government departments, public and police authorities and predominantly from the internal motor insurance claim archives at the National Insurance Company Ltd. The collected data was subjected to rigorous scrutiny and analysis to understand, assimilate and evaluate the precise relationship between the presence or absence of road lighting and the impact it has on road crashes as well as the promotion of safety and security for road users. The study was able to comprehensively establish the stellar role of road lighting in the prevention of road crashes and mishaps and also form a vast repertoire of knowledge about the multifarious street lighting schemes, techniques as well as the popular light sources and luminaires, forming a bedrock for future research.

CONTENTS

CHAPTER -I

OUTLINE & OBJECTIVES

OF THE STUDY

INTRODUCTION

The Chinese philosopher Lao Tzu famously said that the journey of a thousand miles begins with a single step. From ancient times to the hyper-fast paced modern age, roads have formed the backbone of the global and industrial plexus and are the central cog in the wheel, driving the worldwide transportation networks, enabling the movement of goods and people and serving as the lifeblood of logistics and supply chains. Streets, roads, roadways & highways form one of the quintessential components of the modern global economy, ferrying not only people and products between places, but, dreams along with them. The field of Road Lighting is thus, intricately and indispensably linked with streets, roads and highways and mutually interdependent.

The key elements of Road Lighting encompass those of Safety, Security and Casualty prevention for pedestrians, drivers, commuters and all other road users. In rural areas and areas with higher crime rates, Street Lighting plays a vital and often lifesaving role in law and order enforcement and ensuring the security of road users and participants, especially vulnerable sections like women and children and the elderly and feeble. Over the past century and more, advances in Road Lighting have driven and influenced progressions not only in Roads & Highways Safety, but, other far flung fields as well. Street Lighting aims to illuminate the road and aid the vehicle driver's decision making and also to make the vehicle as well as other potential obstacles visibly discernible by other road users.

It's pertinent to note that the monikers "Street Lighting" and "Road Lighting" are often used interchangeably in various countries & territories globally and thus, in the context of the present study they may be construed as implying the same. The overbearing purpose of Street Lighting is to provide appropriate levels of illumination when dark and at poorly lit locales. The history of Street Lighting spans the gamut of lamp development from the archaic and rudimentary gas lamps to cutting edge LEDs and everything in between. Over the course of this study, the various dimensions, aspects and components of Road Lighting are discussed and examined for a broader comprehension of their functions and impacts.

AIMS AND OBJECTIVES OF THE STUDY

The present study shall attempt to paint a comprehensive picture of the overall scenario and perspective of Road Lighting. The study aims to shed light on the various key aspects, components and dimensions of Street Lighting in the present perspective and explore avenues of it's advancement. The prime aim of the present study will beelucidating the contemporary scenario of Road Lighting in the global, national, local and regional perspectives and in all its myriad facets and manifestations and real-time ramifications thereof.

One of the major objectives of the present study, thus, is to discern the paramount and critical role played by Road Lighting in the prevention and pre-emption of potential accidents and casualties and promoting the safety of pedestrians, motor vehicle drivers, passengers and all other users of the roadways. The study attempts to analyze the multifarious street lighting schemes, techniques as well as the popular light sources and luminaires, which illuminate the streets and roads the world over.

One of the cornerstones of every modern scientific & technical endeavor is to generate sustainable and green solutions. Thus, the present study attempts to study the correlation between Road Lighting and energy savings in the wider perspective of sustainable and environmental growth for a greener tomorrow. The study, therefore, strives to explore and propose novel Road Lighting schemes, techniques and trends for all-encompassing and perennial pathways for perpetual progress.

Objectives of Road Lighting:-

The main objectives of road lighting are-

- To improve the visibility of road environs for transiting vehicles, pedestrians as well as all other road users.
- Prevention and reduction of road crashes during the hours of darkness and under conditions of poor illumination.
- Prevention of crime.
- Embellishing the night time appearance of the road and surrounding environs.

Apart from its quintessential role in prevention of crashes, road lighting has long been akey tool for the promotion and adornment of cities, towns or planned residential or commercial areas. Road Lighting, thus, at it' very rudiment is a functional necessity which provides safety and security to motorists and residents as well as pedestrians. It also helps in establishing a distinct identity of the roadside and surrounding environs.

Fixed lighting of public ways for both vehicles and pedestrians can create a night time environment in which people can see comfortably and identify objects swiftly and accurately on the roadway being travelled. Roadway lighting can improve traffic safety, achieve efficient traffic movement, and promote the general use of the facility during darkness and under a wide variety of weather conditions.

The prime objectives of Road Lighting are to illuminate the roadway and aid in the visualization of objects and potential obstacles and hazards for vehicle drivers, pedestrians and all other road users in a conspicuous manner. Road Lighting serves as a major contributing factor in promoting Safety and Security on the road, aiding the prevention of accidents, casualties and other road mishaps and saving innumerable lives. Numerous studies have hinted at the pre-eminent part played by Road Lighting in not only preventing accidents, but, also reducing the incidences of crime.

Road Lighting often acts as a supplement to vehicular head lights or automotive lighting, enabling the driver or motorist to view objects with greater perspicuity, locate them with enhanced certainty and react safely to roadway and traffic conditions present on or near the roadway facility. It is imperative for Road Lighting to ensure that pedestrians are able to see with sufficient detail and to readily recognize the presence of other pedestrians, vehicles, and objects in their vicinity.

Energy-efficient road lighting design integrates efficient lamp technologies, optimum pole spacing, efficient luminaire distribution and pleasing esthetics. The principal purpose of road and motorway lighting, thus, is to improve object visibility for the driver and make everything more perspicuous. From an economic vantage point, the rationale behind installing such lighting systems is based primarily on costing exercises for evaluating the savings generated as a consequence of the estimated reduction in accidents. An additional benefit is that the installed road lighting eases the relatively onerous task of driving, especially on busy roads with thick traffic density. This is particularly the case for older drivers, for whom the glare from oncoming traffic can result in a marked impairment of the capacity to discern objects. Oftentimes, some light from the primary road lighting installation also falls upon adjacent footways, which can augment visibility of pedestrians and passersby. Under certain circumstances, lighting installation designs are made with the preconceived intent of providing adequate levels of lighting for pedestrians as well as motorists traversing the roadway.

Globally, numerous studies and comprehensive research analyses have conclusively revealed road lighting to be a key factor in reducing the number of night-time accidents by more than 30 percent. Some of these studies are of a temporal nature, whereby night-time crash statistics pre and post a change in the lighting are analyzed and compared, with the number of day time accidents serving as a correction factor for possible changes in speed, traffic density and other pertinent parameters, which may have taken place at the specific location during the period of survey. The other studies are those in which night-time accident figures are compared for similar sites that differ only in respect of the lighting. There is evidence to suggest that road lighting can reduce the number of accidents occurring at night, and that this lighting can be largely paid for out of the savings to the community that it brings with it.

The scenario of road lighting on residential and other types of unclassified roads is somewhat different. In such areas, particularly in smaller neighborhoods with relatively lesser traffic, it's often intended for the benefit of pedestrians and passersby and augmenting their visibility over shorter distances. Often, these may include, but, are not limited to the surface of the footway for the transit of pedestrians, the surface of the road (for safely crossing it), and the delineation of the road. Additionally, road lighting greatly aids in facial recognition of fellow pedestrians and passersby, which has a great impact on negating potential criminal activity. It is assumed that motor traffic and pedal cyclists will be using lighting fixed to their vehicles of sufficient quantity and quality to reveal the lie of the road and make their presence known to other road users.

In retrospect it may be observed that from a historical perspective, the illumination of roads, streets, lanes, alleys and sidewalks originated from and with the express intent of preventing and reducing the incidences of crime. Essentially, the objective was to make the roads and roadways a safer place, the terra incognita of the outdoors bearing parity with the safe sanctum of an indoor environment. In a more contemporary perspective, residential roadway lighting has usually sought to enhance pedestrian visibility. However, the significant and almost steady increase in crime rates, particularly during the latter part of the 20th century prompted thorough surveys and analyses into the causes thereof and what role in the transpiring of the crimes is attributable to road lighting and lack thereof. Many of the studies focused on whether the installation of roadway lighting or improving the existing lighting infrastructure can conclusively lead to reduction in crime rates. By and large, the evidence bears testimony to the fact that the presence of proper road lighting does reduce crime and also the psychological perception of being victimized by a criminal act. In other words, it emboldens road users and instills a sense of confidence and safety. This boosts morale and civic pride, which leads to greater usage of and activity in the corresponding road area by pedestrians and other road users. Consequently, this also deters the activities of criminals, due to the heightened risk of their nefarious activities being visible and caught under proper lighting conditions and greater public presence as compared to dimly lit and deserted roads.

To summarize, the prime objectives of our study, thus, would be geared toward evaluating and analyzing whether road lighting does the following:

- Enhances the safety of people and aids the protection and security of property
- Embellishes and augments the esthetic appeal of the area or roadway
- Delivers lighting which is economically viable and generates minimal environmental impact.

Within the realm and span of these broad objectives, proper road lighting attempts to illuminate the roads, streets, highways and thoroughfares ensuring the safety and sanctity of the road environs and minimizing the incidences of crashes and crimes.

CHAPTER - II

FUNDAMENTAL CONCEPTS &TERMINOLOGIES OF ROAD LIGHTING

RUDIMENTS OF ROAD LIGHTING

First and foremost, let us get acquainted with some of the rudimentary concepts and terminologies which form the lingua franca in the parlance of Road Lighting:

Road Lighting Terminology:

The terminology pertaining to Road Lighting may broadly be classified into the following:

1. Terms pertaining to the physical roadways
2. Terms pertaining to the Lighting Installation
3. Terms pertaining to Photometry
4. Terms pertaining to Calculation.

1. Terms pertaining to the physical roadways:-

- **Highways:** A way for passage of vehicles, traffic over which they may lawfully pass.

- **Carriageway:** The portion of highway intended primarily for vehicular traffic.

- **Dual Carriageway:** A lay out for two separated carriageways, each reserved for traffic in one direction only.

- **Layout:** All those physical features of a highway other than the surfacing of carriageway, which have to be taken into account in planning a lighting installation.

- **Central Reserve:** A longitudinal space dividing a dual carriageway.

- **Service Road:** A subsidiary road between a principal road and building or properties facing thereon and connected only at selected points with the principal road.

- **Cycle Track:** A way or part of highway for use by pedal cycles only.

- **Footway:** The portion of road reversed exclusively for pedestrians.

- **Verge:** The unpaved area flanking a carriageway, forming part of highway and substantially at the same level at the carriageway.

- **Shoulder:** A strip of highway adjacent to and level with the main carriageway to provide an opportunity for vehicles to leave the carriageway in an emergency.

- **Refuge:** A raised platform or a guarded area so sited in the carriageway as to divide the streams of traffic and to provide the safety area for pedestrians.

- **Kerb:** A border of stone, concrete or other rigid material formed at the edge of a carriageway.

2.<u>Terms pertaining to the Lighting Installation</u>:-

- **Lighting Installation:** The whole of the equipment provided for lighting the highway Comprising the lamps, luminaries, means of support the electrical and other auxiliaries.

- **Lighting System:** An array of luminaries having a characteristics of light distribution, sited in manner concordant with distribution.

- **Luminaire:** A housing for one or more lamps, comprising a body and any refractor, reflector, enclosure, diffuser associated with lamp.

- **Outreach:** The distance measured horizontally between center of column or wall face and center of luminaire.

- **Overhang:** The distance measured horizontally between the center of luminaire mounted on bracket and the adjacent edge of the carriageway.

- **Mounting Height:** The vertical distances between the center of luminaire and the surface of carriageway.

- **Spacing:** The distance measured along the center line of the carriageway, between successive luminaires in an installation.

- **Span:** The part of highway lying between successive luminaires in an installation.

- **Width of carriageway**: The distance between kerb lines measured at right angles to the length of the carriageway.

- **Arrangement:** The pattern according to which luminaires are sited on installation circuit, for example staggered, axial, opposite etc.

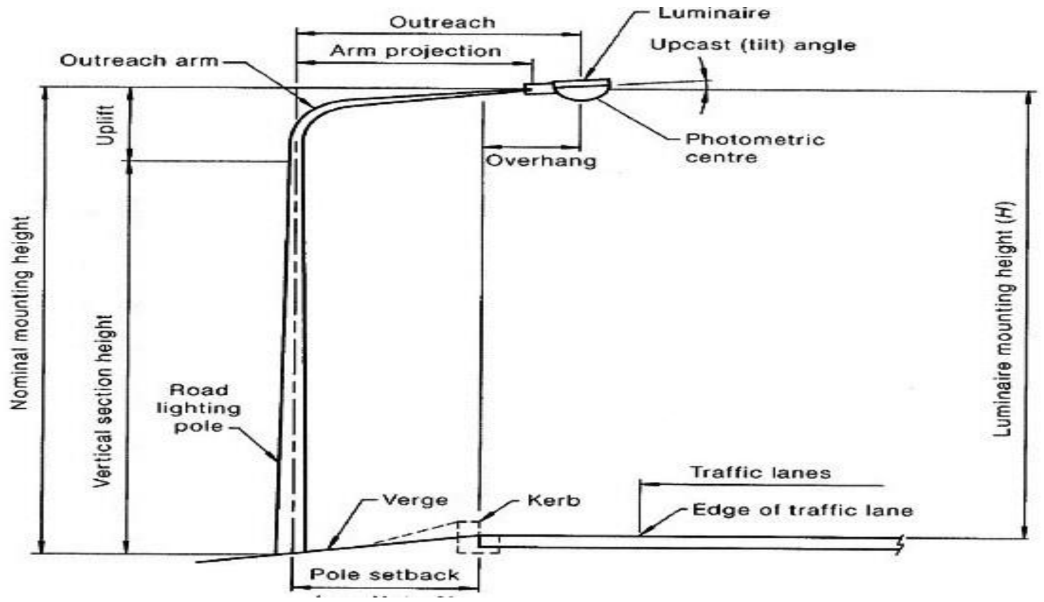


Fig. 1: Layout of a typical Road Lighting System

3. Terms pertaining to Photometry:-

- **Luminous Flux:** The quantity of light emitted per second by the light source is called luminous flux. Unit is lumen (lm) and its symbol is (Φ) and it is a

scalar quantity.

- **Luminous Intensity**: Quotient of the luminous flux leaving the source propagated in an element of solid angle containing the given direction the element of solid angle. Its unit is candela (cd) and symbol is I.

  I = luminous flux (Φ) / solid angle (ω- steradian)

- **Illuminance:** The luminous flux reaching the corresponding working plane per unit area is termed as Illuminance. Its symbol is E and unit is lux.
-
- **Luminance:** luminance is the luminous intensity emitted by a plane in a given direction per unit of apparent area in that direction. Its symbol is L and unit is cd/m2

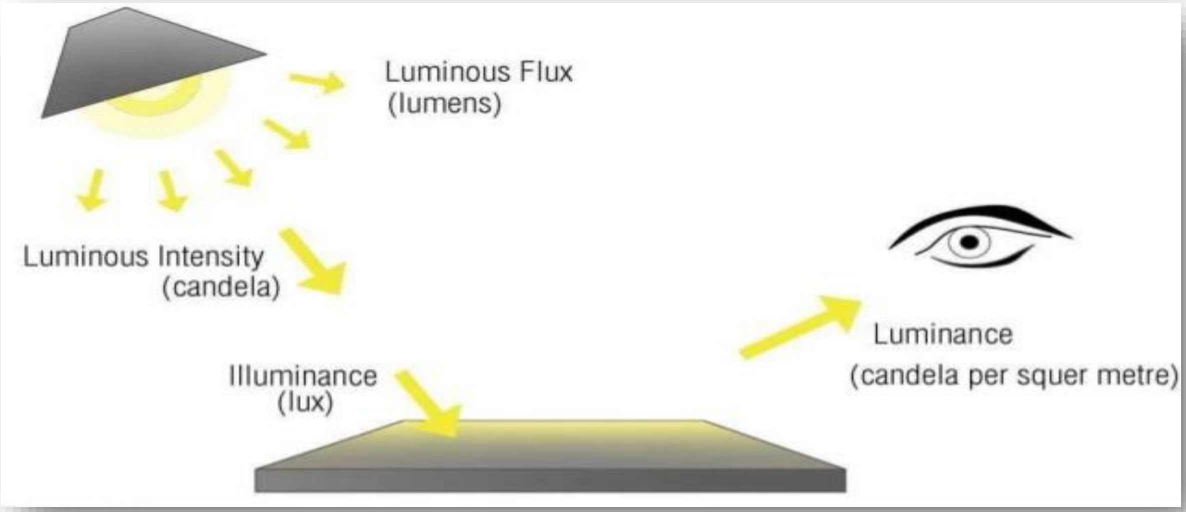


Fig. 2: Inter relationships between the major Photometric parameters

- **Luminous Efficacy:** Quotient of the luminous flux emitted per consumption of power is called luminous efficacy. Unit is:-Lumen per watt. (Lm/W).

- **Luminous Efficiency:** The ratio of the total luminous flux emitted by a luminaire to that emitted by the bare lamp.

- **Lower Hemispherical Flux or Downward Flux:** The luminous flux emitted by a luminaire in all directions below the horizontal.

- **Luminosity:** The attribute of visual sensation according to which an area appears to emit more or less light. It is sometime called brightness.

- **Light Output:** The Light Output is defined as the luminous flux emitted by a luminaire.

- **Symmetrical Distribution:** A distribution of luminous intensity which is substantially symmetrical (conversely asymmetrical) about the vertical axis of the luminaire.

- **Axial Distribution:** An asymmetrical distribution in which the direction of maximum luminous intensity lie (do not lie) in vertical planes substantially parallel to the axis of the carriageway.

- **Peak Intensity Ratio:** The ratio of maximum intensity to the hemispherical intensity of the light emitted below the horizontal.

- **Mean Hemispherical Intensity:** The downward flux divided by 6.28. This is average intensity to the lower hemisphere.

- **Intensity Ratio:** The ratio of an actual intensity from a luminaire in a particular direction to the mean hemispherical intensity.

- **Beam:** the portion of the light output of luminaire contained by the solid angle subtended at the effective center of luminaire containing the maximum intensity, but no intensity less than 90 percent of maximum intensity.
- **Beam Center**: The direction midway between the directions for which the intensity is 90 percent of maximum in vertical plane through the maximum and a conical surface through the maximum.

- **Iso-candela Curve:** A curve traced on a imaginary sphere with a source at its centre and joining all the points corresponding to those directions in which the luminous intensity is the same or a plane projection of this curve.

- **Polar Intensity Curve**: This illustrates the distribution of luminous intensity, in cd/1000 lm, for transverse (solid line) and axial (dashed line) planes of luminaire. The curve provides a visual guide to the type of distribution expected from the luminaire e.g. wide, narrow, direct, indirect etc in addition to intensity. Usually used for intensity distribution luminaire.

- **Isofootcandle (Isolux) Diagram:** A diagram plotted on any appropriate set of coordinates to show all points on a surface for which the illuminance is the same, as represented by a series of isofootcandle (isolux) line curves.

- **Average Initial IlIuminance:** The average level of horizontal ilIuminance on the pavement area of a traveled way at the time the lighting system is installed when lamps are new and luminaires are clean; expressed in average foot-candles (fc) (lux) for the pavement area. See definition of illuminance, foot-candle and lux.

- **Average Maintained Illuminance:** The average level of horizontal ilIuminance on the roadway pavement when the output of the lamp and luminaire is diminished by the maintenance factors (LLD and LDD); expressed in average footcandles (fc) (lux) for the pavement area.

- **Glare:** The sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort or loss in visual performance and visibility.

- **Direct Glare:** Glare resulting from high luminances or improperly shielded light sources in the field of view or from reflecting areas of high luminance. It is usually associated with bright areas that are outside the task being viewed.

- **Disability Glare:** Glare resulting in reduced visual performance and visibility. It often is accompanied by discomfort.

- **Discomfort Glare:** Glare producing discomfort. It does not necessarily interfere with visual performance or visibility.

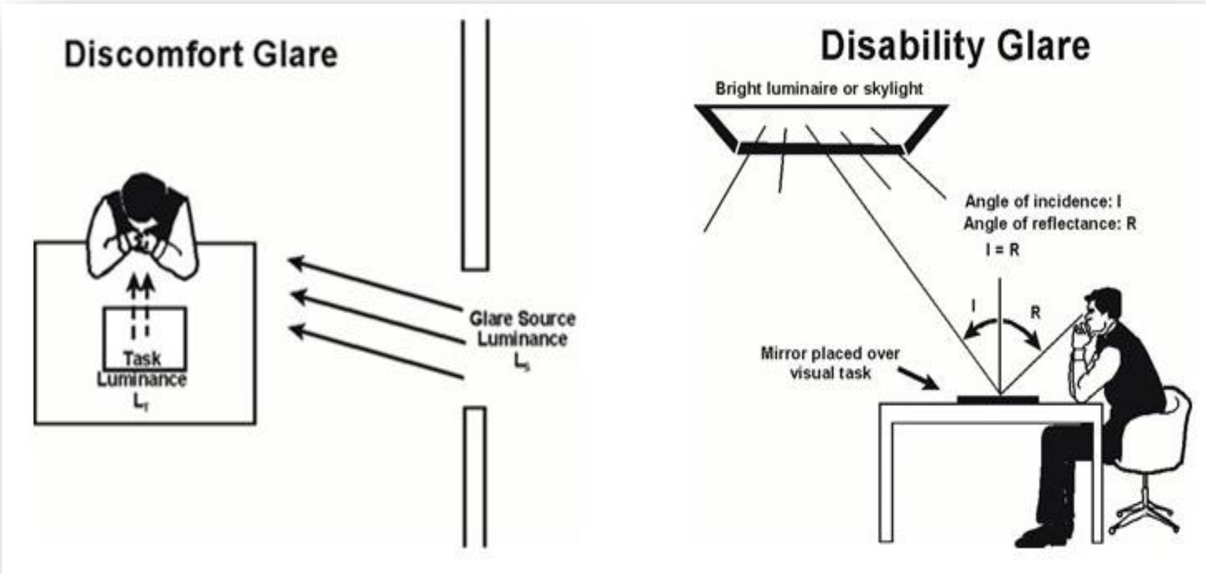


Fig. 3: Illustration of Discomfort Glare & Disability Glare

- **Blinding Glare:** Glare so intense that for an appreciable length of time no object can be seen.

- **Veiling Luminance:** A luminance superimposed on the retinal image that reduces its contrast. It is this veiling effect produced by bright sources or areas in the visual field that results in decreased visual reflected glare.

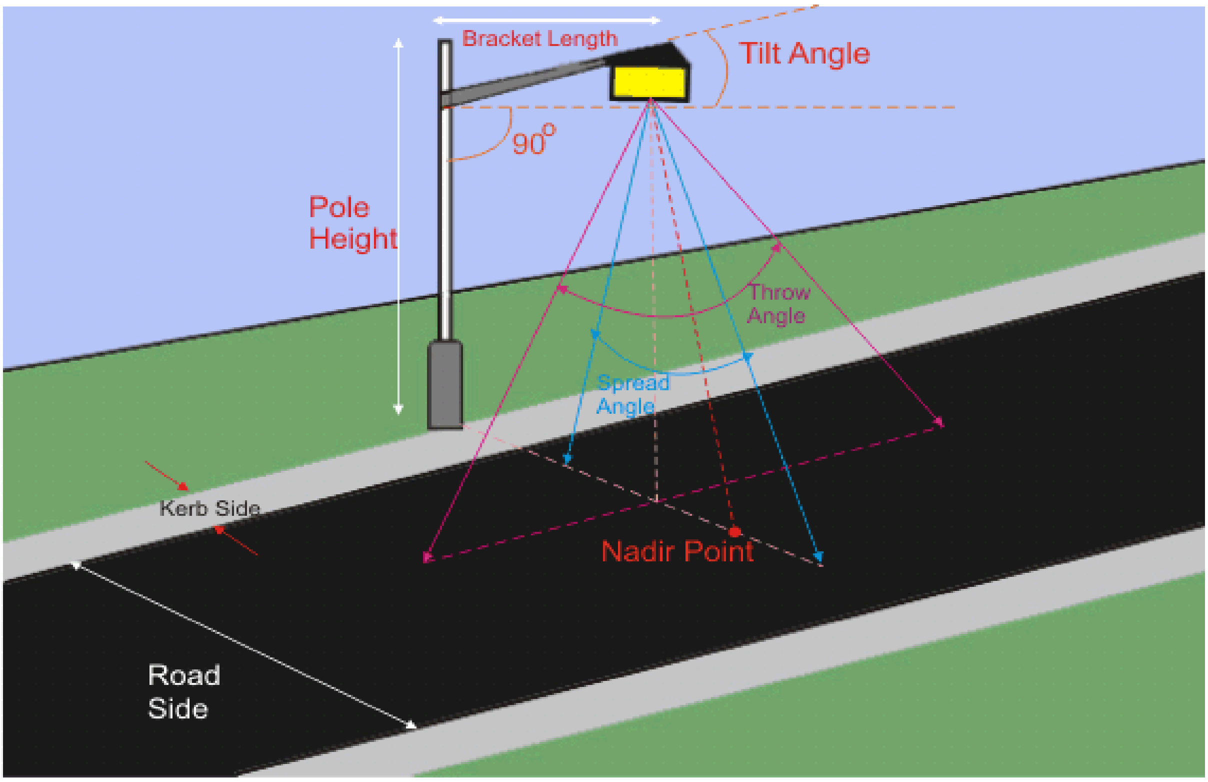


Fig. 4: Photometric Characteristics of a typical Road Lighting installation

4. Terms relating to Lighting Calculation:-

- **Uniformity Ratio:** The ratio of average maintained horizontal illuminance (Eh) to the maintained horizontal illuminance (Emin) at the point of minimum illumination on the pavement. A uniformity ratio of 3:1 means that the average foot-candle (lux) value (Eh) is three times the foot-candle (lux) value (Emin) at the point of least illuminance on pavement.

- **Utilization Efficiency:** A plot of the quantity of light falling on the horizontal plane both in front (street side) of and behind (house side) the luminaire. It shows only the percent of bare lamp lumens that fall on the horizontal surface and is plotted as a ratio of width of area to mounting height of the luminaire.

- **Maintenance Factor (MF):** A combination of light loss factors used to denote the reduction of the illumination for a given area after a period of time compared to the initial illumination on the same area (MF=LLD*LDD)

- **Luminaire Dirt Depreciation Factor (LDD):** A depreciation factor that indicates the expected reduction of a lamp's initial lumen output due to the accumulation of dirt on or within the luminaire over time.

- **Lamp Lumen Depreciation Factor (LLD):** A depreciation factor that indicates the decrease in a lamp's initial lumen output over time. For design calculations, the initial lamp lumen value is reduced by LLD to compensate for the anticipated lumen reduction. This multiplier is to be used in illumination calculations to relate the initial rated output of light sources to the anticipated minimum rated output based on the re-lamping program to be used.

- **Light Loss Factor:** A depreciation factor applied to the calculated initial average luminance or illuminance.

- **Coefficient of Utilization (COU):** The ratio of the luminous flux (Im) from a luminaire received on the surface of the roadway to the lumens emitted by the luminaire's lamps alone.

5. Basic Layout Diagram of a Road Lighting Installation:-

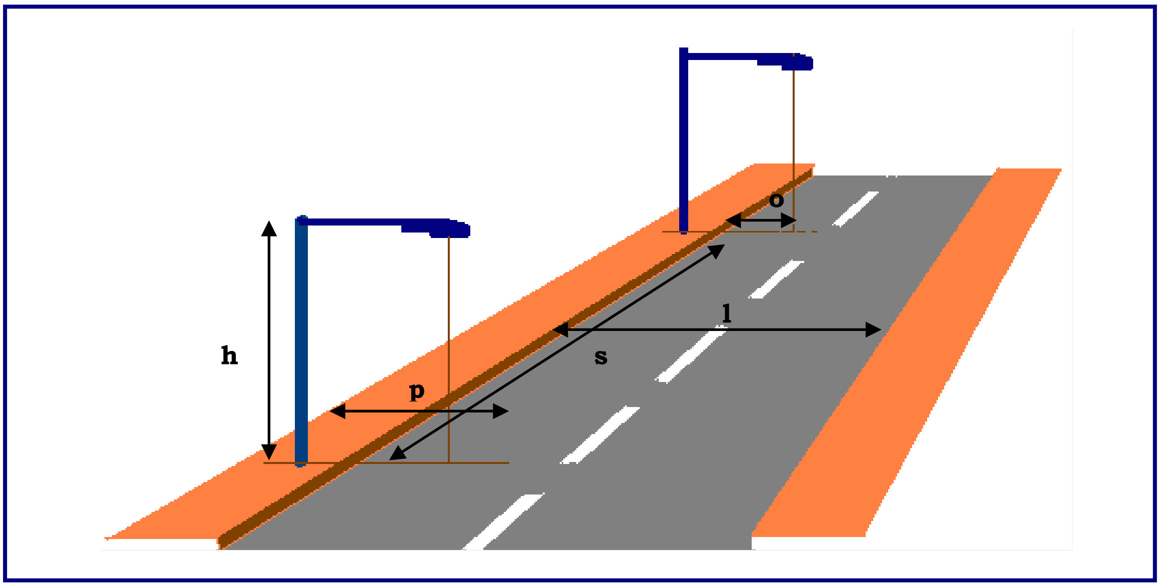
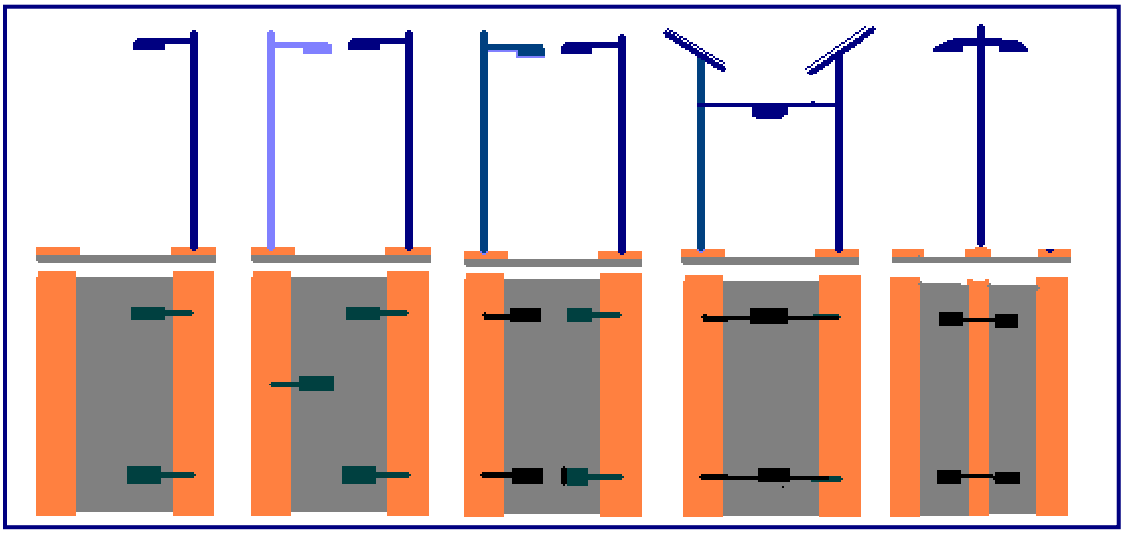


Fig. 5: Layout of a typical road lighting installation

Figure Legend:

h = mounting height of luminaire; s = spacing between two luminaire ;
p = outreach ; l = width of the road;o = overhang ;

6. Luminaire Arrangements in Road Lighting:-



a. **b.** **c.** **d.** **e.**

Fig. 6: Common types of luminaire arrangements in road lighting

Figure Legend:

a. Single Side arrangement **b. Staggered arrangement** **c. Opposite Arrangement**

d. Catenary Suspension arrangement **e. Axial arrangement.**

Ready Reckoner for selecting usual Road Lighting Arrangements:-

1. **Single Side arrangement**: - Carriageway Width =< Mounting Height

2. **Staggered arrangement**: - Carriageway Width <= 1.5 times of Mounting Height

3. **Opposite arrangement**: - Carriageway Width > 1.5 times of Mounting Height

4. **Axial arrangement**: - Carriageway Width <Mounting Height

7. Classification of Roadways:-

1. **Freeway:** A divided major highway with full control of access and with no crossings at grade.

2. **Expressway:** A divided major arterial highway for through traffic with full or partial control of access and generally with interchanges at major crossroads. Expressways for non-commercial traffic within parks and park-like areas are generally known as parkway.

3. **Urban Principal Arterials:** The urban major roadway system that serves the major centers of activities of urbanized areas containing the corridors with the highest traffic volume.

4. **Urban Minor Arterials:** The roadway system that interconnects with and augments the urban principal arterial system. It accommodates trips of moderate length at lower levels of mobility.

5. **Collector:** The distributor and collector roadways serving traffic between arterials and local roadways. These are roadways used mainly for traffic movements within residential, commercial and industrial area.

6. **Local:** Roadways used primarily for direct access to residential, commercial, industrial or other abutting property. They do not include roadways carrying through traffic. Long local roadways will generally be divided into short sections by the collector road way system.

7. **Alley:** A narrow public right-of-way within a block, generally used for vehicular access to the side or rare of abutting properties.

8. **Sidewalk:** Paved or otherwise improved facility designated for pedestrian traffic that is located within public street right-of-way of a roadway used for vehicular traffic.

9. **Pedestrian Way:** Public facility for pedestrian traffic that may or may not be within the public right-of-way for vehicular traffic roadways. Included are skywalks (pedestrian overpasses), sub walks (pedestrian tunnels), walkways giving access to park or block interiors and crossing near centre of long block.

10. **Bikeway:** Any road, street, path or otherwise improved facility specifically designated as being open to bicycle travel, regardless of whether the facilities

8. <u>Classification of different types of Areas vis a vis Road Lighting</u>:-

The type of locality or area where a particular road is located plays a pivotal role in determining the lighting requirements, owing to the traffic flow and density. For all generic intents and purposes of Road lighting and associated usage, road areas are usually categorized as follows:

1.Commercial Areas: Commercial areas consist of areas of a municipality engaged predominantly in business development and where usually there are large numbers of pedestrians and heavy demand for parking space during peak traffic hours or sustained high volume of pedestrian transit and a continuously heavy demand for off-street parking space during the primary business hours.

2.Intermediate Areas: Intermediate areas are those portions of a municipality which are outside the predefined downtown area, but, usually located within the zone of influence of a business or industrial development. They are frequently marked by moderately dense nighttime pedestrian volume and a somewhat lower parking turnover than is found in a commercial area. Intermediate areas include densely developed apartment areas, hospitals, public areas and neighborhoods.

3. Residential Areas: Residential areas comprise of residential complexes, individual apartments or villas or houses or a mixture of residential and commercial establishments, characterized by relatively less number of pedestrians and comparatively low parking demand or turnover, especially during the hours of darkness. Regional parks, cemeteries and vacant lands may also be part of residential areas.

9. <u>Classification of Pavements</u>:-

The type, nature and category of pavements used on the roadways plays a crucial role in the road lighting installation, impacting the surface reflectance of light on the road surface and consequently has a vital impact on road surface visibility. Usually, the following types of classification of pavements are prevalent in terms of various Road Lighting installations:

1. Class R1: Class R1 type of pavements have a mostly diffuse mode of reflectance. R1 pavements include Portland cement concrete road surfaces and asphalt road surfaces with a minimum of 12% of the aggregates composed of artificial brightener materials.

2. Class R2: Class R2 type of pavements have a mixed diffuse and specular mode of reflectance. R2 pavements include asphalt road surfaces with an aggregate composed of minimum 60% gravel with a size greater than 0.375 in (10 mm), and 10% to 15% artificial brightener in aggregate mix.

3. Class R3: Class R3 type of pavements have a slightly specular mode of reflectance. R3 pavements include asphalt road surfaces, both regular and carpet seal, with dark aggregates (e.g., trap rock, blast furnace slag) and exhibit a rough texture after some months of use. Class R3 pavement represents typical asphalt highways and as used on most highway project.

4. Class R4: Class R4 type of pavements have a mostly specular mode of reflectance. R4 pavements include asphalt road surfaces with a very smooth texture.

10. Design Standards & Recommendations as per IS-1944:

Road Classification	Description	Eavg on Road Surface (Lux)	Uniformity Ratio (Emin/Eavg)	Transverse Uniformity (Emin/ Emax)
Group A1	Important traffic routes carrying fast flowing traffic.	30	0.4	0.33
Group A2	Other main roads carrying mixed traffic like main city streets, arterial roads and throughway roads.	15	0.4	0.33
Group B1	Secondary roads with considerable traffic like principal local traffic routes and shopping areas.	8	0.3	0.2
Group B2	Secondary roads with relatively lighter traffic.	4	0.3	0.2

Design criteria for different types of road lighting scenarios usually vary according to the class or category of the roadways, the type of area or locality and also the type of pavement used on the road surface. Accordingly, the following are some of the common scenarios encountered from a road lighting design perspective:

1. Crossroads: Lighting levels on crossroads and major junctions and points of intersection of multiple major and/or minor roads should not be reduced through the interchange area. If, existing crossroad illuminance currently is deemed inadequate, it should be considered for upgrading to ensure safe and efficient traffic operation on the crossroad.

2. Partial Interchange Lighting: Where partial interchange lighting is provided, luminaires should be aptly sited to adequately illuminate the through lanes and lanes of drastic speed changes at both merging and diverging locations. The design controls of basic level of lighting and uniformity should be subordinated to overall lighting of the roadway area at these locations.

3. Underpasses: The design lighting level and uniformity ratios at underpasses should be able to replicate the lighting values on the adjacent facility, as far as practically feasible.

4. Bridges and Overpasses: On continuously lighted freeways and lighted interchanges, the lighting of bridges and overpasses should be at the same level and uniformity of the road way.

5. Transition Lighting: Transition lighting is a technique intended to provide the driver with a gradual reduction in lighting levels and glare when leaving a lighting system. The designer may consider transition lighting after a study of the conditions at a specific location. Typical transition lighting design should extend the lighting system a sufficient distance beyond the normal limits of illumination.

6. Navigable Airspace: Where road lighting projects are considered nearby or in close proximity to active airfield or airport (for instance on Group F category of roads), the impact that the luminaire height has on navigable airspace is a vital factor to be taken into consideration.

11. <u>Lighting Codes & Standards</u>

11.1 The National Lighting Code

The National Lighting Code is one of the hallmark publications of the Bureau of Indian Standards (BIS). It has been specifically formulated for the with the aim of elucidating the relevant requirements for responsible social, commercial and engineering conduct as designers, manufacturers and suppliers of lighting. Lighting technology plays a significant role in achieving basic social safety and environmental objectives. In particular, Part 8 of the National Lighting Code (NLC) 2010 guidelines specify the various codes and specifications to be followed for the lighting roads, streets and thoroughfares.

The major purpose of the NLC is to foster good lighting practices and systems which would minimize light pollution, glare, light trespass and conserve energy while promoting safety, security, utility and productivity.

Over the past few decades, the lighting industry in general has witnessed high levels of fragmentation and has relatively low technical barriers for new entrants. However, despite its prime importance to many basic safety operations, the industry is not very well regulated. As such, end users and consumers often do not have access to accurate and reliable information on what represents a safe, reliable and efficient lighting system. This code aims to build up a conduit between the industry and its customers through integration of commerce and technology.

The **National Lighting Codes (NLC)** encompasses the following aspects:

a) Guidance on illuminating engineering practices to be followed by various types of occupancies;

b) Guidance on good engineering practices to be followed in the design, selection, installation and maintenance of lighting systems for indoor and outdoor areas;

c) Matters related to the science of illumination such as physics of light, electric light sources, luminaires and photometry

d) Coordination aspects to be considered while designing the lighting systems such as day lighting

e) Aspects relating to energy management and energy conservation in lighting installations including guidelines for design and good practices to be adopted for effective and efficient use of light sources.

The National Lighting Code (NLC) is a single document, almost akin to a matrix like network, wherein the information contained in various Indian Standards is compiled into a pattern of continuity and cogency with the interdependent requirements of Sections carefully analyzed and fitted in. This makes the whole code a cogent continuous volume.

The National Lighting Code enlists good practices and regulations which can be immediately adopted or enacted for use by various departments and public bodies. It specifies a set of minimum provisions necessary to protect the interests of the public vis a vis lighting levels and quantity, and safety parameters. For the choice of lighting products and method of lighting design for the lighting professional, detailed guidelines have been provided in this code, while leaving ample opportunity for the integrity of the users, designers, consultants and architects who are the primary intended audience.

The National Lighting Code is applicable to the lighting systems in large varieties of interior and exterior installations including special areas like hospitals, utilities, sports complexes, metro railway, etc, under the control of qualified persons. This NLC is divided into 13 parts, some of which have subsections of their own, bringing the total to 29 parts.

The NLC is based on the present stage of knowledge on the myriad facets of different lighting systems.. The NLC provides a modality for continuous discourse and the dissemination and diffusion of insights gained through technological evolution, users' views over a period of time and results of on-field research would be incorporated into the code from time to time resulting in a dynamically evolving document. Ergo, the code is periodically updated. In the meantime, all or some parts of the code may be adopted with or without changes by delegated legislative authorities in their regulations, administrative orders or similar documents.

11.2 IS: 1944– 1970: Code of Practice for Lighting of Public Thoroughfares

This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 3 March 1970, after the draft finalized by the Illuminating Engineering Sectional Committee had been approved by the Electro-technical Division Council.

This standard was first published in 1961. The number of motor vehicles plying on the streets in the towns and cities of India has increased considerably in these intervening years. Further, more efficient light sources are now available for use in street-lighting installations and levels of illumination which were considered too high then can be achieved economically. It was felt by the Sectional Committee that the values of illumination prescribed earlier are low in practice and need to be increased. Hence this revision has been undertaken.

In this revision apart from traffic routes, the lighting of residential streets, bridges and flyovers, town and city centers, etc, are being dealt with. The code lays down the principles governing the lighting of public thoroughfares and makes recommendations on the quantity and quality of lighting to be provided. The details of design entirely depend on local circumstances.

This standard is divided into Parts I and II. Part 1 includes the new classification and a statement of general principles for non-specialist users; Part II gives recommendations for the lighting of traffic routes (Groups Al, A2 and B).

Basis of Lighting Requirements:

The level and type of lighting adopted for a road or street is based primarily on its traffic importance, both vehicular as well as pedestrian. However, the system of lighting to be provided should take into account all the relevant factors, such as the presence of factories, or places of public resort, the character of the street (whether a shopping area or a ring road in non-built-up area, aesthetic considerations, the properties of the carriageway surface, the existence of humps, bends or long straight stretches and overhanging trees.

12. Road Lighting Design Objectives

12.1 Visibility and Visual Comfort

Light level, uniformity, distribution, contrast, visual size, and glare are factors that impact the visibility of the observer, be it a pedestrian or motorist. In terms of light level, uniformity, and distribution, the visual ramifications of traversing from a bright area to a dark area can momentarily suspend visual capabilities of the observer. Thus, it is imperative for road lighting to provide luminance and uniformity levels which are commensurate and adequate for the application and provide sufficient visual adaptation when moving between brighter and darker areas. In terms of contrast, the relative luminance between adjacent objects and the background against which the said objects are viewed needs to be appropriate for the application. Furthermore, glare from light sources or reflected off surfaces can be particularly disconcerting and diminish visibility. Uniformity of the level of surface illuminance greatly reduces the amount of glare reflected off objects, while shielded luminaires placed carefully can substantially minimize direct glare from lamps, as well as glare reflected off wet pavement on the road surface.

12.2 Visual Efficacy

Luminous efficacy, a metric of photopic lumens per watt, is perhaps the most common indicator of the cost-benefit ratio of a certain lighting installation. However, a more precise metric for outdoor lighting applications including road lighting is a photometry system that considers how the human eye sees under typical nighttime, or mesopic, lighting applications.

The human visual system primarily operates with two types of photoreceptors, rods cells and cone cells. Cones come into play predominantly under daytime (“photopic”) light levels found outdoors during the day and in almost all indoor applications illuminated by artificial electric lighting. Under stellar light or moon light (“scotopic” light levels), only rod cells provide visual information. However, many nighttime applications, such as outdoor lighting of parking lots, provide light levels in the “mesopic” range, where both rods and cones work synergistically to enable the perception of vision. Rods and cones are tuned to different parts of the electromagnetic spectrum and generate varying spectral sensitivities to light, based on the level of lighting available.

12.3 Security

Appropriate and adequate road lighting greatly aids and augments the timely detection and identification of people, animals, and objects. People tend to feel safe and secure when they are able to peer into the distance and identify routes and pathways for evasion from potential unscrupulous people, if, required. If adequate visibility is provided by the installed road lighting, people are much more likely to enter a particular location, encouraging others to do the same, which can be a deterrent to crime.

Ensuring the security and protection of property, such as vehicles parked in designated parking spots or permanent and semi-permanent structures along the roadside, is a vital objective of road lighting. The usually adopted technique is to adequately illuminate the whole area to be secured, providing at least double the illuminance of the surrounding areas. This enables people in the area to be easily seen. Another strategy is to keep the area to secured relatively dark, while brightly illuminating the entrances, aiming luminaires outward. However, this method may sometimes generate unwarranted glare. It's imperative to note that these methods need to be evaluated on a case-by-case basis and weighed against the counter balance of possible light trespass or light pollution. Although the jury is still out on whether lighting conclusively enhances security, adequate levels of road lighting does appear to unambiguously heighten the personal perceptions of safety and security.

12.4 Esthetics and Economic Progress

Esthetic considerations often play a significant role in the design of proper road lighting installations, especially in important downtown suburbs, shopping districts as well as areas with significant historic and heritage significance. A structurally efficient and esthetically appealing lighting installation can draw significant numbers of shoppers and patrons to places such as outdoor shopping centers, flea markets, as well as on roads adjoining museums, plazas, piazzas, concert auditoria and parks, fostering the economic progress and viability of cities and communities. Such lighting may be theme based and must necessarily embellish and accentuate the appearance of the area and act as a prop to the functionality of the area. Higher illuminances need to be used to emphasize and underscore the presence of paths, signs, building facades and landscape features. Some of the vital design consideration are the color and color rendering capability (CRI) of the light source to be used, the appearance of luminaires and ensuring that the luminaires blend in and lend an esthetic appeal to the surroundings as well as minimizing glare and stray light pollution.

13. Light Sources& Luminaires used in Road Lighting

13.1 Contemporary Road Lighting Sources

There are numerous light sources used for road-way lighting. However, there are only a few practical choices when considering availability, size, power requirements and cost effectiveness. We shall now briefly acquaint ourselves with the lamps and light sources commonly used in road lighting as enumerated in the following table:

Lamp Type	Nominal efficacy (lm/W)	Lifetime (hours)	Color Temperature (Kelvin)	Color Rendering Index
Incandescent lamp	4–17	2–20,000	2,400–3,400	100
Halogen lamp	16–23	3,000–6,000	3,200	100
Fluorescent lamp	52–100	8,000–20,000	2,700–5,000*	15–85
Metal Halide lamp	50–115	6,000–20,000	3,000–4,500	65–93
High Pressure Sodium (SON)	55–140	10,000–40,000	1,800–2,200*	0–70
Low Pressure Sodium (SOX)	100–200	18,000–20,000	1,800*	0
LED	10–110	50,000–100,000	2,700 - 6,000*	70–85

13.2 Vital Aspects of Road Lighting Luminaires

The luminaires used in Road lighting bear an almost equally crucial role in ensuring the efficacy of the lighting installation as well as eliminating unwarranted light pollution as the lamps and light sources themselves. Following are some of the important aspects and parameters relating to road lighting luminaires:

Throw:- The Throw of a luminaire signifies the extent to which the light from the luminaire thrown in lengthwise direction of road. The throw is defined by the angle γ which the beam axis makes with the downward vertical. The beam axis is defined by the direction midway between the two directions of 90% I_{max} in the vertical plane of maximum intensity.

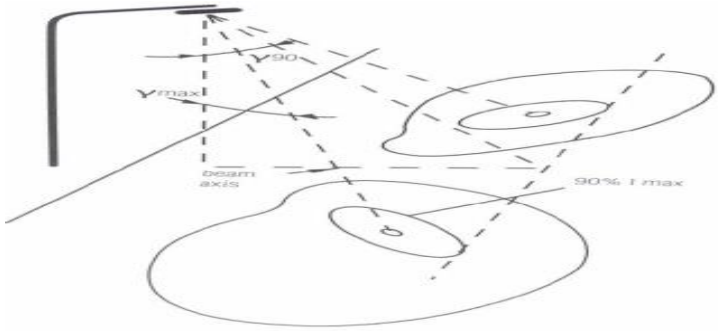


Fig. 7: Depiction of Luminaire Throw

Spread:-The Spread of a luminaire implies the extent to which light emanating from the light source housed within the luminaire is spread out across the surface of the road. The Spread is determined by the position of the line running parallel to the road axis that just touches the far side of the 90% I_{max} contour on the road surface.

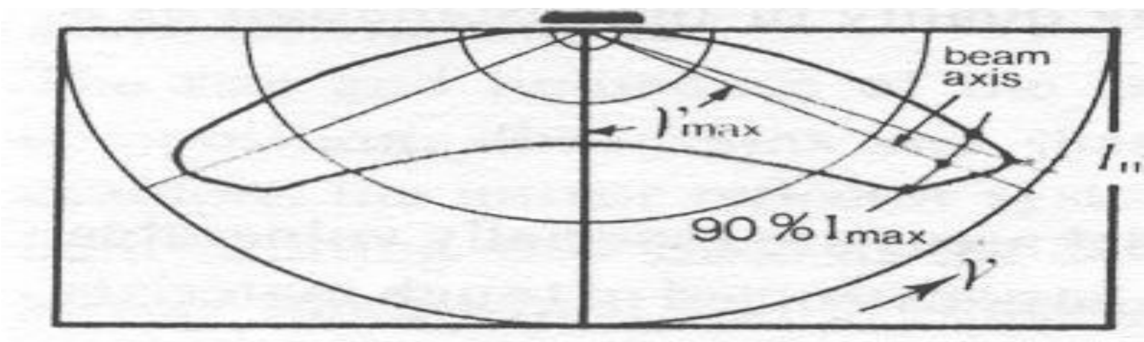


Fig. 8: Depiction of Luminaire Spread

Control:- The Control of a luminaire implies the ability and extent of the luminaire in controlling and regulating unwarranted glare, which can cause visual distraction to motorists, pedestrians and other road users. The degree of Control afforded is determined by the luminaire characteristics that also determine its glare control mark G. Control is defined by the Specific Luminaire Index or SLI.

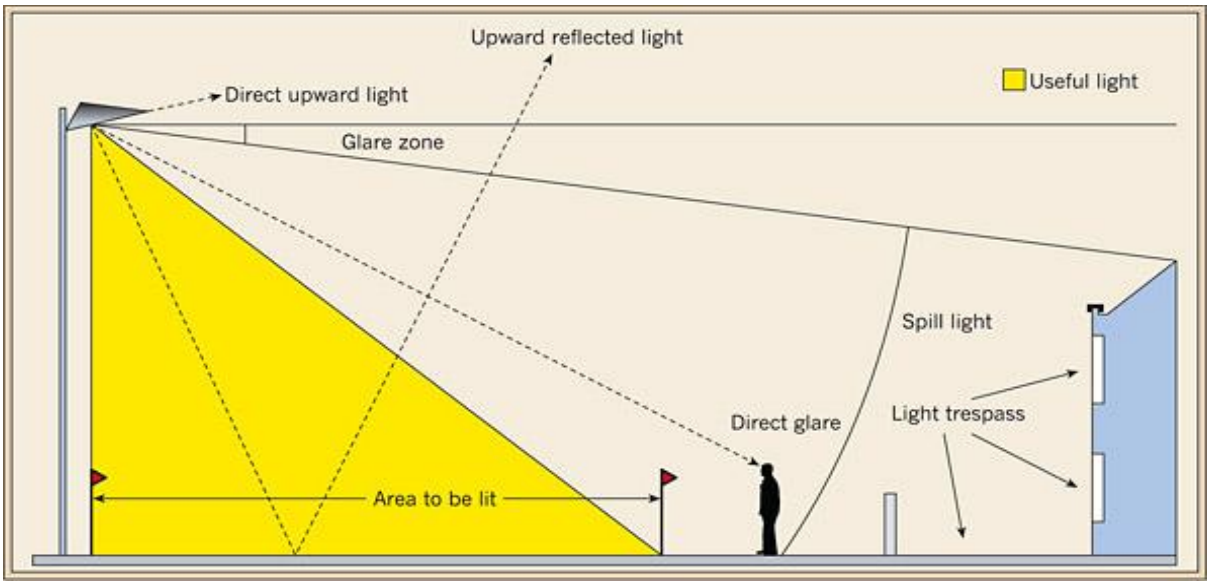


Fig. 9: Depiction of Luminaire Glare and Control Aspects thereof

There are multitude types and categories of road lighting luminaires with varying specifications. The basic shapes of luminaires and their corresponding classifications are usually defined in terms of vertical and lateral distribution of light as well as the control of the said distribution above maximum candlepower. This is termed as the cutoff. Vertical and lateral light distributions apply primarily to the shape of the area to be illuminated. Both of these distributions can be important when determining the amount of light trespass from a source. A non-cutoff fixture allows the light to be distributed easily so that the light is aimed less precise while a cutoff fixture allows for better aiming and therefore better and more precise glare control.

Cut-off luminaire: A luminaire whose light distribution is characterized by a rapid reduction of luminous intensity in the region between about 80° and the horizontal. For Cut off luminaires, the intensity at the horizontal should not exceed 10 cd per 1000 lm of flux from the corresponding lamps and the intensity at 80° is of the order of 30 cd per 1000 lm. The direction of the maximum intensity may vary but should be below 65°. In such luminaires, the candlepower per 1000 lamp lumens does not numerically exceed 25(2.5%) at an angle of 90°above the nadir (i.e. horizontally), and 100(10%) at a vertical angle 80° above the nadir point. The prime advantage of Cut Off luminaires is the significant reduction in Glare. They are mainly used in matte carriageway surfaces, areas which mostly lack buildings or have presence of large trees, long straight sections, bridges &relatively less number of roadside obstructions.

Semi-cut off luminaire: A luminaire whose light distribution is characterized by a less severe reduction in the intensity in the region 80°to 90°. The intensity at the horizontal- should not exceed 50 cd per 1000 lm of flux from the light sources* and the intensity at 80° is of the order of 100 cd per 1000 lm. The direction of the maximum intensity may vary, but, should be below 75°. When the candlepower per 1000 lamp lumens does not numerically exceed 50(5%) at an angle of 90°above the nadir point (i.e. horizontally), and 200 (20%) at a vertical angle 80° above the nadir point. The major advantage of Semi Cut off luminaires is the fact that they allow for greater flexibility in the siting of luminaires in the installation. Their primary usages include operation on smooth carriageway surfaces, areas with presence of heritage buildings and constructions of architectural and cultural value along the roadways and other similar

Non-cut off: A luminaire whose luminous intensity in directions making an angle equal to or greater than 80° from the downward vertical is not reduced materially and the intensity of which at the horizontal may exceed the values specified for the semi-cut-off distribution ,but, should not nevertheless exceed 100 cd. Non-cut-off luminaires are permissible only when a certain amount of glare may be accepted and when the luminaires are of large size and of reduced brightness. Under certain circumstances, they also increase the illumination on facades.

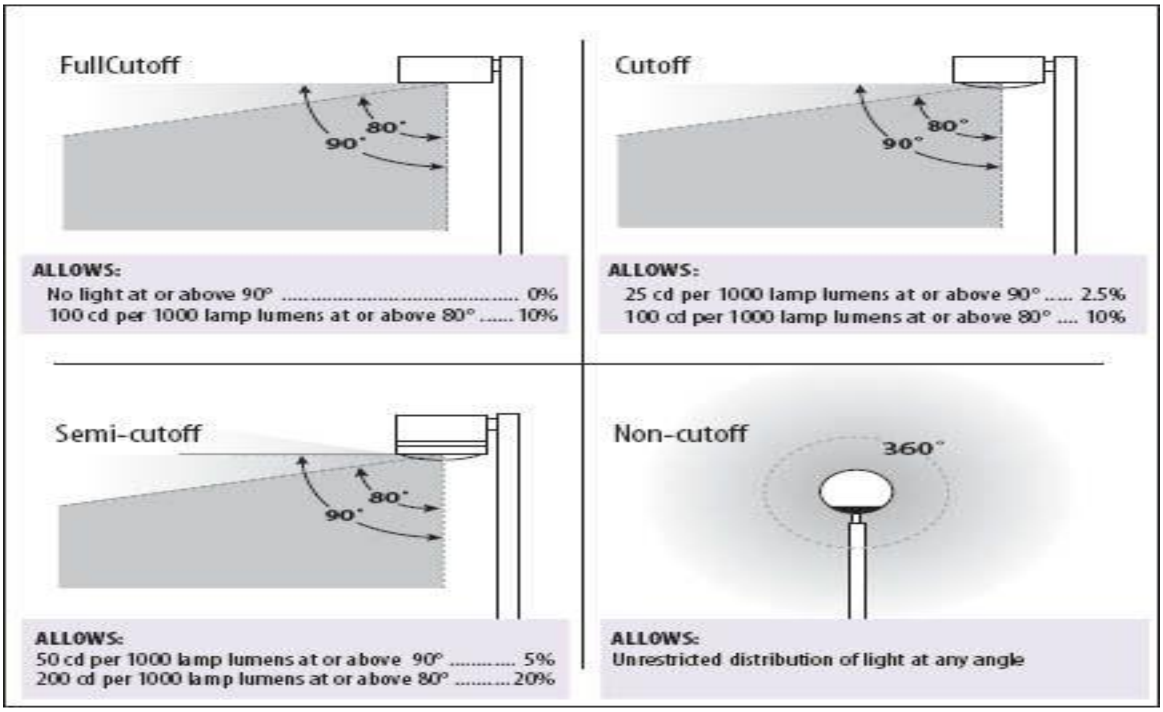


Fig.10: Depiction of Luminaire Glare and Control Aspects thereof

CHAPTER - III

SYNOPTIC SURVEY OF EXTANT WORK

REVIEW OF EARLIER WORK

Prior to embarking on this full-fledged study, significant groundwork had been conducted to analyze and assimilate the results of research work that had already been carried out to establish the correlation between road lighting and promotion of safety of road users and mitigation of road mishaps. The present segment shall endeavor to provide us with a comprehensive comprehension of the research work and studies already undertaken in the field of Road Lighting. The major aim of this section is to gain vital insights into the contemporary perspective of research work and corpus of knowledge currently available on Road Lighting vis a vis it's myriad facets, especially from the aspects of promotion of safety and heightening of security. By studying and analyzing contemporary research work conducted by some of the pioneering researchers in Road Lighting, we shall be up to speed with the latest developments in Road Lighting and be at an optimal vantage point, which shall form the underpinnings of our study. Some of the extant work surveyed for this study have been enumerated below:

[1] CASE STUDY # 1

Paper: " Improved Street Lighting and Crime Prevention"

David P. Farrington, Brandon C. Welsh ,Justice Quarterly journal, Volume 19, Issue 2, pp 313- 342, June, 2002

Objective of the Paper: -

Assessing the correlation between road lighting and incidences of crime in urban and suburban areas.

Methodology adopted : -

The study evaluates the observations and information obtained in multiple Evaluation Studies in the United States and the United Kingdom in order to establish whether any correspondence exists between road lighting and reduction in criminal activity during after dark hours.

Outcome of the paper: -The study found variability in the impacts of Street Lighting in reducing crimes in different areas and communities. An overbearing theme which supported the study hypotheses was that increased community pride, augmented by improved Street

Lighting led to a reduction in crime rates in most of the communities evaluated in the study. On the contrary, it's also feasible that increased Street Lighting may augment the crime potential in certain areas as higher levels of illumination may draw greater number of potential victims and offenders together in the same area.

Avenue for further Studies –

Future studies may undertake the surveys of people with prior history of offenses in experimental and control areas in order to investigate their opinions of the area, their street-usage patterns, and factors that might inhibit them from offending (e.g., informal social control by older residents, increased surveillance after dark). Household surveys need to be conducted also, focusing on the perceptions of improvements in the community, community pride, informal social control of young people, street use, and surveillance after dark.

[2] CASE STUDY #2

Paper: " Road Lighting and pedestrian reassurance after dark: A review"

S. Fotios, J. Unwin, S. Farrall ,Lighting Research & Technology journal, Volume 47, Issue 4, pp 449- 469, April, 2015

Objective of the paper:– Evaluation of road lighting in residential areas.

Methodology adopted : – The study defines residential areas as areas of villages, towns and cities, suitable for, or occupied by dwellings. In said residential areas, lighting is designed primarily, but, not exclusively for the benefit of the need of pedestrians vis-a-vis those of drivers. The study analyzes the level of *Reassurance* being provided by the Street Lighting scheme to the pedestrians and road users. In the context of this study, the term *Reassurance* is used as a descriptor for the level of confidence that a pedestrian may find to walk the along a road from the Street Lighting, especially if walking the road alone.

Outcome of the paper: – The prime aim of this pioneering work by Fotios et al was to determine whether Road Lighting and in particular Road Lighting in residential areas enhances the sense and perception of *Reassurance* of pedestrians, their level of confidence when walking alone on the concerned roads during the hours of darkness. The other major goal was to determine how the characteristics of road lighting might be used to enhance pedestrian's *Reassurance* when walking after dark. The study soundly established the fact that higher levels of illuminance led to enhanced perceptions of *Reassurance*.

Avenue for the further Studies:– Future and further research should be aimed at validating the level of optimum illuminance, the ideal parameter for characterizing lamp Spectral Power Distribution, and the most desirable characteristics of Spatial Distribution. Subsequent studies should also factor the effect of lighting on Reassurance, considering the physical features, in particular the analysis of the fact that places with significant sense of entrapment (enclosed locations or cul-de-sacs) might not greatly benefit from a change of lighting. Also, the type and mode of pedestrian walk needs to be considered - whether it's a brisk walk or a more leisurely stroll.

[3] CASE STUDY #3

Paper: "Quantifying the impact of road lighting on road safety - A New Zealand Study"

Michael Jackett, William Frith , International Association of Traffic and Safety Sciences Research journal, Volume 36, Issue 2, pp 139- 145, March, 2013

Objective of the paper:– The study seeks to enhance comprehension about how the quantity and quality of road lighting influence the frequency of night time crashes vis-a-vis daytime crashes in New Zealand.

Methodology adopted : – The study followed a "**Relation Methodology**" approach. Values for the standard CIE light technical parameters were measured under existing lighting conditions in situ and the obtained results were matched with the five year crash history for the same section of road. Regression methods were then used to establish the most important predictor variables of the night to day crash ratio.

Outcome of the paper: – This study is one of the pioneering analyses conducted on road lighting Down Under (Australia and New Zealand). It is counted as a landmark study for establishing the following:

- Developing a field method for examining the effect of road lighting on urban night time crashes.
- Establishing a dose-response relationship between Road Luminance and night-time crashes. Average Road Luminance was determined to be the key dose-response variable in night time crashes and accidents.

Avenue for further Studies:– Subsequent and future studies should aim to improve knowledge of the safety benefits of intersection lighting, lighting rural roads and state highways. Future studies should also aid in the establishment of “new technology” guidelines, benefiting from the results and database developed for the present study. Such future guidelines would aid decision making on the judicious applications of lighting levels using adaptive LED technology and other associated technologies as also the benefits of using broad spectrum lighting in promoting roadway safety.

[4] CASE STUDY #4

Paper: "Road lighting and energy saving"

PR Boyce, S. Fotios, M. Richards , Lighting Research & Technology journal, Volume 41, Issue 3, pp 245- 260, September, 2009

Objective of the paper:– The study aims to analyze the different energy saving aspects of road lighting design.

Methodology adopted: – The study examines the efficacy and energy saving potential of various light sources used for road lighting which initiated with the humble gas lamp has over the decades proceeded through incandescent, fluorescent, mercury vapor, Low Pressure Sodium (LPS), High Pressure Sodium (HPS) and Metal Halide (MH/CDM) electric light sources with LEDs being the emergent light source of choice in a more or less chronological fashion.

Outcome of the paper:– The essence of the probable ways of effecting energy savings is to reduce the hours of usage of existing road lighting. Probably, the simplest possibility is to adjust the switching levels of existing photocell control units. Greater energy savings can be made by switching road lighting off permanently, either after a set time as traffic and pedestrian densities fall or at all times. Also, new light sources and remote monitoring systems that allow the lighting to be dimmed as and when needed are emerging. These upcoming technologies need financial subsidies for the installation of new or replacement road lighting installations.

Avenue for further Studies:– Future studies may focus on improving the sustainability of some of the proposed changes in the present study. Also, as newer, cheaper and renewable energy and lighting sources are being harnessed, the effects and implications of the same on road lighting in a conventional sense may be examined and the potentials studied and implemented.

[5] CASE STUDY #5

Paper: " The effect of reduced street lighting on road casualties and crime in England and Wales: controlled interrupted time series analysis"

Rebecca Steinbach et al , Journal of Epidemiology & Community Health, Volume 8, Issue 5, pp 1118- 1124, May, 2015

Objective of the paper:– The study attempts to assess whether reductions in road lighting at night cause an increase road traffic injury, crime and fear of crime.

Methodology adopted : – For the purposes of the study, the researchers had direct contact with 125 (72%) of the 174 local authorities in England and Wales, resulting in data submissions from 71 local authorities of which 62 provided usable data. The participating local authorities were evenly distributed according to population density (persons per hectare), covered the range of deprivation levels as measured by the Index of Multiple Deprivation 2010, and covered each of the six urban–rural classifications of areas. The project was called the LANTERNS (Local Authority collaborators' National Evaluation of Reduced Night-time Streetlight) project and ranks as a landmark study on the subject.

Outcome of the paper: – The results of the study did not find irrefutable evidence that switch off, part-night lighting, dimming, or white light adaptations to street lighting significantly impacted night-time traffic collisions. The results also provided no evidence that these lighting strategies are associated with an increase in crime at an area level. However, it's to be borne in mind that the study had several limitations which possibly skewed the results. The results tended to suggest that in the aggregate, dimming and white light regimes were associated with reductions in crime, though estimates were imprecise.

Avenue for further Studies :– While the study failed to find conclusive correlation between reduced nighttime roadside visibility and increase in crimes and mishaps, it's pertinent to note that the study had certain limitations like Selection bias, whereby the study was able to obtain street lighting data from only 62 of 174 local authorities. The study also suffered from Information bias: the study used routine data sources on road traffic collisions and crime. These data sets have several limitations; in particular, they may be incomplete due to under-reporting of incidents. Thus, subsequent and follow up studies should be conducted addressing the above shortcomings and their scope should be extensive to conclusively establish the correlation between road lighting and road mishaps and crimes.

Contemporary research into Road Lighting and its impact on accident prevention and safety promotion have provided us with an overview of the wide gamut of roles, applications, aspects, light sources, techniques and methodologies of Road Lighting. From the survey of prior work and existing literature, it may be surmised that Road Lighting plays a crucial role in accident prevention and crime reduction.

The present study shall take into cognizance the findings and information contained in the existing literature and attempt not only to advance and augment the current body of research, but, to answer many unanswered queries raised by the current literature as well as conclusively establish the predominant role of road lighting in mitigating road mishaps, while also assimilating and incorporating the treasure trove of insights and information which has been revealed by contemporaneous research into road lighting.

CHAPTER - IV

COLLECTION AND ANALYSIS OF DATA

METHODOLOGY ADOPTED

The study was conducted on location at various sites in the states of Gujarat, India and West Bengal, India over a substantial period of time. The prime focus in conducting the study was at all times to obtain the best possible and most accurate measurements. Ergo, utmost care and caution were exercised while conducting the study and the corresponding field work so as to be concordant with all the relevant photometric standards and guidelines and pertinent metrics.

As outlined at the outset of this disquisition, the prime objective of embarking on this study was to identify, elucidate and in certain instances also to validate and corroborate some of the postulates and findings of earlier works in terms of the effects, efficacy and impact of Road Lighting vis a vis accident prevention and fostering of a safer road environment for all users in as unambiguous a fashion as feasible. Thus, in keeping in tune with the said objectives of this treatise, requisite steps were adopted and employed to ensure that the data collection met and adhered to all the relevant protocols.

The principal ground and field work of this study hinged around analyzing road accidents and casualties data over a substantial period of years. Road accidents data sets were obtained from various Govt. depts., police authorities and predominantly from internal insurance claim archives at my place of work at the National Insurance Company Ltd. The collated data sets provide a true treasure trove of rich, detailed and sequentially cataloged information about road accidents and their multitude facets and enables vital and in-depth analysis to be conducted into the various aspects of road accidents and their essential correlation with the presence (or absence), type, nature, efficacy and impact of road lighting as both a mitigating factor and in many cases also as a contributing cause in road mishaps.

The fieldwork phase of this study involved observing and measuring on location of relevant photometric parameters like the illuminance level (lux level) as well as physical characteristics of the Road lighting installation like the mounting height of poles, spacing and placement as well as the presence of Glare or Dark patch corresponding to the collected and tabulated road accidents data obtained from the aforesaid sources.

Relevant instruments were used for collecting and measuring the illuminance level of the working plane of the road surface where the road mishap had occurred as per the accidents data and also the corresponding physical characteristics of the lighting installation. To be specific, the following instruments and accessories were used in collecting the relevant data, which laid the cornerstone for this dissertation:

1. Metravi Lux Meter

2. Fluke Laser distance meter

3. Measuring tape

4. Marker

The above instruments were carried with utmost protection in padded backpacks during field trips to the specific locations, corresponding to the road mishap locations indicated by the collected road accidents data. The measuring tape, Fluke laser distance meter and marker were indispensable in measuring the various vital parameters like the spacing between successive luminaire poles, road width, mounting height among others. The Metravi Lux meter was used to measure the point specific illuminance on the working plane of the road surface nearest to the pole hosting the luminaire. The illuminance level on the road surface corresponding to the pole mounted luminaire was measured by the following procedure:

1. The luminaire and light post closest to the accident spot was identified.

2. The working plane on the road surface corresponding to the relevant luminaire mounted on the light post was noted.

3.The area of the working plane on the road surface was segregated into grids of suitable dimensions, as practicable.

4. The illuminance value (lux level) at each grid point was measured. Extreme caution was exercised to prevent any hindrance or obstruction to the sensor of the Metravi Lux meter, so as not to impede the accuracy of the measurement in any way.

COLLECTION & TABULATION OF DATA

The field work phase of this project was carried out in sync and in correspondence with the road accidents data, which had been collected and procured from various sources and public authorities, as described in the preceding sections. The fieldwork phase of the study entailed physically visiting the areas and locales identified and indicated by the road accidents data with the prime endeavor of obtaining a more in-depth and informed idea about the lighting conditions, light level (lux level) as well as the physical characteristics of the road area and the photometric traits of the lighting installation which precipitated in and may have caused or contributed to the transpiring of the accident or mishap.

The systematically collected, organized, sequenced and tabulated data is presented herein in its entirety. Owing to the sheer volume of the tabulated data, it has been presented in an annex format post the References section of this opus and may easily be accessed in its original and unabridged form for suitable perusal and ready reference.

The predominant theme of this treatise has been to elucidate and also in many ways unambiguously and irrefutably establish the preeminent role played by road lighting in the avoidance of accidents, mishaps and catastrophes and also in the promotion and elevation of road safety and security from the perspectives of not only the passage of vehicular traffic and the physical challenges posed by cars and motor vehicles to pedestrians and other roads users, but, also from the aspect of crime prevention and providing adequate safety and visibility, in particular for more vulnerable demographic segments like women and children, the elderly and the infirm. It is pertinent to observe here that the terms safety and security vis a vis pedestrians and various other road users have a poly dimensional aspect to them. Safety and security may, in a very corporeal sense, refer to the physical infrastructure and installation of the road lighting system, which promotes the objectives of improved road efficiency in eliminating road mishaps as well as fostering the welfare and protection of road users. On the other hand, the terms safety and security, observed from a psychological and psychoanalytical vantage point, tend to articulate the elevated perception of feeling protected and the sense of wellbeing, from the perspective of pedestrians, passengers and other road users, which is espoused by the presence of the road lighting system.

The collection of the road lighting data was done with the specific aims and objectives of the study in mind. In keeping in tune with the said themes and objectives, the fieldwork phase of our study set out to quantify the relevant parameters that determine the nature, quality, efficacy and effectiveness of the road lighting installation to serve it's intended purposes of illuminating the roads and streets during periods of darkness and in areas of low or poor visibility. The data collection attempted to perspicuously illustrate and establish the vital parameters which aid to define the efficacy, impact and overall purposefulness of the road lighting installation. Accordingly, the data collection was conducted in such fashion as to accommodate the relevant parameters, which would provide us with a very clear perspective of the local conditions that prevailed at the roadside from a photometric standpoint , that significantly contributed to the transpiring of the road accident.

The finalized overall form of the data synergizes the multiple individual segmental sets of data pertaining to the road accidents as obtained under authorization from the various Govt. agencies and departments along with the corresponding data from the fieldwork phase of the study which correlates the prevalent localized lighting conditions, alignment, geometry of the lighting installation and also the physical layout of the road, street, highway, carriageway or thoroughfare where the particular accident or mishap transpired.

The data pertaining to the road accident statistics was obtained for a period of several years from the period 2005 through to the end of 2018, representing more than a decade's worth of traffic and road accidents in various locations across India. The decadal span and sampling of the road accidents data affords us the perfect opportunity to study in-depth the various factors at play which cause and contribute directly or indirectly, either explicitly or implicitly to the occurrence of the road accidents and also to understand and analyze trends and patterns which may emerge upon slicing and dicing the data. The emergence of such trends and patterns would open up new and broad vistas in our comprehension of the causes and factors leading to road accidents from the perspective of the lighting designer and also enable us to better predict the possibilities of road disasters under specific circumstances and also to devise methods to avert and mitigate the same. We must at all times be reminded of the prime aim of road lighting, which is to save lives and also to secure the environs of the roads and highways.

The sheer volume of the decadal data sets pertaining to the road accidents also enables us in many instances to corroborate and validate prior assumptions and surmises, which had often been encountered at many junctures while surveying the existing literature on road lighting and its efficacy in averting accidents and promoting roadway safety and security. The voluminous data sets and the large sample space of the collated and tabulated accidents data and the trends, analyses, conclusions and inferences drawn there upon can serve as a bedrock, which may prove or dismantle prior hunches or inconclusive findings. In the same breath, they may also incontrovertibly validate and vindicate certain observations and conjectures, which may hitherto have seemed to be at the edge of reason for lack of ample data supporting it or otherwise.

The fieldwork phase of the study, undertaken in direct correlation and correspondence with the garnered road accidents data sought to identify, understand and evaluate the precise conditions and factors that were present at the time of occurrence of the road mishap or vehicular crash, primarily from a photometric perspective which possibly precipitated in the crash. Accordingly, the locations, as indicated by the garnered road crash datasets were identified and the necessary field visits conducted to study and survey the on-ground photometric aspects and conditions of the road or highway area where the crash had taken place. The fieldwork phase of the study, thus, in many ways took on an almost forensic investigative approach - visiting the crash site to analyze, identify and scientifically deduce the contributory causes of the road crash or mishap and in a very realistic sense reconstructing the accident scenario with the aid of the information gathered at the location.

The data collected during the field study focused primarily on the vital physical parameters of the lighting installation which provided essential information about the lighting geometry like type of the road, as per the classification defined by the Indian Standard (IS) 1944, availability or lack of high mast or pole lighting over the concerned road surface area, height of the pole if available, the arrangement of the pole mounted luminaires whether in an axial, opposite, single side or staggered pattern, the width of the pole, the spacing or distance of separation between consecutive poles in the lighting installation and the nature and type of light source or lamp used to illuminate the span of the road or in many cases the entire stretch of the particular road. The field study also accumulated data pertaining to the pivotal photometric parameters like the level of illuminance or the Lux Level over the Working Plane of the road surface corresponding to the spot or area where the crash occurred as implied by the road accidents datasets as well as the presence of any impeding Glare which may have contributed to the accident by obstructing vision of the concerned driver or drivers or pedestrian or other road user involved in the crash. The study also evaluated the presence or absence of any Dark patches at the crash site, which are essentially " blind spots" of very little or practically no illumination.

The presence of potential Dark patches on the span of the road where the accident transpired would have been a significant contributing factor or one of the prime causes in the occurrence of the crash, as it would have rendered the visibility of any potential objects or obstacles on the road surface like any oncoming traffic or vehicles or pedestrians moving along the road surface or trying to cross the road or the presence of other objects, which would be hazardous to the movement of the vehicle to be very low or poor. The fieldwork phase of our study thus sought to ascertain the presence or absence of the above elements at the crash site, and the extent to which the aforesaid factors may have influenced and contributed to the occurrence of the said crash under the precise and unique set of local lighting conditions prevalent at the time of happening of the road accident or crash.

The fieldwork and data collection phase of our dissertation, thus, generated two distinct categories of data sets - **1.** The raw data sets containing rich, in-depth and highly granular information about the road crash statistics from various locations across India, which may be further segregated and granularized according to state, territory, city, township or locality and **2.** the relevant photometric data and vital information about the nature of the road alignment and the layout, geometry and specific traits of the lighting installation, the type and characteristics of the light sources used as well as other germane physical characteristics.

The tabulation of the categories of data as described in the preceding segments was done in Microsoft Excel, a renowned spreadsheet software which is a part of the MS (Microsoft) Office suite of software, developed by the global software behemoth Microsoft Inc. of Redmond, Washington, USA. The consolidated form of the tabulated data, as has been appended herein at the annex of this oeuvre was a commingling and melding of data from the two distinct data sets as described earlier - the data pertaining to the road crash statistics collected over a span of a decade and culled from various sources and authorities and the adjoining columns of the table representing the corresponding data pertaining to the lighting installation and the road alignment and physical and photometric characteristics.

The road crash data which was garnered from the various aforesaid public authorities and Govt. departments and concerns were tabulated according to the following fields - the date of occurrence, including the month and year of the crash, the time of day when the accident occurred (for the purposes of this study only the accidents which occurred during the periods of low or no natural lighting, particularly during the hours of darkness were considered so as to study and analyze the impact of the road lighting installation on the accident), the state where the accident occurred, the city/town/area where the crash transpired, the type and nature of the collision - whether it was a Head On collision, a collision from the Back/Rear or a Side Hit type of collision. The age of the driver of the colliding vehicle (s) or the vehicle involved in the crash was also enlisted in the tabulated data so as to study the demographic aspect of the crash data and what impact the age of the driver and by corollary of other road users have in the perceived level and nature of the road lighting and also the impact and correlation that various types of lamps and road lighting sources may have with the age of the driver, observer or road user.

The collected and tabulated data lends itself amenable to rigorous in-depth and segmental analysis of the various facets and aspects of road lighting, from photometric as well as physical perspectives and provides us with a rich palette of information about the quintessential role played by road lighting in the realm of accident prevention and disaster mitigation not only for vehicular traffic, but, also for pedestrians and road users of all types, especially during the hours of darkness or under low or almost no natural lighting and the espousal of safety and security for different road users and also as a deterrent to crime being perpetrated on the road and environs of the roadside.

Thus, in its final form, the collected, tabulated , combined, sequenced and streamlined data from the raw data sets pertaining to the road crash statistics as well as our own fact-finding field research on location which yielded copious amounts of detailed information and measurements pertaining to the prevalent lighting conditions and road conditions at the crash sites provide us with the perfect foundation for comprehensive evaluation, audit and interpretation of the intricate interplay and interconnected relationships of the various dynamic factors and plethora of parameters in the ecosystem of roads and highways, road lighting installation, transit and passage of vehicular traffic and most importantly the observer and road user who may be the driver of the vehicle (s), pedestrians, passersby, traffic security personnel or any other person who has a direct need or usage based relation to the roadside and it's neighboring environs.

ANALYSIS AND INTERPRETATION OF DATA

The bedrock and cornerstone of any field research and scientific disquisition is data and pertinent information, relevant to the major theme and subject matter being discoursed upon, which enables us to study and comprehend the subject matter at great depth, to unravel new insights and elucidate hitherto obscure and unsubstantiated ones, to validate or quash prior hypotheses and conjectures. The collected, compiled, tabulated, synthesized, systematized and sequenced data provides us with a vast array of knowledge and substantial repertoire of information about not only the current scenario of roads and road accidents, traffic and pedestrian safety in India and the world over, but, also learn about and explore in detail the latest cutting edge technologies, techniques and methodologies which are in vogue and being employed to mitigate the hazards of road mishaps and casualties and improve the quality, usability, utility, efficiency and safety of roadways, streets, thoroughfares, carriageways and highways across different domiciles.

Before delving deep into the analysis, survey and evaluation of the collected and tabulated data, it would be prudent to be reminded of the fact that roads and the transport network form the lifeblood of any economy and society at large, carrying not only goods and objects, but, precious human lives. Thus, it is imperative that the streets, roads and highways and by corollary road lighting which illuminates them be designed and maintained appropriately to promote, aid and foster the safety and security of all road users, be it the drivers and passengers of a luxury Sports Utility Vehicle (SUV) or sedan, the driver and helpers of a goods carrying commercial vehicle like a truck or a large road train or pedestrians traversing the road, traffic security personnel or even casual passersby. The aspects of physical safety and of security, which can be both in the physical sense as well as perceived, are ones which should be consistently and uniformly maintained at all times and all hours of the day as the passage of people and commodities over the road is a continuous event, under usual circumstances, barring certain special happenstances like road blockages, strikes and civil commotions, passage of convoys, roads being cordoned off by the authorities etc.

Thus, road lighting which plays a crucial and absolutely indispensable part in not only promoting the vital aspects of safety and security, but, also in ensuring the smooth functioning of the roadways and highways themselves during the hours of darkness and low illumination and also in areas of poor or low visibility, must ensure that the level, orientation and distribution of the road lighting arrangement ensures the overall visual comfort of the driver and observer and also aids in the proper and **timely detection of any potential obstacles** or hazards on the road surface, as well as providing **visual guidance**. From the perspective of pedestrians and passersby who are traversing or crossing the road on foot, road lighting must also provide adequate visual comfort in seeing objects on the road and ensure timely detection and identification of potential hazards or obstacles like oncoming vehicular traffic or any stray object which might impede their movement and be potentially hazardous. In the context of timely detection of objects, it may be noted that the road lighting installation must allow for the **adequate reaction time** by the eyes and brain of the driver or pedestrian to get out of harm's way or take appropriate evasive action to avert a collision or crash with another person, vehicle or object.

So, for properly quantifying the parameter of **timely detection** of objects and obstacles, a **time buffer** for the **adequate reaction time** needs to be inherently considered in the lighting design that allows for the in-time detection and appropriate reaction to potential hazards and other stimuli that present themselves to the driver or pedestrian.

As has been discussed in some of the preceding segments of this discourse, the accumulated and tabulated data represents a true treasure trove of information about the road accident statistics and metrics over India over a substantially long span of time. The data which corresponds to over a decade's worth of collated reports of accidents and crashes occurring over different locales across India, was collected from the databases and archives of various Government departments, public authorities and primarily from the internal motor insurance claim records and archives at the National Insurance Company Ltd., which is also a Government agency.

The decadal span and capacious volume of the garnered data provides us with a bird's eye view over the current milieu of road networks and road and traffic safety and security from the perspective of road lighting. The nature of the data and the parameters and the corresponding fields according to which the data was gathered, arranged and systematized allows us great flexibility and freedom to slice and dice and perform in-depth analysis using various techniques to reveal subtle and intricate details and insights into the causes and contributing factors which led to the transpiring of the road crashes from a generic and road lighting standpoint and also to confirm or controvert prior assumptions, conjectures and hypotheses that had been surmised in the existing literature pertinent to the subject, but, were not able to be proven or discarded owing to the paucity of adequate data samples. The large sample size of the data accumulated over the course of this disquisition, thus, provides us with distinct advantages over many conventional studies, which had hinted at strong correlations between road lighting and it's impacts on many socio-cultural and technical aspects, but, had been unable to conclusively validate the same due to the relatively limited datasets and other relevant limitations.

The unabridged and unexpurgated full-scale tabulated data has been presented at the annex part of this dissertation owing to space constraints. Even a cursory glance at the full-scale datasets reveal the breadth and span of the comprehensive and copious amount of information contained therein. It will be our endeavor in this phase of the study to understand and assimilate the interplay of the various elements and factors in the microcosm of the road environment and determine, quantify and analyze the precise role played by road lighting and in many cases lack thereof in preventing or contributing to the road crashes that occurred over the substantial period of time for which the data was gathered.

Keeping in view the stated intents and objectives of this study as outlined in the relevant sections, the gathered data shall be analyzed and evaluated from multiple perspectives and angles in an attempt to establish precise correlations between the different factors that define the usability and efficacy of the road lighting installation in performing it's intended functions and objectives and also glean intricate details, patterns and trends which might emerge and aid us in better comprehending, predicting and ultimately preventing future accidents and crashes from transpiring.

The collected data has been segregated and arranged into several vital fields. The purpose of this classification was to enable us to streamline the road crash statistics and also the corresponding physical and photometric data pertaining to the roadway in the area or locality where the crash occurred, which would eventually aid in the analysis and evaluation of the data. Referring to the tabulated data which has been appended in the annex section of this dissertation, we find that the data has been arranged according to the following seventeen (17) fields:

1. Date of Occurrence
2. Time
3. State
4. City/ Place
5. Type of Collision
6. Age of the Driver
7. Type of Road
8. Position
9. Availability of High Mast Lighting
10. Height of the pole
11. Type of Lamp
12. Arrangement of the poles
13. Road Width
14. Distance of separation of consecutive poles
15. Illumination Level (lux)
16. Glare
17. Dark Patch

As is evident from the ongoing discussion, the aforesaid data fields have aided us immensely in capturing a wide array of detailed information about the most vital aspects and parameters of the concerned roads, areas and localities and the corresponding crash records and the nature, degree and level of road lighting which was available at the said location, if at all and thus providing us with a much broader comprehension about the wide gamut of contributing factors which may promote or prevent the prevalence of road crashes and mishaps.

Let us now acquaint ourselves with what each of the captured data fields signifies and represents, which would aid our cognition and eventual analysis and evaluation of the systematized data. For the sake of convenience and clarity, we shall discuss about the individual data fields in sequential order:

1. Date of Occurrence: This data field represents the calendar date when the road crash had occurred, as recorded in the official archives of the Govt. dept or public authority or agency from where the data had been collected. The calendar date of occurrence of road crashes bears special significance as various prior studies have hinted at seasonal impact and variations in road crash trends and frequency of occurrence.

2. Time: This data field signifies the precise time of the day when the road crash had occurred, as recorded in the official archives of the Govt. dept or public authority or agency from where the data had been collected. In accordance with the objectives of this dissertation, only crashes which occurred during the night or hours of darkness were considered, so as to segregate and study the impact of road lighting on the road crashes.

3. State: This data field signifies the state, province or territory of India where the accident or road crash had transpired. The data presented in this dissertation represents road crashes primarily in the states of Gujarat and West Bengal, India where physical measurements of photometric and road alignment data had been feasible.

4. City / Place: This data field signifies the city, town, district or locality within the concerned state where the road crash occurred. The data presented herein predominantly represent accidents and road crashes that had occurred in the Kutch district and Ahmedabad municipal areas of Gujarat as well as the metropolitan and suburban areas of Kolkata and the district of South 24 Parganas in West Bengal, where physical measurements of photometric and road alignment data had been feasible.

5. Type of Collision: This data field signifies the alignment and spatial orientation of the vehicle with respect to the other vehicle or vehicles or any other object or obstacle with which the vehicle had collided. The type of collision is a very significant parameter and elucidates whether the type of collision was:

i. Head On: implies a full frontal collision between two oncoming vehicles usually from the opposite or transverse direction.

ii. Back Hit: implies a type of collision where the concerned vehicle was hit from the rear by another vehicle or object.

iii. Side Hit: implies a type of collision where the concerned vehicle was hit from either of it's sides or laterally by another vehicle or object.

6. Age of the driver: This data field signifies the biological or chronological age of the driver involved in the crash, as per official records. The age of the driver of the vehicle is a very significant parameter which aids in vital demographic analysis of the road crash data and also in studying what impact the human ageing process has on the visual perception of different types of road lighting sources and also reaction time to potential obstacles on the road.

7. Type of Road: The type and category of the road on which the reported crash had occurred plays a very important part in understanding the nature and cause of the crash, as the requirements of road lighting often change depending upon the classification of the road, it's location and the density of traffic traversing it. For the purposes of this study, the road classification used was as per the recommendations given in the **Indian Standard IS: 1944 (Parts I & II)** guidelines. and may be briefly summed as follows:

i. Group A- For main roads. This is sub-divided into two categories:

a. Group A1 - For very important routes with rapid and dense traffic where the only considerations are the safety and speed of the traffic and the comfort of the drivers.

b. Group A2 - For other main roads with considerable mixed traffic like main city streets, arterial roads and thoroughfares.

ii. Group B-For secondary roads which do not require lighting up to Group A standard. This is also divided into two categories:

a. Group B1-For secondary roads with considerable traffic, such as principal local traffic routes, shopping streets, etc.

b. Group B2 -For secondary roads with light traffic.

iii. Group C- Lighting. for residential and unclassified roads not included -n the previous groups.

iv. Group D - Lighting for bridges and flyovers.

v. Group E - Lighting for town and city centers.

vi. Group F- Lighting for roads with special requirements, such as roads near airfields, railways and docks.

8. Position: This data field signifies the physical alignment and spatial location or part of the road where the crash occurred. The precise location of the crash could be at any of the following positions on the road surface:

i. Junction: It implies a major crossroads or an intersection area of multiple roads. Junctions are usually areas of very heavy traffic density and accordingly the lighting requirements for junctions are also meant to be more rigorous.

ii. Turning: A turning implies areas of minor indents or gaps on a continuous stretch of road surface where it is permissible as per local traffic rules for vehicles to cross over to the other side of the road in case of dual carriageways or onto another road or street in case of other roads. Proper road lighting and traffic signals or signs should be imperatively present at turnings to prevent mishaps.

iii. Side Entry: A side entry implies areas of a continuous stretch of road surface where it connects with other adjacent roads or lanes and from where vehicles from and to such roads or lanes may enter or leave the concerned continuous road. Road lighting and traffic signaling for side entries needs to be adequate and appropriate to provide proper visual guidance and caution to drivers.

9. Availability of High Mast Lighting: As the name suggests, this field depicts the presence or absence of proper pole mounted or high mast road lighting luminaires at the site of the crash. The absence of any high mast lighting could be a significant contributing factor to the precipitation of the accident as it would render the particular area of the roadside dark and reduce visibility. On the other hand, the presence of improper lighting can also be a contributor to road mishaps, as glare and over illumination can also obstruct vision and lead to crashes.

10. Height of the pole: This data field signifies the height of the high mast pole atop which the corresponding road lighting luminaire is mounted. The height of the pole is a significant factor for selecting the **Mounting Height** as it determines the spread and light distribution of the light emanating from the light source over the road surface.

11. Type of Lamp: This is one of the most crucial aspects of the entire field of road lighting. The light source or lamp supplies the luminous energy responsible for rendering objects visible on the road surface and thereby ensuring proper functioning of the roadways and safe and efficient transit of people and goods. The common types of lamps or light sources used in road lighting are low and high pressure Sodium Vapor lamps, popularly known as SOX and SON lamps, Mercury Vapor lamps, Fluorescent lamps, Metal Halide lamps and in the present context Light Emitting Diodes (LEDs) which are gradually replacing most other conventional light sources due to their myriad benefits.

12. Arrangement of the poles: This data field refers to the arrangement of the poles and the corresponding road lighting luminaires. According to the **IS 1944** guidelines, the arrangement of the pole mounted luminaires is usually of the following major types:

a. Single Side Arrangement: Arrangement where all the luminaires are on one side of the carriageway, is recommended only when the width of the carriageway is equal to or less than the mounting height. The illumination on the road surface on the side remote from the luminaires is inevitably lower than that on the same side as the luminaires.

b. Staggered Arrangement: Arrangement where the luminaires are situated on either side of the carriageway and in a zigzag formation, may be employed when the width of the carriageway is greater than the value recommended for single side lighting but not exceed 1.5 times the mounting height. It is superior to the single side arrangement in that it provides more nearly uniform illumination and better visibility of the two sides of the road.

c. Opposite Arrangement: Arrangement mounting in which the luminaires situated on either side of the carriageway opposite to one another is advisable when the width of the carriageway is more than l-5 times the mounting height.

d. Axial Arrangement: Arrangement in which the luminaires are placed along the axis of the carriageway, is admissible for narrow roads the width of which does not exceed the mounting height. In some tree-lined roads axial mounting may be the only acceptable device. It has in wide roads the undesirable effect of drawing the attention of the driver towards the center of the carriageway and of reducing the illumination at its edges, obstacles may appear.

13. Road Width: This data field signifies the width of the road or the carriageway or dual carriageway, as the case may be. The width of the road is defined as the distance between kerb lines on the road, measured at right angles to the length of the road or carriageway. The Road Width is a significant parameter as along with the mounting height of the poles, it determines the arrangement of poles and light sources and luminaires which could be either Single Side. Staggered, Opposite and Axial arrangements. The wider the road surface, the light distribution needs to be commensurate to ensure the uniform availability of light along the road surface and avoid the presence of dark patches, which would hinder visibility.

14. Distance of separation of consecutive poles: This data field signifies the physical separation of successive pole mounted high mast luminaires. This distance is also known as the Spacing. Proper Spacing between successive luminaires on the road stretch is essential for maintaining the **Longitudinal Uniformity** of the road lighting installation. The IS 1944 guidelines lay down definitive ratios between the luminaire's Mounting Height and the Spacing in order to ensure that the Longitudinal Uniformity is maintained, based on the type of luminaire, whether Cut Off, Semi Cut Off or Non Cut Off luminaire.

15. Illumination Level (lux): This is perhaps the most significant field for which data was collected at least from a photometric perspective. The Illumination level or Lux level gives us the precise quantification and idea about the amount of light which was available on the road surface where the crash occurred and has one of the most direct correlations with rendering objects visible in time. The parameter Illumination is defined as the amount of luminous flux emanating from the pole mounted high mast luminaire which is incident on the corresponding road surface per unit area. The unit of Illumination is the lumen per square meter or lux.

16. Glare : This field signifies the presence or absence of Glare at the location where the crash occurred. Glare is a visual sensation resulting in the difficulty of seeing or identifying objects and obstacles, which is usually caused by the presence of excessive and uncontrolled brightness in the field of vision of the observer**.** Glare in public lighting is generally caused by improperly shielded or unshielded luminaires. There are two major forms of glare:

a. Disability Glare: It may be defined as Glare which depresses the visual capacity of the eye and hence the visibility of objects.

b. Discomfort Glare: It may be defined as Glare which diminishes visual comfort and which may eventually lead to irritability and fatigue.

Glare on road surfaces may also be caused by other factors such as the presence of large highly reflective surfaces, specular surfaces, excessively bright shop windows, advertisement signs or road direction signs. However, Glare primarily depends mainly on the illumination produced by the luminaires on the eyes of the observer. For a luminance of given luminous intensity:

a) the glare decreases as the projected area of the luminaire increases and as it is seen further from the direction of vision; and

b) the glare diminishes as the background against which the luminaire seen is brighter. This background comprises not only its immediate surround, but also the totality of the visual field, in particular the road surface, its surrounds and any facades. The limits set for the luminous intensity may be relaxed when the level of luminance of the carriageway is increased, or when there are lighted facades which form a background to the luminaire. If several luminaires are present in the visual field, the glare elect which results increases by an additive process.

17. Dark Patch: This field signifies the presence or absence of dark patches on the road surface where the crash occurred**.** Dark patches are areas of low or no levels of illumination, which renders the area either completely or partially dark. Dark patches on the road surface poses significant risks to the passage of vehicular traffic and/or pedestrians and may predispose toward hazards and crashes. Dark patches are usually caused due to improper alignment or inordinately long spacing between successive luminaires, which severely reduces the amount of available illumination in the intervening spaces between the luminaires. Dark patches may also occur, if for instance single side luminaire arrangement is employed on a very wide road, where one side of the road would be well illuminated and the other side would have very poor visibility.

Now that we have familiarized ourselves with the different parameters captured in the data fields of the tabulated data and what each of them signify, we shall attempt to understand how the individual fields captured in the data sets correlate to each other and what role is played by the various elements in precipitating the crashes that had occurred. Over the course of the following evaluation and survey of the collected and tabulated data, we shall thus endeavor to paint a comprehensive picture of the myriad facets and aspects of road crashes and how it intricately correlates to the level, quanta and nature of road lighting available (or absence thereof), the deep inter-relations between the various road lighting parameters and the crashes that occurred, inter-relations between the various parameters pertaining to the crash data as well as the demographic dimension to the road crashes and how demographic factors relate to both the rate and frequency of the accidents as well as the different road lighting parameters.

In the following segments, we shall venture to study and evaluate the correlations between vital individual parameters as supported by the road crash data and also the data collected during our fieldwork and attempt to establish precise one on one relationships between the specific individual parameters, but, also to discern the overall interconnectedness and of the multitude aspects and elements of the different parameters and sub parameters and how their collective synergy causes and contributes to the crashes. Once, we have been able to comprehensively establish a leitmotif which emerges over the pattern of accidents and their contributing causes, we'll be better equipped to propose ways of averting accidents and crashes and suggest novel modalities of enhancing the safety and security of all road users.

The analysis and slicing and dicing of the collected and tabulated data from various perspectives shall also afford us the opportunity to verify, validate or dispel prior conceptions and conjectures which had been brought to light in the extant literature and relevant case studies and thus form an in-depth evaluation of the contemporary context of roads, road crashes and road lighting and also a compendious resource of reference for further research and refinement.

Analysis of Road Crash Data according to Road type

In this segment, we shall strive to study and understand the correlation, if any, between the incidences and frequency of road crashes and the type or category of roads, as per the guidelines laid down in the Indian Standard IS 1944 (Parts I & II). Turning our attention to the road crash data, we find that the crashes occurred on almost all types and categories of roads in different locales, neighborhoods, boroughs and suburbs of major urban conglomerations and metropolitan cities like Kolkata and Ahmedabad as also on expressways, bridges, flyways, flyovers and interstate and national highways which may pass through urban, semi urban and also rural areas and arterial roads of which may pass through city centers and urban traffic routes in many instances, rural and semi urban areas and townships like in various parts of South 24 Parganas district, West Bengal and Kutch district, Gujarat.

In the case of large urban areas like metropolitan Kolkata, the crashes occurred not only on major roads, junctions, downtown city centers, public hubs which witness some of the highest traffic densities at rush hours and also throughout the day, but, also on smaller roads in areas with relatively lesser traffic density and residential areas and neighborhoods with sedate traffic flow. In major cities, considerable amount of crashes have been found to have transpired at bridges, flyways, skyways and flyovers which would be classified as Group D roads as per the IS 1944 guidelines. Significant incidences of road crashes have also been reported and accordingly tabulated in our datasets occurring at or near major transport hubs like rail stations, airports, ports, ferry docks, interstate and local bus terminals as well as other specialized areas and ports of entry which also witness substantial traffic egress and exit throughout the day as well as night.

We can glean the aforesaid information by a cursory or even moderately nonchalant perusal of the tabulated data. However, in order to gain in-depth insights and a more comprehensive perspective into the precise relationship and association between the extensive road crashes and the category of road, we need to delve deep and study the mathematical interconnection between these two parameters. In order to do so, we may employ statistical and graphical tools which greatly ease the process of establishing one on one relationships between sets of parameters. The usage of graphical tools also enables the convenient and intuitive visualization of the interconnection between the different parameters, which enhances and speeds up the data evaluation and analysis process and aids quick comparisons.

For the purposes of our analysis of the collected data and establishing inter relationships between the tabulated data fields, we shall employ the ubiquitous graphical tool of Pie Charts. Pie Charts are a type of circular statistical graphical tool, which are renowned for their simplicity and are a very powerful instrument for representing, comparing and analyzing data in a very convenient, easy and efficient manner. The Pie Charts for this analysis shall be drawn with the aid of the Microsoft Excel software, which is a part of the Microsoft Office suite of software. The 3-D Pie Charts presented in this study plot bivariate data taken from the tabulated datasets pertaining to the specific parameters which we intend to study or analyze and represent them as a three dimensional pie like structure which show sectoral segments as parts or fractional percentages of the overall circular pie. This provides us with a very simple, intuitive and convenient infographic from which to quickly gain a comprehensive idea about the distribution of the data and how the different constituent factors contribute to the overall perspective of the data being studied.

In this segment, we shall analyze the road crash data with respect to the category of road, where the crash occurred. As discussed earlier, the road crash data appears to be well distributed over all the major categories of roads, streets, highways and carriageways in different types of locales, areas and neighborhoods in urban, semi urban, rural and also industrial areas spanning all sorts of demographics and traffic density distributions. However, by analyzing the data in the light of graphical and pictorial statistical tools like 3D Pie Charts, we will be able to have a precise picture of the exact types or categories of roads where the highest frequency and distribution of crashes were recorded and be better able to understand the causes thereof.

The 3D Pie Charts use different color coding techniques to represent the multiple constituent elements being evaluated, providing a rich palette of easily accessible and relevant information. The proportional weightage or effect of each of the constituent elements or categories with reference to the parameters being studied are represented as percentages, indicating the portion or slice of the pie that each of the categories occupies. This allows us an extremely intuitive, visually appealing and easy graphical representation of the data to be compared and analyzed and aids greatly in the process of collecting point-wise feedback about the data and drawing crucial conclusions.

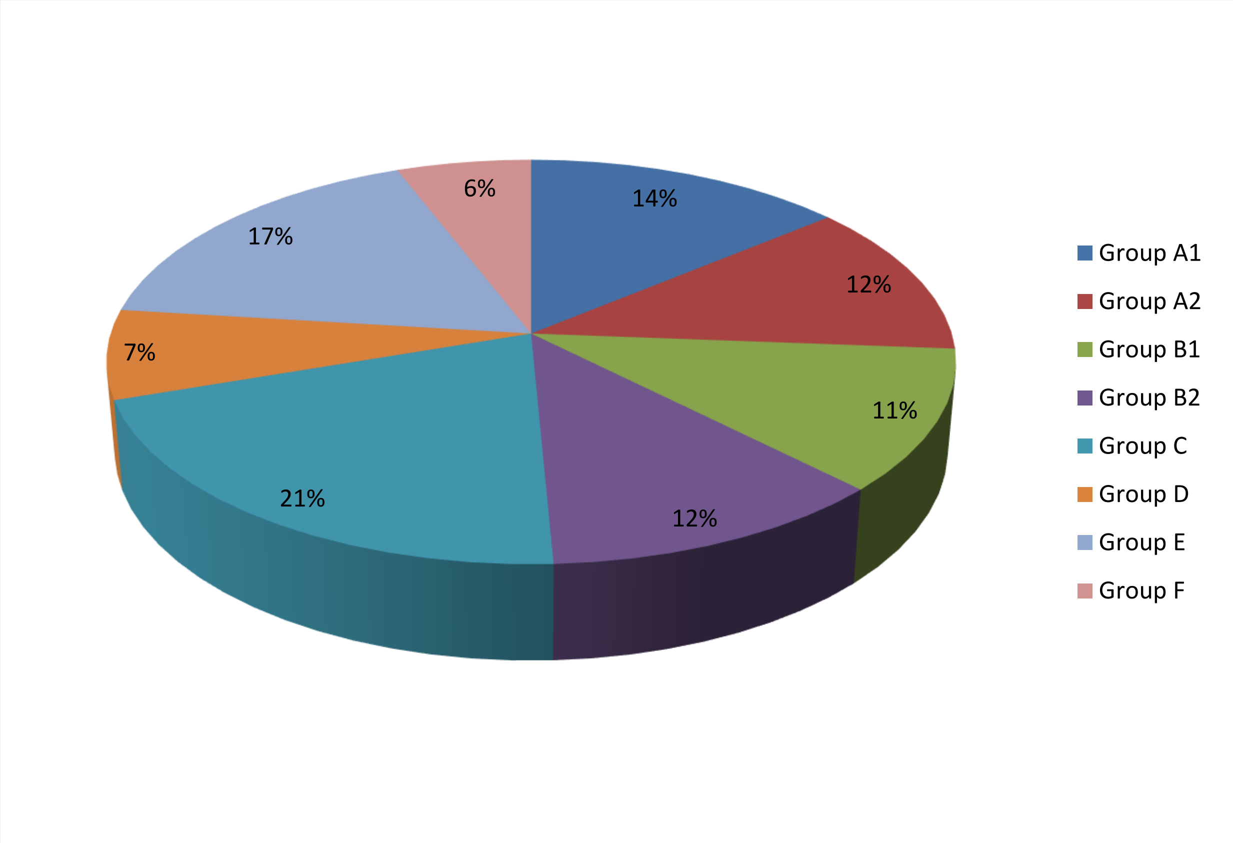


Fig.11: Incidences of road crashes by road category

In the above infographic, the simplicity and sheer efficacy of 3D pie charts is fully visible. The pie chart depicts the distribution of the entire tabulated road crash data sets, spanning over a decade according to the type or category of road (as per the IS 1944 classification) where the crash occurred. The different categories of roads are color coded for convenience and visual clarity. The color coding of the different road categories are as follows:

1. **Deep Blue** for **Group A1** type roads.
2. **Red** for **Group A2** type roads
3. **Green** for **Group B1**type roads
4. **Violet** for **Group B2** type roads
5. **Cyan/Turquoise** for **Group C** type roads
6. **Orange** for **Group D** type roads
7. **Light Blue** for **Group E** type roads
8. **Pink** for **Group F** type roads

The road crash statistics for the different categories of roads were obtained from the tabulated and enumerated data. The total number of reported crashes which transpired on each category of road was segregated and their sum total calculated using appropriate mathematical techniques in the Microsoft Excel software. The computed sum total of number of crashes for each category of road along with the corresponding nomenclature of the type of road was then fed as input data for the 3 D pie chart. One of the great advantages of the Microsoft Excel software lies in the fact that it allows great degree of flexibility and intricate customization options to the user for selecting the type and nature of the visual and pictorial graphs, as per the specific requirements of the analysis. For the sake of convenience and the ease of evaluation, the 3D pie chart depicting percentage data was chosen.

The road crash data was entered as the sum total number of crashes per individual road category. The Microsoft Excel software then automatically converted the input data into a percentage distribution, corresponding to the frequency or number of incidences of road crashes for each road type and displayed the 3 D percentage pie chart as output, which has been presented in this section of the study. The percentage figures depicted in the resultant 3 D pie chart were also automatically color coded by the Microsoft Excel software. For elucidating our evaluation, the relevant color codes corresponding to the different road categories have been enlisted in the prior sections and provide us with the requisite keys to visually comprehend the information being depicted by the 3 D pie chart.

Upon perusing the highly visual graphical data presented by the 3 D pie chart, we are granted exclusive access to a wealth of information in a very simple yet compelling manner. Looking at the visual representation of the road crash data corresponding to the different road categories, we can find the percent weightages of the crash incidences for each road type as a proportion of the entirety of the road crash figures for a period spanning more than a decade, as per the collected data. The pie chart provides us a clear and conspicuous picture of the number and proportion of crashes for each category of road and also startling and perhaps unexpected revelations of the nature of the road crashes and what entailed them.

Using the color coded slices of the pie as indicators of the number of crashes occurring on each type of road, we may enlist the following as the percentage of crashes which transpired on the different road categories:

1. Group A1 - 14 % of the total number of recorded crashes.

2. Group A2 - 12 % of the total number of recorded crashes.

3. Group B1 - 11 % of the total number of recorded crashes.

4. Group B2 - 12 % of the total number of recorded crashes.

5. Group C - 21 % of the total number of recorded crashes.

6. Group D - 7 % of the total number of recorded crashes.

7. Group E - 17 % of the total number of recorded crashes.

8. Group F - 6 % of the total number of recorded crashes.

From the above percentage figures, it is clearly evident that the distribution of road crashes according to the road category or type is are relatively evenly spread out one, rather than being heavily skewed toward a certain specific road category. Sifting through the figures, we can make some very distinct and striking observations about the road accidents and what role the category and setting of the road environs had on the crashes that transpired.

First and foremost, we find that the number or proportion of road crashes for the road categories Group A1, Group A2, Group B1, Group B2 are very similar to each other with only a few percentage points separating the actual number of crashes for these four major categories of roads. Road groups A1, A2, B1 and B2 account for 14%, 12%, 11% and 12% of the total number of reported road crashes respectively. Thus, we have a more or less symmetrical or even distribution of road crashes for the road categories enumerated herein. It may be recalled that the Group A category of roads are the major types of roads which witness the highest and densest transit of traffic and are usually located in the precincts or neighborhoods with the busiest traffic like major crossroads, downtown junctions, highways etc. As we learnt earlier, Group A type roads are further subdivided into two categories, namely Group A1, which are the roads covering the most important traffic routes with very rapid and dense transit of traffic and where the only considerations are the safety and speed of the traffic and the comfort of the drivers and Group A2, which are primarily meant for other type of main roads with considerable mixed traffic like main city streets, arterial roads and thoroughfares. Group B roads, on the other hand, are secondary roads with relatively lesser traffic density and speed and which do not require road lighting up to Group A standard. Group B roads are also subdivided into 2 sub categories, namely Group B1, which are secondary roads with considerable traffic, such as principal local traffic routes, shopping streets, etc. and Group B2, which are other types of secondary roads with comparatively lighter traffic vis a vis Group B1 roads.

From the ongoing discussion, it is evident that the road category Group A, comprising of the sub groups A1 and A2 represent the principle or major routes with the highest traffic speeds and density and thus, the corresponding road lighting requirements for these categories of roads are also the most stringent and demanding. It may be surmised that since the road category Group A, particularly the sub category Group A1 has the highest, densest and fastest traffic transit, the number of road crashes transpiring on such roads would be the highest, owing to the sheer volume of traffic that these roads transport on a daily basis. The data collected and tabulated in this study does tend to corroborate such assumptions to a certain degree, as reflected in the 3 D pie chart representation of the said data. The Group A type of roads, represented by the sub groups A1 and A2 accounted for respectively 14% and 12 % of the entirety of the road crashes that occurred over the decade long period for which the crash data was recorded. However, contrary to our intuitive assumption that the road Group A1 or even Group A2 would have the highest number of crashes, the data indicates otherwise as the highest incidence of road crashes was found to be transpiring on other category of roads, which shall be discussed in detail in the forthcoming segments.

It is imperative for us to observe at this juncture that the nature and quality of available road lighting or lack thereof plays an absolutely vital role in the road crashes of any specific type in conjunction with the density and speed of traffic. For instance, upon perusing the road crash datasets we find that on major types of roads like national and interstate highways, expressways and other similar roads, which are classifiable under Group A1 and which witness the transit of not only very dense traffic, but, also heavy cargo and sometimes hazardous materials laden trucks, flatbed trucks and large "road train" like vehicles, the road lighting is utterly conspicuous by its stark absence. The unavailability of any form of road lighting on such vital routes and major roads is a crucial contributing factor in the precipitation of road crashes, mishaps and eventual casualties stemming from such occurrences.

Focusing our attention to the secondary category of roads which are classified as Group B roads, as per the IS 1944 guidelines and are further subdivided as Group B1 and Group B2 category of roads, we find that here too the distribution of the incidences of crashes is pretty symmetrical and almost identical between the two categories Group B1 and Group B2, namely 11% and 12% of the total number of recorded crashes respectively. Group B1 roads are the types of secondary roads which witness lesser traffic speed and density as compared to the standard of Group A type roads. Roads traversing through busy shopping districts or connecting principal local traffic routes with the transit of mild to heavy intercity traffic and public and private vehicles as well as local main roads connecting nerve centers or vital downtown neighborhoods and districts are some of the examples of Group B1 roads. As such, even though the speed, density and volume of traffic on such roads may be relatively less vis a vis Group A1 or Group A2 type of roads, Group B1 type of roads still witness substantial flux of urban and intercity traffic at speeds which are quite considerable, given the fact that such roads are usually located in vital business and commercial centers, shopping areas or areas of heavy public transportation and transit. Thus, the nature and amount of road lighting needs to be commensurate with and adequate for the requirements of such types of roads for mitigating and preventing road crashes and mishaps.

Group B2 roads on the other hand are the type of secondary roads which have considerably lower rate of traffic flow than those of the Group B1 type of roads. Secondary streets which connect intermediate areas between busy commercial hubs, downtown areas and sprawling shopping districts, roads between moderately sized city, boroughs and blocks and connecting different neighborhoods are some examples of Group B2 category of roads. Although the density and volume of traffic and the average speeds of vehicular traffic are somewhat less than those of Group B1 roads, we find that the number and proportion of road crashes reported for such roads over a decade long period is almost the same in cases of both Group B1 and Group B2 categories of roads. In fact, the total incidences of road crashes on Group B2 type roads is slightly higher at 12% of the total number of reported crashes in the data, as compared to 11% for the Group B1 category of roads.

In attempting to analyze and understand the reasons and rationale behind the approximately symmetrical distribution of the incidences of road crashes on the Group A1, Group A2, Group B1 and Group B2 categories of roads we need to look at the crash reports emanating from these roads from different standpoints and perspectives. The most rudimentary contributory factor in the number of crashes reported on Group A1 and also

Group A2 categories of roads is the sheer volume of traffic that traverses such roads and the substantial speeds at which such traffic passes on these roads is often the *primam causam* which predisposes or bears a relatively higher risk of the precipitation of crashes on such roads. While considering the flow of traffic on such roads, the risk and potential hazard of crashes and mishaps is compounded especially in the hours of darkness or low illumination, wherein the factors of speed and traffic density can have an even greater cumulative effect on the propensity of a crash. The data we have collected in this study appears to corroborate and validate that fact. As such, during the hours of darkness or low illumination, the road lighting needs to work in an adequate and flawless manner in order to avert potential disasters.

According to the **Bureau of Indian Standards(BIS) 1981guidelines**, the recommended Avg. level of illumination on the road surface for Group A and B categories of roads are 30 lux, 15 lux, 8 lux and 4 lux respectively for Group A1, Group A2, Group B1 and Group B2 types of roads. Focusing on the road crash data corresponding to the Group A type of roads, we find that in many instances the level of illumination for the Group A1 and Group A2 categories of roads did not meet the recommended minimum level of illumination (lux level). This appears to have been one of the pivotal factors in the precipitation of the crashes on these roads. Also, in many other instances, where the road lighting was adequate to provide at least the basic recommended lux levels, other photometric parameters came into play which may have potentially played a significant role in the crashes that transpired.

Evaluating the crash data corresponding to the Group A1 and Group A2 type of roads, we find that the in many instances where the minimum levels of illumination were not only maintained, but, comfortably exceeded the pivotal factor of Glare came into the equation. Glare is a visual sensation which results in the difficulty of seeing or identifying objects and obstacles, which is usually caused by the presence of excessive and uncontrolled brightness in the field of vision of the observer**.** Glare in public lighting is generally caused by improperly shielded or unshielded luminaires. The effect and impact of Glare in road transit can be extremely detrimental. Glare from improperly shielded luminaires or light sources which are excessively bright can severely impede the vision of the driver and may also cause a blinding effect, which in many instances can persist up to an hour or more. The immediate impact of Glare is to disable or depress the visual capacity of the observer, be it the driver of oncoming vehicles, a pedestrian attempting to cross or walk along the road or even traffic and public authority personnel trying to regulate the proper passage of traffic. Thus, Glare can be a significant and major contributing cause in the occurrence of the road crashes on Group A roads as with other categories of roads. In the collected and tabulated data, we find numerous instances of crashes where there was excessive amounts of Glare present at the site of the crash which would have possibly obstructed or blinded vision and potentially played a significant role in the transpiring of the mishap.

On roads with less and even significantly low levels of illumination, a different factor namely the generation and presence of Dark patches on the road surface plays a major role. Dark patches are spots or areas of very less or practically nil level of illumination, which renders the area either entirely or partially dark. Dark patches on the road surface poses significant risks to the passage of vehicular traffic and/or pedestrians and may predispose toward hazards and crashes. Dark patches are usually caused due to improper alignment or inordinately long spacing between successive luminaires, which severely reduces the amount of available illumination in the intervening spaces between the luminaires. Dark patches may also be generated, if for instance single side luminaire arrangement is employed on a very wide road, where a particular side of the road would be well illuminated and the other side would have very poor or low visibility. Dark patches are of course, also present on roads where road lighting in any form is completely absent.

Thus, we observe that under most situations in Group A or other categories of roads, the presence of Glare or Dark patches is one of the most crucial and decisive factors in the precipitation of road crashes and possible casualties. The level of illumination available on the road surface is the de facto prime factor in determining the level of visibility and visual comfort and visual guidance which the driver of the vehicle is afforded by the available road lighting and in aiding object detection, identification and in-time decision making. In many instances, the level of illumination is also a determinant in the presence of glare or dark patches. However, glare is usually caused by the improper alignment of the luminaires and the usage of Non Cut-off or Semi Cut-off luminaires. Glare may also be caused by the unshielded or improperly focused headlights of oncoming cars and vehicles. Thus, in the case of Group A1 and also Group A2 categories of roads, the presence of improper levels of illumination, the usage of inappropriate luminaires and the presence of glare and dark patches on most of the locations where the crashes transpired has an additive and compounding effect with the relatively high speed and copious traffic densities which predisposes such roads to greater risk of road crashes. In an Indian perspective, there is also a strong proclivity among drivers to flout traffic norms and speed regulations, which themselves can further compound the probability of crashes on such roads.

Focusing our attention on the secondary Group B roads, especially the Group B1 category roads, we find that here too much the same criteria are relevant in discerning and evaluating the causes and reasons of road crashes. Group B1 roads, as may be recalled are the major types of secondary roads which are to be found in typical intercity or suburban settings like busy commercial centers or shopping areas and witness moderate to heavy traffic, which may be variable at various times of the day. On Group B1 roads, the considerations of traffic speed, while somewhat more relaxed than those on Group A1 or Group A2 categories of roads, are nonetheless still substantial. The same applies for traffic density and the volume of vehicular transit, which often rises during the evening peak hours when people often frequent shopping localities and there is heavy vehicular egress from and around commercial centers and office areas.

From a photometric perspective, as with all other categories of road, the level of illumination or lux level is the most primary determinant of the degree of visibility, visual comfort and visual comfort being provided to different observers like vehicle drivers, pedestrians and other road users. Perusing the collected and tabulated decade-long road crashes data statistics, here too we find that the presence of glare and dark patches, as the case may be, plays an absolutely vital role in the possible precipitation of road crashes. On deeper inspection, it was found that the even the minimum recommended lux levels for Group B1 and Group B2 roads were sometimes not met, which naturally predisposes such roads and environs to greater crash probabilities. On the other hand, there were also substantial number of crash sites where the level of illumination comfortably overshot the minimal recommended values and was actually excessive. In such instances, vital photometric parameters like glare and visual comfort are of prime importance. As has already been discussed, glare can pose significant challenges to drivers of vehicles and automobiles as well as other road users as it tends to disable or depress the visual ability of the observer and impede his or her capacity to properly detect and identify potential obstacles or hindrances on the road in time to come up with appropriate response and thus can be potentially hazardous. Glare can be caused as a direct consequence of excessively bright light sources or unshielded or poorly shielded and mis-oriented and misdirected luminaires and also from very bright headlights and dippers of oncoming vehicles. The presence of glare in the field of vision of the vehicle's driver can thus be a great impediment in proper visualization and potentially a causal element in the precipitation of road crashes.

Along with Glare and the presence of Dark patches on the road surface, which have already been discussed in the ongoing segment of study, some other vital parameters also play a pivotal role in ensuring the safety of the motorists and road users and averting crashes. Some of the other prime photometric parameters which impact road safety are as follows:

1. Uniformity: A good overall uniformity of the lighting distribution on the road surface ensures that all the spots on the road have adequate visibility. A good longitudinal uniformity ensures comfortable driving conditions without the so called "Zebra effect", which produces repetitive bright and dark regions on the entire road surface, which may generate very prominent visual, behavioral and psychological impediments to the drivers and other motorists.

2. Surround Ratio: The Surround Ratio is defined as the ratio of the average illumination on strips 5 m wide, or less if space does not permit, which are adjacent to the edge of both sides of the carriageway to the average illumination on the adjacent strips, 5 m wide or half the width of the carriageway, whichever is the smaller in the carriageway.

The function of the Surround Ratio (SR) is to ensure that sufficient light falls on the surrounds to provide a bright background for objects towards the edge of the carriageway to be revealed. It also helps the driver to anticipate the movement of pedestrians about to cross the road. It is important in curved roads where the surround forms the greater part of the background against which objects are seen. For dual carriageways, both carriageways together are treated as a single carriageway unless they are separated by more than about one-third the carriageway width and there are obstructions such as trees. The Surround Ratio is usually determined by calculating the illuminance on a regular array of points on the strips and finding the average. In a situation where the surround ratio is applicable, a value of 0.5 is recommended.

3. Visual Guidance: Visual guidance for drivers, motorists and other road users either seated in or from the vantage point of a motor vehicle can be provided by the following principles:

a) Positioning of poles;

b) Using light sources of varying colors; and

c) Use of high masts or poles (> 20 m).

Curves of large radius of the order of 1000 m can be treated as straight. For curves of smaller radius, a study of the respective shows that it is mainly the luminaires which are placed at the outside of a bend which contribute to the brightness of the carriageway, and that in order to bring about the same degree of juxtaposition of the patches the spacing should be progressively reduced as the bend is more pronounced. For comparable reasons, the overhang should not be excessive. Under such scenarios, single side arrangement is preferred as it also provides effective beaconing of the curve. Staggered arrangement should be avoided in such cases, since not only does the beaconing effect usually disappear, but, the driver may even be deceived into thinking that there is a side road. At curves on roads where the road width exceeds 1.5 times the Mounting Height additional luminaires should be mounted on the inside of the curve, so as to minimize the possibility of misreading the pattern of lights.

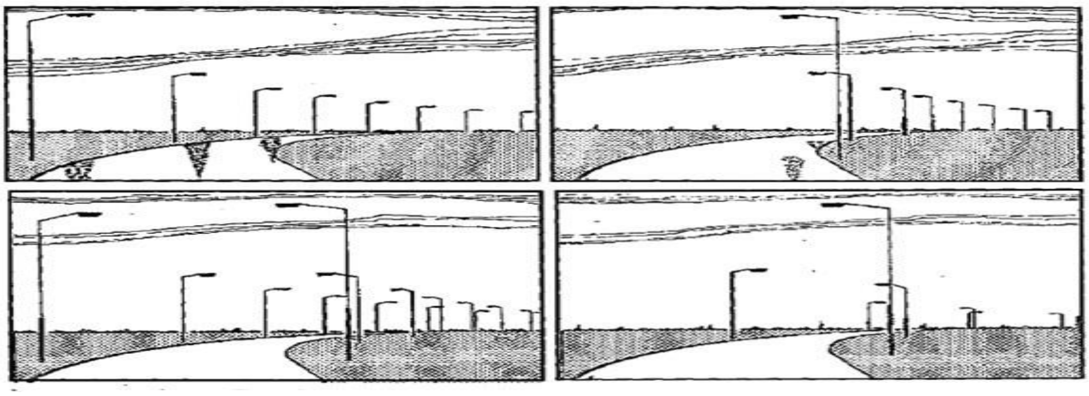


Fig. 12: Ideal alignment of Road lighting poles for proper Visual Guidance

4. Visual Comfort: Visual comfort is a rather impressionistic and individually perceived dimension of the quality of road lighting. If the degree of visual comfort be inadequate, a driver or motorist's level of fatigue will be augmented and his/her visual performance and alertness will consequently be reduced. So, both visual comfort and visual performance are crucial aspects for road safety. Subjective appraisal studies have shown that the lighting level, the uniformity of the road surface luminance pattern and glare categorically impact the perceived level of Visual Comfort. The spectrum of the lamp or light source used also has an influence on the last mentioned. LEDs may sometimes have a special influence on visual comfort because they are available in a much wider range of spectra than are the conventional light sources. Their small light-emitting surfaces allow for more pronounced beams to be produced, which then may influence the perceived Visual Comfort or lack thereof. Most LED luminaires consist of a multiple array of small LEDs resulting in a non-uniform luminance distribution of the light-emitting surface, which may have an influence on their discomfort glare aspect.

In order to maintain an adequate degree of Visual Comfort over a sustained period of time, the road user must be able to feel comfortable in his visual environment. If, the driver has the feeling that it is tedious and stressful to get the visual information needed for safe driving, he/ she will feel visually uncomfortable. Consequently, the driver or motorist's level of fatigue will rise rapidly. This has a detrimental impact on both the visual performance and alertness of the driver. Thus, Visual Comfort is a rather individualistic perception based aspect of road lighting as it is concerned with the individual road user or driver. Several vital photometric parameters like the level of illumination (lux level), the uniformity of the lighting pattern, and glare influence the perceived degree of Visual Comfort vis a vis the driver or the road user.

5. Small Target Visibility: Small Target Visibility or STV is defined as the visibility level, VL, which is calculated according to strictly and well-defined conditions. The conditions are defined by the IES, and ANSI/IESNA (2000, 2014) standards as follows:

• flat target with diffuse reflectance factor of 0.50

• target size: 18 cm × 18 cm seen from a distance of 83m (visual angle 7.45 min),

• observer-to-target sight line: parallel to the road-axis line,

• observer age: 60 years,

• contrast threshold according to Adrian’s model for an observation time of 0.2s,

• observation height: 1.45m (the target at 83m is seen with a downward viewing angle of 1°),

• background luminance: average of the point luminance at the bottom of the object and at the top of the object (as seen from the observer's vantage point),

• regular calculation grid starting at 83m from the observer, between a span of luminaires.

The rationale behind the genesis and usage of the parameter of Small Target Visibility is not only to provide insights into how the different aspects of road lighting influence visibility of objects, but, also to use this parameter as a standard design marker for efficient road lighting installations. Thus, while evaluating and analyzing the road crash data we need to factor in all the aforesaid photometric parameters along with the presence of glare or dark patches in order to be able to paint a realistic portrait of the precise causes behind the occurrence of the crash.

Continuing with our evaluation of the road crashes according to the different categories of roads, in the case of Group B2 categories of roads, we find that the overall number of reported crash incidences is slightly higher than the corresponding one on Group B1 roads, which usually witness somewhat greater densities of traffic and also the speed of such transit is marginally higher in most cases, at least in theory. In evaluating the cause and rationale behind the significant number of reported crashes on Group B2 category of roads, it needs to be observed that the adherence to strict design standards as regards road lighting and alignment, arrangement or orientation of luminaires is often pretty lax and also on such roads there is usually lesser number of traffic personnel employed, who are often tasked with manning larger roads in greater numbers. As a consequence, there is greater propensity among drivers, motorists, pedestrians and other road users to flout and defy traffic norms and regulations, which results in increased probability of crashes on such roads. On Group B2 type of roads, it was also found on multiple occasions during the field study that proper traffic signals were either absent, defunct, inadequate or located in very non-descript and inconspicuous locations, which made it extremely hard for them to be located and properly used in conjunction with the flow of traffic.

From the perspective of photometric parameters and the road lighting installation, it is also pertinent to note that very often on secondary roads, especially on Group B2 type roads, the Lighting Maintenance plan, if any, is not rigorously maintained or executed by the civic and municipal authorities. As such, it was found that in many instances, age-old luminaires and light sources which are in dire need of retrofitting, re-lamping and upgrading are still being used as workhorses on a regular basis. Such light sources and luminaires greatly degrade the quality of available road lighting and provide very low and poor levels of illumination, which in turn can be a very vital contributing factor in the transpiring of road crashes and mishaps. Thus, for secondary roads, all the above photometric factors in conjunction with the poor repair and maintenance schedules and re-lamping of lamps and retrofitting of luminaires appears to have a significant effect on breaching the requisite standards of road safety on such roads, which consequently leads to greater number of crashes and mishaps.

As has been evidenced over the course of this discussion and analysis of the pictorial 3D pie chart representation of the incidences of road crashes according to the road category, the highest number of road crashes reported were incidentally not on the major traffic routes or speedy highways, which are usually classified under Group A roads. Sifting through the data and the 3D pie chart info graphic, we find that in fact the highest incidences of road crashes transpired on the Group C category of roads. The Group C category of roads as per the IS 1944 classification are the roads traversing primarily through residential areas, neighborhoods, surrounding residential complexes and communities as well as other unclassified locales like , which cannot otherwise be specifically categorized elsewhere.

By their very definition, Group C roads are located in areas where the speed of public transport and traffic flow is meant to be lower as compared to other road categories as the roads in the general environs of residential and neighborhood complexes are theoretically supposed not to impede or interfere with the regular lives of residents and other occupants of the area. However, in the Indian perspective, a somewhat different scenario emerged with regard to the road environs and the road crashes which transpired thereon. In residential and unclassified roads, much of the factors which are attributable to contributing to a high number of the reported crashes in some of the secondary roads like Group B2 category of roads are also found to hold sway for the Group C category of roads. Frequently during the fieldwork phase of the study it was found on such roads that traffic personnel were very few and in substantial instances non-existent. Even traffic signs or markers were either not to be found or found in a very rundown, dilapidated or illegible state and in obscure and inconspicuous locations, which makes it very difficult for motorists or other road users to sight them for maintaining proper traffic regulations and sustaining traffic safety. Also, Group C roads being often present in off-beat and non-prime locations, rampant violation and defiance of basic traffic rules were most noteworthy on such roads, which greatly increases the likelihood of potential crashes.

On Group C roads, as with other categories of roads, it was found that on many occasions the level of illumination was almost miniscule and negligible and in several instances totally nil, which makes it extremely difficult to spot even large objects at fairly short distances. The visibility of smaller objects on such roads was also abysmally low, which is a crucial element in road safety as it enables the driver or motorist to spot potential hazards or obstacles in time to react appropriately and avert disaster. The presence of dark patches was noticeable on many circumstances due to the pretty low levels of illumination. On occasions where the level of illumination were adequate, the luminaires were often found to be poorly designed or oriented which led to stray and excessive light being emitted from them and present in the observer's Field of View (FOV), which gives rise to unnecessary and visually disconcerting glare, often a major cause for road mishaps. The contrast of objects on such roads was also pretty poor which is a great detriment to visibility and object identification, due to the low levels of uniformity of the lighting distribution. Due to the poor levels of uniformity, the so called "Zebra Effect" was also observed on many Group C category of roads.

Some relatively distinctive aspects of road lighting on Group C category of roads which were observed during our field studies was the rampant vandalism and encroachment and civic violations being noticed on such roads with regards to the theft, pilferage, sabotage and destruction of road lighting luminaires and lamps. This leads to many areas with little or no road light at all in the hours of darkness and is a major cause of concern in terms of road safety and also security. Areas where such vandalism and civic violations transpire often report higher incidences of crime and general misdemeanors. Also, another frequently observed problem on Group C roads is the poor maintenance scheduling of the road light sources and luminaires. Maintenance also needs to take care of and trim accompanying trees, foliages and vegetation growth which in many cases were observed to completely block the road lighting poles and masts and obscure the light from the corresponding luminaires in reaching the road surface. In many residential areas it was further noticed that temporary constructions of uncertain legality had been erected which were blocking the high mast poles and luminaires and consequently obstructing the light from adequately illuminating the intended road surface area. In many circumstances, poorly reflected light from such constructions and vegetation growth and foliage was the cause of glare, impeding and depressing the observer's visual capacity which can be a major contributory factor to road crashes.

All of the above elements in conjunction with the poor lighting design and equally poor and in many cases non-existent maintenance, repair, re-lamping and retrofitting schedule when considered as a collective appear to significantly account for the high number of road crashes and accidents that have been reported on Group C category of roads.

We shall now attempt to analyze and understand the road crashes reported for Group D category of roads. Group D category of roads are the roads which form the public passageways for transit on bridges, flyways, flyovers, skyways and other such structures. Group D roads have their own unique characteristic traits and challenges. Under most circumstances, Group D roads, due to their very nature are often located at a substantial elevation from the normal street level, appearing to be almost juxtaposed into the landscape alongside the roads and streets and buildings which are at a normal elevation. Bridges, flyways, skyways and similar constructions are all suspended structures being propped up by pillars or similar constructs, careful consideration needs to be made to ensure that the road lighting design factors in all the requisite elements. In particular, if the size and configuration of the bridge or flyway is very narrow or if it has interesting columns that may interfere with normal roadway lighting installation, special mounting and special lighting considerations may be needed.

All bridges and flyways and by extension the bridge lights experience a great deal of vibration from not only the passage of vehicular traffic, which on many occasions can include heavy goods carrying vehicles that strain the load bearing limits of the bridge or flyway, but, also from the ravages of inclement weather, wind turbulence, strong drafts and headwinds etc. Bridges and similar constructions which are located over or near the proximity of waterways and water bodies like rivers, lakes or even in certain circumstances portions of sea or lagoons, seaports etch also experience additional tidal and hydro forces, which can significantly impact the proper functioning of the structure over a period of time. As a result, bridge lights need to be properly and rigorously tested to withstand extreme vibrational forces.

Although the incidences of road crashes on Group D category of roads is somewhat lower compared to the other road categories, namely at 7% of the total number of reported crashes for all the road categories combined, the crashes on such roads represent some very vital aspects of road lighting and it's correlation with road accidents. Usually roads on bridges and flyways are considered to be part of the broader roadway system, following the standard fare of traffic rules and regulations governing such roads. However, in many instances, the special location and orientation of bridges, flyways and skyways vis a vis the ground level roadways necessitates additional considerations. For example, if a roadway is adjacent to pedestrian walkways on the bridge, light levels must accommodate for pedestrian safety as well as catering to the safety of passage of vehicular traffic.

Upon most bridges and flyovers, there are specific speed limits for the passage of vehicular traffic and on some bridges there are also limitations on the transit of extremely heavy or large sized vehicles, in a concerted effort to reduce the forces of vibration which may even cause bridges to capsize and rip apart. However, during our field study it was found that most bridges even in metropolitan locations were not manned by traffic personnel, although on some notable and newly constructed bridges and skyways, automated speed measuring and regulatory infrastructure were present. In rural and suburban areas, the situation was far worse. Thus, on many occasions it was found that the stipulated speed limits on such bridges were easily crossed especially after the hours of darkness. Viewed from the perspective of road crashes, this compounds the problem as the state of the current road lighting infrastructure on bridges all over India and in particular in West Bengal paints a rather grim and sordid picture. It was found that on many bridges and flyovers in crucial downtown locations and connecting vital traffic routes, the level of illumination as well as the uniformity of illumination were abysmally poor, which creates dark patches and pockets of very low illumination and thus can exacerbate the probability of road crashes. On the other end of the spectrum, upon many bridges, flyways and skyways there was availability of high mast lighting. However, the poor design of the lighting installation and improper alignment of the luminaires led to undesirable effects like glare, poor object contrast, poor Surround Ratio for enhancing the visibility of objects around the edge of the carriageway and overall a highly non-uniform lighting distribution. It is also apposite to observe here that the sheer location of bridges and flyovers makes the proper execution of a well-defined Lighting Maintenance Plan a relatively difficult task. As such, on many bridges it was noticed that worn out and defunct luminaires and light sources had not been changed or retrofitted for many years and in some cases even more than a decade. Consequently, highly degraded lighting quality and poor levels of illumination with poor color rendition were observed on many Group D type roads which greatly enhanced the risk of crashes and the same has been reflected in the recorded road crash statistics.

Focusing our analytic attention on the Group E category of roads, we find that a substantial number of road crashes, namely 17% of the total reported number of crashes was found on such roads, which ranks second only to the number of crashes reported under the Group C category of roads. Group E roads are the ones which are found to traverse through towns and city centers, downtown urban and semi urban areas, high streets in suburban and rural areas and townships, which are often the nerve centers of commercial and popular activity in such locations, Thus, we find that Group E category of roads are often found to connect shopping hubs and epicenters of downtown business and activity in urban settings and in suburban and rural areas they serve as major district roads, linking production centers and markets where the exchange of commodities can take place. Group E roads usually experience mixed traffic, both in terms of speed of vehicular movement and also the density and volume of traffic. Oftentimes, especially in suburban or rural townships, such roads are chock-a-block with various types of vendors, hawkers and sundry tradesmen plying their trades and selling goods and merchandise on the roadsides. Such activity, which usually takes place during specific periods of the daytime and evening often impedes with the flow and motion of vehicular traffic and also the transit of pedestrians. Thus, by their very nature, many types of Group E roads can cause a bottleneck for vehicular transit and also pose serious physical obstacles in the path of vehicular movement, which can be a contributing factor to road crashes and accidents.

During the fieldwork phase of the study, it was observed at multiple locations that vehicles had to steer and veer significantly off their intended course in an attempt to avoid hitting vendors, peddlers and other purveyors of roadside merchandise and in so doing greatly augmented their risk of colliding with other objects or crashing against oncoming vehicles or kerbs or other impediments and obstacles on the road surface. Over the course of our fieldtrips it was also found that in many of the Group E roads and locations, the overall lighting infrastructure was pretty poor and in many instances completely non-existent. The arrangement and siting of luminaire poles was also very shoddily planned and executed in a substantial number of the sites, which led to very poor levels of uniformity of lighting and consequently poor visual guidance for the driving motorists. In fact, the poor lighting design, alignment and orientation of the luminaires and corresponding light sources were a cause of significant visual fatigue for the drivers and other road users, instead of augmenting their visual comfort. The color rendition of the lamps and light sources were also found to be poor as many of the lamps had already reached or exceeded their usable life cycles and periodic re-lamping, maintenance and retrofitting activities were hardly undertaken, if at all. In fact, on a few occasions it was even found that some of the roadside lamps had been taken off their housing luminaires by local tradesmen and were being improvised and used as light sources for their impromptu shops for selling merchandise on the roadsides. Such reckless vandalism and civic violations severely undermine the efficacy of the road lighting installation in maintaining the safety and security of the roadside and surrounding environs on such roads and localities.

Finally, we shall try to comprehend the nature, causes and characteristics of road crashes on Group F category of roads, particularly from a photometric vantage point. Group F category of roads enumerate some of the most specialized types of roads as they are the roads which are specifically found near airports, airfields, railroad stations, ports, docks, jetty piers and other such transport hubs and portals of land, surface or air travel and also in many instances near private or public airfields, military air bases etc. Although the incidences of road crashes on Group F category of roads are the lowest among all the road categories, namely 6% of the total number of road crashes reported during the decade-long span of the datasets, they nonetheless are a very vital and significant aspect of our study, as they represent some of the most specialized and unique traits found in all the categorization and classification of public roads use for the passage of vehicular traffic.

Group F category of roads are often the transporters of some of the heaviest and most massive cargo payloads, large convoys and cavalcades of goods carrying trucks, flat bed trucks for outsized payloads and specialized machinery and equipment and multi-wheeled "road train" trucks for carrying interstate and also international cargo. Group F roads near public transportation hubs like rail stations and airports often witness some of the heaviest and densest traffic due to the constant entry and egress of passengers and travelers to and from the stations and airports around the clock. On the other hand roads near docks and large ports as well as major airports are often the sites and routes through which large fleets of heavy and voluminous cargo vessels often carrying international and intercontinental heavy goods, machinery, equipment, food grains, oils, minerals and even hazardous and inflammable chemical substances are transported to various centers of commerce, distribution, refinement as well as export. From the ongoing discussion, it is pretty evident that Group F category of roads have some of the most onerous and demanding lighting requirements of all types of categories of roads in order to ensure the safe and hazard free transit of not only people, motorists and drivers, but, also of such high value, voluminous and under many circumstances also high-risk and hazardous cargo materials.

While surveying various Group F category of roads on location during the fieldwork phase of this dissertation, it was found on many occasions that the levels of lighting on such roads, especially the ones near major rail stations and also ports and docks were often woefully inadequate, which led to . The presence of dark patches was noticeable on many circumstances due to the pretty low levels of illumination, which rendered it very difficult to attain any sort of proper visual comfort or provide any visual guidance to the drivers or motorists. On some other instances like near airports and airfields, the lighting levels were found to be excessively high. On occasions where the level of illumination were adequate, the luminaires were often found to be poorly designed or oriented which led to unnecessary, stray and excessive light being emitted from the luminaires and obscuring the Field of View (FOV) of the driver, motorist or other observer which gives rise to unnecessary and visually disconcerting effects like glare as well as alarming levels of visual fatigue and discomfort, which can be major contributing factors to potential road crashes. The contrast of objects on such roads was also pretty poor which can be a vital deterrent to visibility and object identification, due to the low levels of uniformity of the lighting distribution. The so called "Zebra Effect" was also observed on many Group F category of roads, particularly near rail stations and docks and piers due to the relatively poor uniformity of the installed lighting distribution.

As discussed earlier, Group F category of roads are among the most specialized types of roads and as such require well-defined specialized Lighting Maintenance Plans for proper and periodic upgradation, retrofitting, repairing and re-lamping as needed of the existing lamps, luminaires and other associated accessories and paraphernalia for the proper function of the lighting installation as it is intended to be. However, during our fieldwork it was often found at various sites and locations of Group F type roads that a proper Lighting Maintenance Plan either did not exist or was rarely, if ever implemented as vital roads near airports, major ports and rail stations which form the lifeblood of the economy carrying essential food grains and raw materials were illuminated with ages old and almost defunct luminaires often without the necessary Ingress Protection (IP) rating required to protect them from inclement weather and potential spills from some of the hazardous chemicals being transported on such roads and also many of the lamps and light sources being still used on such roads have long reached the end of their useable or serviceable lifespan, but, are still being used in circulation. Consequently, the crucial Group F category of roads are often left to operate under very poor lighting conditions, which naturally predisposes them to the risks of potential crashes and accidents. In many instances, the alignment and siting of luminaires housed upon high mast poles was found to be inappropriate for the road width and physical characteristics of the roads which also led to the poor uniformity of illumination emanating from the light sources. As with several other categories of roads, the perennial problems which plague Indian roads like rampant vandalism and pilferage of costly lamps, luminaire parts and accessories as well as other essential elements of the lighting installation were found to affect the vital Group F roads as well, often due to the lack of adequate number of traffic or civic personnel or monitoring by technological implements like Closed Circuit Television (CCTV) cameras etc. All these factors considered in their entirety, appear to have had a cumulative effect on the precipitation of the reported road crashes on Group F category of roads.

Over the course of the ongoing discussion, we have been able to survey, scrutinize and comprehend the multifarious intricate elements which have led either implicitly or explicitly to the precipitation of road crashes and mishaps on the different categories of roads as per the IS : 1944 classification in India. During the course of the present analysis, it emerged that the residential and other types of unclassified roads, which constitute the Group C category of roads accounted for the highest crash incidences, followed closely by Group E, Group A1, Group A2 and Group B2 and Group B1 categories of roads respectively. On the contrary, the specialized roads classified under the Group F category of roads recorded the lowest incidences of road crashes in the collected datasets which represent more than a decade long period of road accidents. This was followed closely by the Group D category of roads, which comprised of bridges, flyways, skyways and other similar roads which are at a substantial level of elevation from the normal street level. The evaluation conducted in the present segment provides us a broad perspective into the number or incidences of road crashes according to the category of road and attempts to analyze the causes thereof from a photometric perspective in terms of the available road lighting and it's characteristic traits on location where the crash transpired. In the subsequent segments, we shall aim to study the crashes in greater and more subtle detail in order to glean more information about their cause and to devise improvements to circumvent and avert the same.

Analysis of type of collision on Group C category of roads

In the preceding segments, we have analyzed and evaluated the tabulated road crash statistics and datasets, representing more than a decade's worth of road crash data according to the different categories of roads, streets, highways and specialized thoroughfares classified as per the Indian Standards IS 1944 (Parts I & II) guidelines. The voluminous reams of raw data, collected during the fieldwork phase of the study and corresponding to the road crash data and reports, collected painstakingly from various public and Government authorities and departments had been compiled and synthesized and systematized into tabular form and finally the relevant data fields were streamlined and segregated and analyzed with the aid of visual and pictorial aids like 3D pie chart, which provided a very intuitive and graphic method of quickly and efficiently performing detailed data analysis, interpretation and assimilation. The results of our assessment of the road crashes as per the category of road yielded some startling results in many instances, reaffirmed some old assumptions and conjectures and also opened up new vistas of further investigation and deeper comprehension of the precise correlation of road crashes and the intricate role played in particular by road lighting in the same, which is the primary leitmotif of this dissertation.

In our assessment and segregation of the road accidents as per the category of roads, it emerged, perhaps somewhat surprisingly that the roads catering to transportation in residential areas, localities and neighborhoods and also areas near warehouses, factories, garages and other types of non-classifiable areas were the ones which accounted for the highest frequency and incidences of road crashes, mishaps and also casualties. At the outset, it may have appeared that some of the major categories of large roads, occupying some of the busiest and densest traffic routes like the Group A1 or Group A2 category of roads would account for the highest number of road crashes and calamities. However, the in-depth assessment of the road crash data using efficient tools like the 3 dimensional pie charts presented a somewhat different picture. In the present segment, we shall attempt to assess and understand the road accidents and crashes occurring on the road category with the highest number of reported incidences of crashes from the perspective of the types of collisions that transpired. Studying and evaluating the road crash data from the vantage point of the type of nature of the collisions would enable us to comprehend the data at a much deeper level of granularity and subtle intricacy, providing deeper insights into the causality of the crashes and the interrelationship between the positional orientation of the crash the role played by the available road lighting at the site (or lack thereof) and other pertinent factors in the precipitation of the crash at the particular position.

The evaluation of the road crash data according to the category of collisions, depicting the relative positional orientation of the vehicle with respect to the obstacle or object with which collided or crashed, be it another vehicle, a pillar, post, block of stone, pavement or a pedestrian or other person traversing the roadway would provide us with crucial information about the areas or relative positions where the most number of crashes occur, especially from a photometric perspective and enable us to improve the quality and efficacy of the lighting present in order for it to be able to appropriately and adequately fulfill its intended functions of augmenting the safety and propriety of the road environs and to foster the sense of security, both experienced and perceived for all road users and occupants.

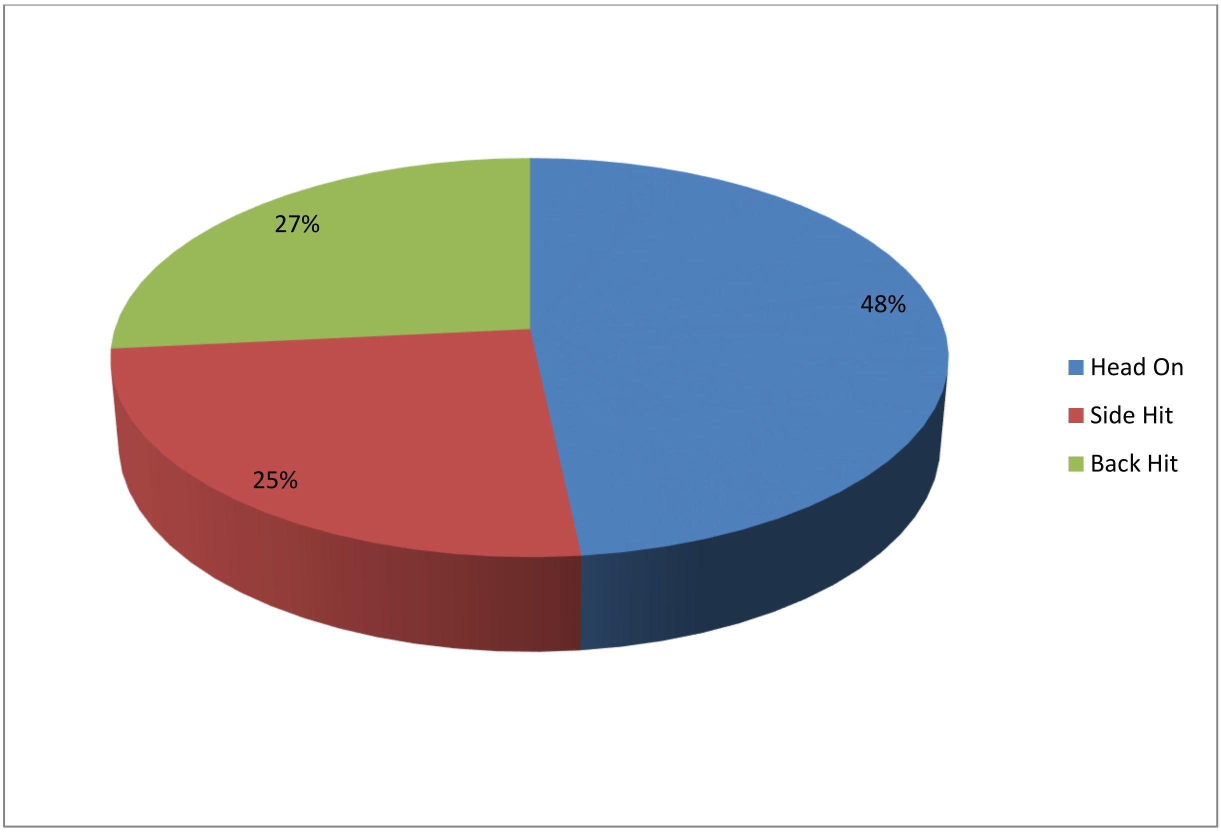


Fig. 13: Proportion of Road Crashes by Collision Types on Group C roads

In the above infographic, the pictorial 3 D pie chart has depicted the the distribution of the relative proportions of the number of road crashes according to the category of collision, which is a representation of the relative positional alignment or orientation of the concerned vehicle or person with respect to another vehicle, object, obstacle or person with which the collision or crash took place. The different categories of collisions are color coded for convenience and graphical clarity. The color coding of the different collision categories are as follows:

1. **Blue** for **Head On** type of collisions
2. **Red** for **Side Hit** type of collisions
3. **Green** for **Back Hit** type of collisions

The categories of collisions occurring under the Group C type of roads, which account for the maximum incidences of road crashes, accidents and casualties in the reported, recorded and tabulated data were first and foremost streamlined and filtered to highlight only the crashes transpiring on the Group C category of roads. Once the incidences of road crashes had been streamlined to reflect only those pertaining to the Group C roads, focus was tuned toward the corresponding collision categories, signifying the relative positions of the colliding objects with respect to each other on different spots or areas of the road surface. The total number of reported crashes which transpired corresponding to each positional collision category was then segregated and their sum total calculated using mathematical techniques in the Microsoft Excel software. The computed sum total of number of crashes for each positional category of collision was fed as the input data for the 3 D pie chart.

The road crash data corresponding to the category or positional orientation of collisions was entered as the sum of the number of crashes for each of the collision types, which the Microsoft Excel software seamlessly converted into a percentage distribution, corresponding to the frequency or number of incidences of road crashes for each category of collision and displayed the 3D percentage pie chart as output, which has been represented as a figure in this segment. The percentage figures depicted in the resultant 3D pie chart were also automatically color coded by the Microsoft Excel software for clarity of visualization. For the ease of our comprehension, the relevant color codes corresponding to the different road categories have been enlisted in the prior sections and provide us with the requisite keys to visually comprehend the information being depicted by the 3 D pie chart.

Before proceeding with the evaluation and assessment of the incidence of road crashes according to the category of collision on Group C type of roads and their relevant significance, it will be prudent for us to be acquainted with the major types of collisions themselves. The type of collision is a crucial parameter in comprehending the road crashes and elucidates the relative spatial orientation of the crashing objects like vehicles with respect to each other. Accordingly, collisions may be of the following major categories:

i. Head On Collision: Head On type collisions, as the name implies are the category of collisions wherein a full frontal collision occurs between two oncoming vehicles or a vehicle and an oncoming person or other object. By their very nature, Head On type collisions usually transpire when the colliding objects are traveling at a direction which is opposite or transverse with respect to each other. Head On type collisions due to the magnitude of their impact shock are often the most hazardous and precipitate the most damages and casualties.

Fig. 14: Head on type collision between two oncoming vehicles

ii. Back Hit or Rear Hit Collision: Back Hit or Rear impact type collisions are the category of collisions, wherein the colliding vehicle or object rams into or collides against the rear side of the collided vehicle and usually causes impact damages to their rear portion as well as secondary damages to other parts of the collided vehicle. Back hit or rear impact collisions, usually occur when the two vehicles or objects are traveling in the same or transverse direction with respect to each other.

Fig. 15: Back Hit or Rear Impact Collision between two vehicles

iii. Side Hit Collision: Side Hit collisions are the category of collisions where the colliding vehicle or object collides against another vehicle of object at either of the sides of or from the lateral direction of the collided vehicle or object. In Side Hit category of collisions, the two vehicles or objects are usually moving at a transverse or cross direction with respect to each other. Side Hit collisions often result in damages to the side doors of vehicles and can cause serious injuries or casualties as the impact of the collision often occurs at the areas where the passengers or driver are seated.

Fig. 16: Side Hit type collision between two vehicles

Studying the intuitive and highly visual graphical data presented by the 3 D pie chart, we are presented with a very simple, yet powerful and in-depth insight into the types of collisions occurring on the Group C category roads, which registered the highest number of road crashes. Looking at the visual representation of the road crash data corresponding to the different types of collisions which occurred according to the relative spatial orientation of the colliding vehicles or objects or persons, we can find the percent weightages of the crash incidences for each category of collision as a proportion of the entirety of the road crash figures occurring on Group C roads for a period spanning more than a decade, as per the collected data. The pie chart provides us a intelligible and perspicuous picture of the number and proportion of crashes for each of the collision categories and also novel revelations and intricate insights into the precise correlation of the crashes and the available road lighting (or lack thereof) and also the role played by the important photometric and other relevant parameters in the precipitation of the crashes.

The data in the 3 D pie chart is presented as slices of a gourmet pie, with the size of each colored slice or chunk of the pie being proportional to the percentage of road crashes which occurred under the corresponding category of collision. Using the color coded slices of the pie as the key indicators of the number of crashes vis a vis each type of collision, we may enlist the following as the percentage of incidences of road crashes occurring for each type of collision:

1. Head On collision: 48% of the total number of road crashes.

2. Back Hit collision: 25% of the total number of road crashes

3. Side Hit collision : 27% of the total number of road crashes

From the above figures extracted from the infographic presented by the 3 D pie chart, it is evident that the Head On category of collisions representing the full frontal crashes between oncoming vehicles or objects were the most frequent and accounted for nearly half of all the road crashes that transpired on the Group C category of roads. The Head On category of collisions are followed by the Side Hit or lateral type of collisions, which represent 27% of the total number of crashes that occurred. The Back Hit or Rear Impact collisions rank in pretty close to the total number of crashes under the Side Hit or lateral type of collisions and represent 25% or exactly a quarter of the overall total incidences of road crashes that transpired on the Group C category of roads.

The data in the visual info graphic as presented in the 3 D pie chart elucidates that the full frontal or Head On category of collisions were the most prevalent on the Group C type roads, which themselves bore witness to the highest incidences of crashes and accidents of all the road types studied in this dissertation. The Head On collisions accounted for precisely 48% or nearly half of all the collisions that transpired on the Group C category of roads, which are predominantly present in residential and other unclassified types of roads.

In attempting to decipher the rationale and causes behind the occurrence of full frontal collisions between vehicles, pedestrians and/or other objects and obstacles in such high frequencies on Group C category roads, we must first and foremost understand the lighting and physical road conditions that are prevalent on such roads. As we have learnt during our discussions in the preceding segments of the study, Group C roads in an Indian context, by their very nature are often bereft of even any semblance of proper traffic personnel, traffic signs or signaling systems and relevant installations and also of proper road divisions or markers for dividing the streams of traffic in opposite directions. Consequently, there were rampant flouting and violations of all manner of traffic rules and regulations, which only heightened the probability of crashes transpiring. As a case in point, it may be mentioned herein that during the fieldwork phase of our study, it was often observed on Group C category of roads that vehicles were traveling in opposite directions of each other at great speeds even when there was provision for only unidirectional travel. Such driving behavior had the obvious consequence of predisposing these roads to greater prospects of potential crashes.

The prevalent traffic and physical road alignment scenario on Group C roads furthermore is greatly exacerbated by the sheer lackluster state of lighting on such roads. During our field surveys, it was found that on many occasions the level of illumination was almost miniscule and negligible to the point of being almost non-existent and in several instances was actually totally nil, which makes it extremely difficult to spot even large objects at fairly short distances. The visibility of smaller objects on such roads was also noticeably low, which is a crucial element in road safety as it enables the driver or motorist to spot potential hazards or obstacles in time to react appropriately and avert disaster. The presence of dark patches was noticeable on many circumstances due to the abjectly poor levels of illumination. All these photometric factors in conjunction with the poor traffic situation and reckless driver behavior greatly contributed to the number and frequency of full frontal Head On collisions on Group C category of roads, as the vehicles would often travel at substantial rates of speed on residential roads with no proper distinctive refuge or physical delineating structures or even markers for segregating the streams of traffic and also the poor levels of illumination which creates dark patches and the lack of proper visual guidance greatly increased the likelihood of collisions. Consequently the number and frequency of Head On type of collisions among oncoming traffic on such roads is relatively quite high and accounts for nearly half of all the collisions transpiring on such roads.

Focusing our attention toward the Back Hit or Rear Impact category of collisions which transpired on Group C type of roads, we find that much of the elements which had a distinct causal impact on full frontal crashes hold sway for rear impact type of collisions as well. Back Hit or rear impact type of crashes are more prevalent when the vehicles are traveling in the same direction or one vehicle is approaching another from a transverse direction and happens to collide with the rear end of the other vehicle at a crossing or intersection point between two roads which themselves are in a transverse orientation relative to each other. During our field surveys it was observed that in different roads, classifiable under the Group C categorization, due to the lack of appropriate and adequate traffic monitoring and often in utter disregard of all traffic rules and road etiquettes, vehicles would ambulate at significant rates of speed on residential roads and in particular on relatively narrow and cramped roads in residential areas, neighborhoods and localities.

Also, as discussed earlier, the quality and efficiency of the road lighting installation on such roads was found to be pretty shoddy, sub-par and inadequate on most occasions. On occasions where the level of illumination were adequate, the luminaires were often found to be of poor design or oriented in such fashion that led to stray and excessive light being emitted from them and present in the observer's Field of View (FOV), which gives rise to unnecessary and visually disconcerting glare, usually a prime factor in many road mishaps. The poor levels of illumination from old and almost derelict lamps and corresponding luminaires led to very poor visual performance which greatly degraded the level of visibility and significantly increased visual fatigue and discomfort on such roads in the hours of darkness, caused poor visual contrast and object identification and timely reaction to threats and obstacles on the road surface. As such, these vehicles often drove at relatively high speed on narrow, congested and cramped residential roads and owing to the predominantly poor lighting conditions in the hours of darkness, collided against both stationary and mobile objects like pillars, pillions, posts, roadside kerbs, stray stones and boulders, people and other moving motor vehicles and cars in catastrophic rear impacts which severely damaged objects, property and the vehicle(s) in question, injured, maimed or even led to casualties of people as well as roadside animals and pets.

Concerning the Side Hit category of collisions, we find that the lateral impact or Side Hit collisions accounted for more than a quarter of all the crashes that transpired on the Group C type roads, 27% of the total number of crash incidences to be precise, which ranks second only to the number of crashes reported under the Head On or full frontal type of collisions. Side Hit or lateral impact category of collisions usually are the ones which transpire when a vehicle, person or object is usually moving in a direction to transverse to the colliding vehicle, person or object. Group C category of roads are usually the ones traversing residential blocks, neighborhoods and localities as well as roads connecting relatively offbeat properties like warehouses, garages, derelict and rundown apartments, back alleys, neighborhood streets and other such types of streets and roads which cannot otherwise be properly classified. Due to the very nature of residential and other types of associated neighborhood and unclassified roads, we often find intricate grid like structures emerging within the streets and road networks in such areas, with interconnecting and interlocking streets and alleys being commonplace in such local roads, which makes them a fertile ground for Side Hit or lateral collisions among different vehicles which are traversing the interconnected network of alleys, streets and roads.

Also, as was witnessed during our field surveys, most Group C roads in different locales which formed the essential backdrop of this study, were completely devoid of any proper traffic personnel, traffic signs or signaling systems and other requisite monitoring equipment. Ergo, there were unbridled flouting and violations of traffic rules and regulations, which only augmented the probability of road crashes. It was found in many instances, that drivers were hit by the speed bug and drove at higher speeds than was warranted on such residential and local roads. As discussed in the preceding sections, the condition of the installed road lights and luminaires was pretty deplorable with very low illuminance levels and poor uniformity of illumination being prevalent in the majority of roads, streets, alleys and locales which consequently lead to vast swathes and patches of the roads being rendered dark with very low visibility and also the visual contrast was significantly less.

The alignment of the road lighting poles and high masts, whenever present is pretty ill spaced and improperly oriented, which fails to provide adequate visual guidance for drivers and the resultant visual fatigue is a major concern on such roads. On the contrary, in instances where the requisite levels of illumination were met, the luminaires were often unshielded or inadequately shielded which led to the generation of unwarranted glare causing a great deal of visual distraction and discomfort and even momentary blinding effects for the drivers and motorists. It may also be noted that the timely execution of Lighting Maintenance Plan and repairs and retrofitting of defunct lamps and luminaires for Group C roads was probably the poorest among all the categories of roads surveyed under this study and on many occasions repairs and upgradation of old lamps, poles and luminaire housings were not conducted even over a period of several decades.

The culmination of the narrow interconnecting grid like network of roads, streets and alleys along with the poor traffic monitoring and even more atrocious condition of the road lighting installations and essentially non-existent repairs and retrofitting operations, combined with unrestrained driving behavior precipitated the large number of Side Hit or lateral impact type of collisions, which often resulted in serious injuries and casualties due to the very nature and zone of the impact on the Group C category of roads, which account for the highest incidences of road crashes as surveyed in this study.

Analysis of collisions by road position on Group C type roads

In the preceding segment, we have assessed and evaluated the nature and categories of road collisions, whether full frontal/Head On type of collisions, Back hit/rear impact type collisions or Side Hit/ lateral impact type of collision which were prevalent on the Group C category of roads, primarily present in residential areas, neighborhoods, localities as well as connecting off beat and unclassified locations. As we had evidenced in our earlier discussions, the Group C category of roads witnessed the highest incidences of road traffic crashes and catastrophes, accounting for no less than 21% of all the major types and categories of streets, roads and roadways surveyed and analyzed under this study as per the IS 1944 classification and guidelines.

In our evaluation of the types and groupings of the collisions, it emerged that the full frontal or Head On type of collisions, usually among oncoming vehicles from differing directions were the most commonplace, representing nearly half of all the crashes on Group C roads and resulting often in severe injuries or even fatalities owing to the momentum and impact of the crashes. This was followed by the Side Hit or lateral impact type crashes, which comprised of 27% of all the recorded crashes on the intertwining and interconnected Group C roads, where lateral and transverse movement of vehicles with respect to each other is pretty frequent. The Back Hit or rear impact type of crashes also represented nearly similar incidences of crashes as the lateral impact ones, accounting for exactly a quarter (25%) of all the recorded road crashes and mishaps on Group C type of roads. In the previous segments, we have analyzed and studied at length the probable causes and prevalent scenarios which led to the precipitation of each of the categories of collisions on the Group C roads and what significance was played by the same. In the present segment, we shall endeavor to study the physical positions or areas of the road surfaces which accounted for the most incidences of crashes and collisions on the Group C category of roads, where the highest overall number of road crashes were reported in the collected and tabulated data sets pertaining to the decade long road crash statistics.

The evaluation of the road crash data according to the physical position of collisions, depicting the area of the road whether a major crossroads or junction or intersection of several key local roads or streets or a midway turning point, representing a demarcated area of intersection of two or more roads or a point of side entry, signifying a portal of entry or egress to or from the concerned roadway would provide us with invaluable information as to the nature and mechanism of the road crashes and the impact played by the available road lighting installation on the precipitation of the same. The assessment of the road crashes according to the position or location of the road surface area would provide us with subtle and intricate details about the traversing the roadway would provide us with crucial information about the how the positional and location based impact and differentiation effected the crashes and possible role played by the same in the precipitation of the crashes. This evaluation of the road crashes according to the position, especially from a photometric perspective would thus enable us to evaluate the quality and efficacy of the lighting present in order for it to be able to adequately fulfill its functions of enhancing the safety of the road environs and to augment security, both experienced and perceived for all road users and occupants.

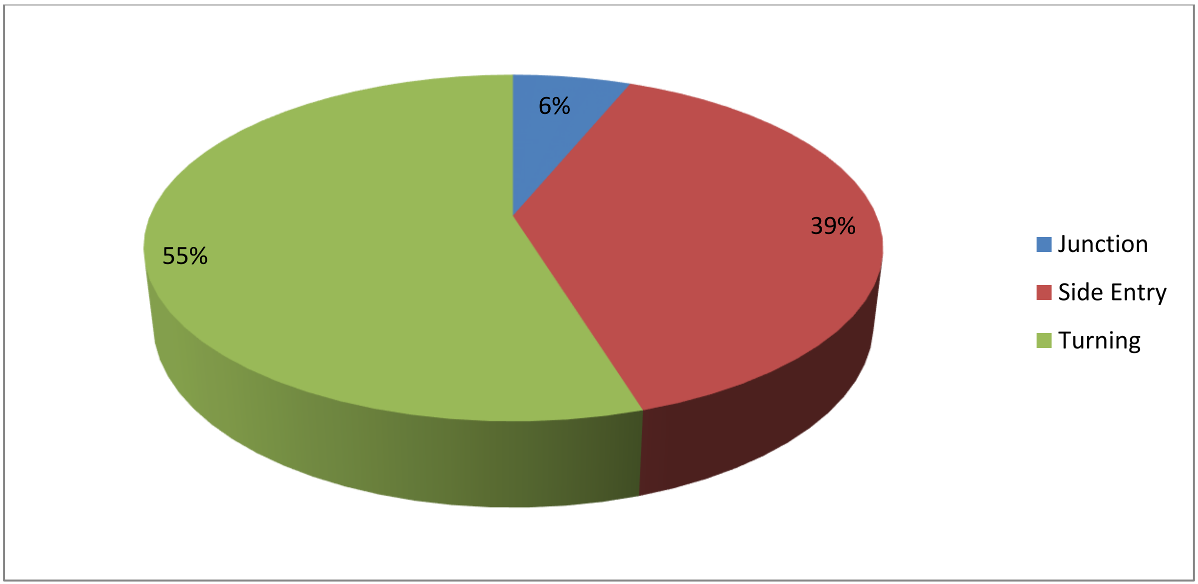


Fig. 17: Road crashes distribution by road position on Group C type roads

In the visual pictogram presented above, the 3 D pie chart has depicted the distribution of the relative proportions of the number of road crashes according to the position of collision or the site of collision on the road surface. The different major types of road positions are color coded for convenience and ease of visual comprehension. The color coding of the different categories of road positions are as follows:

1. **Blue** for **Junctions**
2. **Red** for **Side Entry**
3. **. Green** for **Turning**

The categories of road positions corresponding to the road crashes transpiring under the Group C type of roads, which account for the maximum incidences of road crashes, accidents and casualties in the recorded and tabulated data were streamlined and filtered to underscore only the crashes that took place on the Group C category of roads. Once the incidences of road crashes had been streamlined to represent only the ones occurring on the Group C roads, our analytic attention was aligned toward the positions on the road area where the crashes occurred, signifying the prominent traffic locations of vehicular passage and interflow where the collisions between the vehicles and/or other vehicles, pedestrians and objects transpired. The total number of reported crashes which occurred corresponding to each traffic position on the road was then segregated and their sum total calculated using mathematical techniques in the Microsoft Excel software. The computed sum total of number of crashes for each road position was subsequently fed as the input data for the 3 D pie chart.

The road crash data corresponding to the category of the crash site or location of collisions was entered as the sum of the number of crashes for each of the road spots, which the Microsoft Excel software seamlessly converted into a percentage distribution, corresponding to the frequency or number of incidences of road crashes for each traffic spot on the road surface and displayed the 3 D percentage pie chart as output, which has been represented as a figure in this segment. The percentage figures depicted in the resultant 3 D pie chart were also automatically color coded by the Microsoft Excel software for clarity of visualization. For the ease of our comprehension, the relevant color codes corresponding to the different road categories have been enlisted in the prior sections and provide us with the requisite keys to visually comprehend the information being depicted by the 3 D pie chart.

Prior to delving deep with the assessment and assimilation of the incidence of road crashes according to the position or area of the road surface where the collision transpired on the Group C type of roads and their relevant significance, it will be prudent for us to be conversant with the major types of traffic positions on the road surface. The position of the road surface or the site of crash is a very crucial parameter in comprehending the mechanism of the road crashes and elucidates the significance of the presence or absence of road lighting and it's variations as per the position and location of the road surface. Accordingly, the major types of road surfaces may be enumerated as:

i. Junction: A junction is a major traffic area**.** It is a crossroads or an intersection area of multiple roads. Junctions on major roads are usually areas of heavy traffic density and are supposed to be manned by traffic personnel and monitored constantly for the safe regulation of traffic. The road lighting requirements for Junctions and major road intersections are also the most stringent.

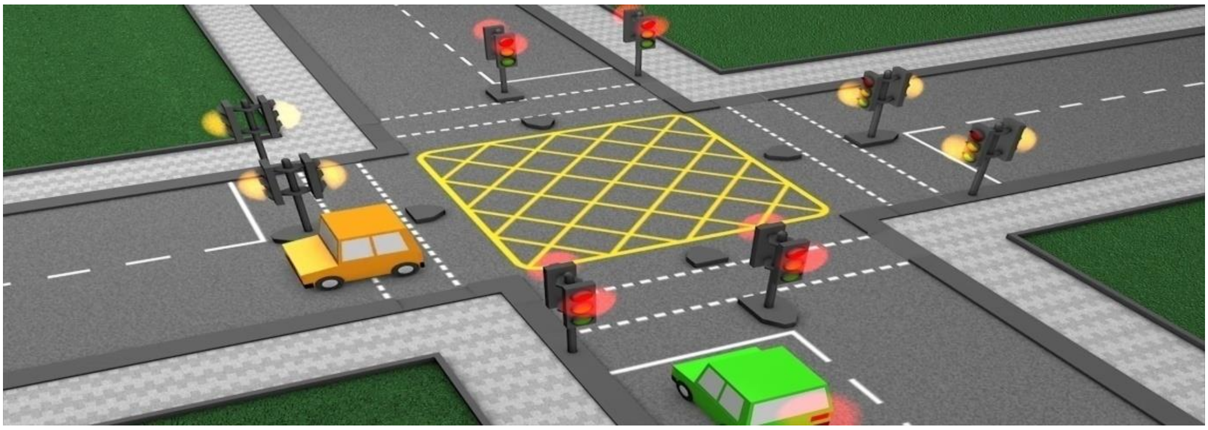


Fig. 18: Visualization of a typical road junction or crossroads

ii. Turning: A turning implies areas of indents or gaps on a continuous stretch of road surface where it is permissible as per local traffic rules for vehicles to cross over to the other side of the road in case of dual carriageways or onto another road or street in case of other roads. Proper road lighting and traffic signals or signs should be imperatively present at turnings to prevent mishaps. Areas demarcated as U turns are also part of Turnings.

Fig. 19: Visualization of a Turning on a Dual Carriageway type road

iii. Side Entry: A side entry implies areas of a continuous stretch of road surface where it connects with other adjacent roads or lanes and from where vehicles from and to such roads or lanes may enter or leave the concerned continuous road. Road lighting and traffic signaling for side entries needs to be adequate and appropriate to provide proper visual guidance and caution to the drivers, motorists, pedestrians and all other road users.

Fig. 20: Visualization of a Side Entry on a continuous road stretch

Evaluating the infographic data, we are presented with simple, information rich and intricate bird's eye view into the road crashes occurring at different locations and positions on the road surface on the Group C category roads, which recorded the highest incidence of road crashes of all the road categories studied in this discourse. Looking at the visual representation of the road crash data corresponding to the different locations of collisions or the respective crash sites, we can obtain the percent weightages of the crash incidences for each road positions as a proportion of the entirety of the road crash figures corresponding to the Group C roads for a period spanning more than a decade, as per the data collected from the various Government and public authorities and departments. The 3 dimensional (3D) pie chart provides us with an easily comprehendible and highly perspicuous picture of the number and proportion of crashes for each of the road positions and also hitherto unheard of revelations and intricate insights into the precise correlation of the crashes and the available road lighting (or lack thereof) and also the role played by the important photometric and other relevant parameters in the precipitation of the crashes.

The data in the 3 D pie chart is presented as slices, just as one would expect in a food dessert pie, with the size of each colored slice or chunk of the pie delicacy being proportional to the percentage of road crashes which transpired at the corresponding road position or crash site under the Group C category of roads. Using the color coded slices of the pie as the key indicators of the number of crashes vis a vis each crash position, we may hereby enumerate the following as the percentage of incidences of road crashes occurring for each crash position:

1. Junction - 6% of the total number of road crashes.
2. Side Entry - 39% of the total number of road crashes.
3. Turning - 55% of the total number of road crashes.

From the above percentage figures, which have been distilled from the 3 D pie chart, it is apparent that the Turnings on road surfaces were the sites which witnessed the highest frequency and occurrences of road crashes on Group C category of roads and accounted were the predominant majority, namely 55% of all the road crashes that transpired on the Group C category of roads. The number of crashes recorded at the Turning position are followed by the Side Entry or lateral entry type of collisions, wherein the continuous roads are connected with adjacent side roads and which demarcate points of entry or exit to or from the continuous road. The number of collisions at the Side Entry intersections represent 39% of the total number of crashes that occurred on the Group C roads. Finally, on Group C category of roads, we find perhaps somewhat surprisingly that large Junctions which often witness relatively hefty magnitudes of traffic flow on most roads accounted for just 6% of the total number of road crashes on the Group C roads. In the forthcoming sections, we shall aim to understand the causes and mechanisms behind the precipitation of the crashes on the different types of road positions and the crash sites.

In endeavoring to unravel the reasons and rationale behind the occurrence of collisions between vehicles, pedestrians and/or other objects and obstacles at the Turnings and intersections of different road surfaces, we must primarily comprehend the lighting and physical road alignment and conditions that are prevalent on such roads. Turnings are the areas of indents or gaps on continuous stretches of the road surface where it is permissible as per local traffic rules for vehicles to cross over to the other side of the road and in case of dual carriageways or onto another road or street in case of other roads. It is germane to observe here that the points of "U turns" as they are colloquially referred to are also considered to be Turnings. Turnings represent a significant location on any road surface, and calls for the highest levels of caution as it is often visually not possible to anticipate what vehicle, object, obstacle or person may lie at the edge of the bend in a Turning. Thus, proper road lighting and traffic signals or signs play an absolutely indispensable role in averting crashes and mishaps at the points of Turning.

During our fieldwork surveys, it was often observed that on, Group C roads, Turnings, U turns and other similar interconnects between roads, lanes, alleys and streets which involved the vehicles veering or change the course of their direction and movement, proper traffic signs and signals and also road lights were conspicuous by their notable absence. In the vast majority of observed cases, traffic signals were either absent or were concealed under other objects or poorly visible. Road Lighting was found to be present in many Turnings. However, their presence was sporadic and inconsistent even on the same stretch of road surface with multiple turnings, wherein they would be present at one point of turning and absent on the rest, This led to the present of large swathes of dark patches where visibility would be very poor under darkness or conditions of low lighting. On the instances where high mast lighting was indeed available, it was often found to be too bright or poorly shielded, which led to inadvertent glare and visual distraction. Also, the alignment of the poles was not in a manner concordant with the provision of good visual guidance and consequently visual fatigue and discomfort was prevalent under such lighting conditions. As discussed earlier, it was frequently observed on Group C roads that there were unrestrained traffic violations and over speeding in residential roads which exacerbated the prevalent lighting and road conditions and made the situation ripe for possible crashes and may be attributable to the very high frequency of crashes observed at Turnings and U turns on such roads.

The alignment of the residential and other unclassified Group C type of roads is often such that they form interlocking and interconnecting mesh or grid like structures of lanes, alleys, streets, roads and also highways and interlinks between minor and major roads. As such, the number of laterally connected roads which generate points and portals of Side Entry for vehicular traffic and motorists is quite high on such roads. As with most Group C types of roads, it was observed at the points of Side or lateral entry of vehicles that the road lighting conditions were abject to say the least. Points of Side Entry or lateral intersections are often among the most vulnerable areas on road surfaces due to the angular movement of vehicles and other objects with respect to each other, which renders mutual visibility a daunting task and the lack of proper road lighting makes this task an even more herculean endeavor. It was often found that that level of illumination at most points of Side Entry were pretty low and negligible to the point of being almost non-existent and on many occasions, such points on the road surface were actually devoid of any form of lighting whatsoever, which makes it extremely difficult to spot objects at even short distances. The presence of dark patches was noticeable on many circumstances due to the substantially poor levels of illumination and object contrast was also detrimentally effected, which all leads to very poor visual performance for the concerned driver, motorist or other observer. Also, as has been discussed in prior sections, the presence and execution of proper Lighting Maintenance Plans for repairing and upgrading derelict lamps and luminaires on Group C category of roads was among the poorest of all the road categories. All these physical and photometric elements, working in synergy with the poor traffic situation and oftentimes reckless driver behavior greatly aided and were instrumental in the number and frequency of lateral collisions at the points of Side Entry as the vehicles were literally driving blind on many occasions due to the lack of any proper Visual Guidance being afforded to the driver or motorist by the available road lighting installation.

Finally, we observe that the number of road crashes reported at crossroads or Junctions on the Group C category of roads were relatively low, at a mere 6% of the total number of reported crashes on such type of roads. Usually, on major types of roads, Junctions are the points which witness the maximum flow of traffic, which often require the highest levels of illumination and consistent monitoring of traffic to successfully avert incidences of crashes. However, on the Group C category of roads, perhaps due to their very nature of being located in predominantly residential areas, neighborhoods and other offbeat and non-conventional locations, the number of major intersections between roadways or crossroads and Junctions was relatively much lower than on other categories of roads. However, at the crossroads that were indeed observed during our field survey expeditions, it was found that the levels of illumination were pretty low compared to the standards expected of junctions and many of the crossroads were completely devoid of any form of high mast road lighting. Consequently, this led to a significant number of crashes at such areas even though the overall number of crashes recorded there were low compared to the overall incidences for all the crash sites combined.

In the foregone and ongoing sections, we have studied and analyzed the incidences of the road crashes on the Group C category of roads, which accounted for the highest number of road crashes according to the parameters of the type and nature of collisions as well as the physical locations or the collisions or the crash sites. In the forthcoming sections, we shall aim to analyze and evaluate the road crashes according to different parameters on the other major categories of roads, which also contributed significantly to the overall number of road crashes.

Analysis of type of collision on Group A1 category of roads

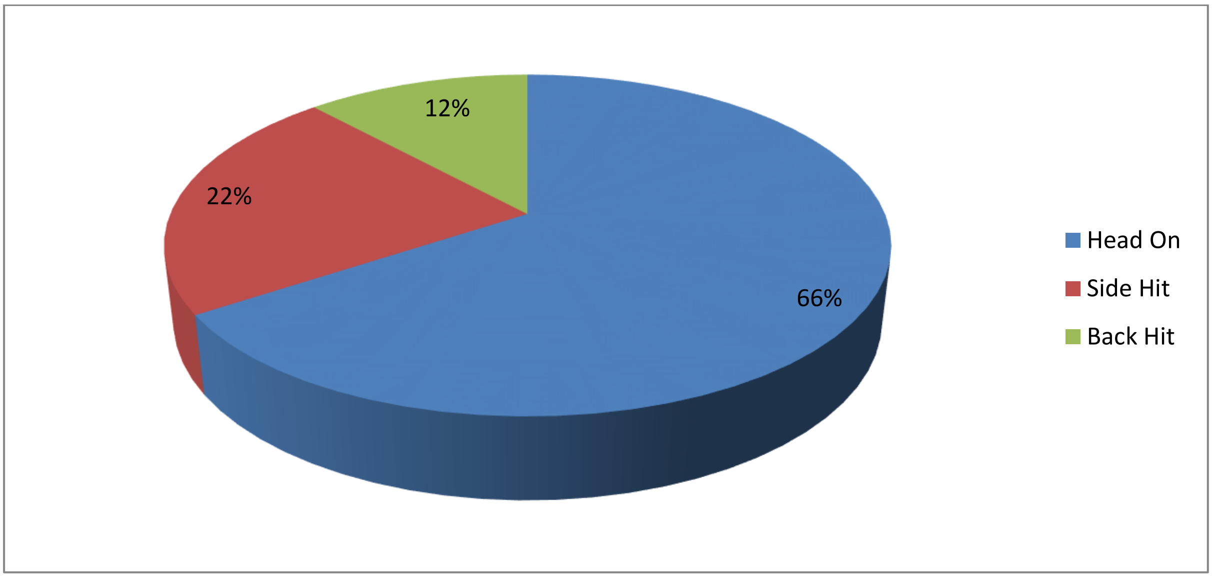


Fig. 21: Proportion of Road Crashes by Collision Types on Group A1 roads

In the visual pictogram presented above, the 3 D pie chart has depicted the distribution of the relative proportions of the number of road crashes according to the type and nature of collision or. The segregated data pertaining to the crashes that transpired according to the various road and traffic positions on the Group A1 category of roads were examined by computing the sum total of the number of crashes reported for each type of collision and entering the same as inputs for the 3 D pie chart graphic tool in the Microsoft Excel software, which then produced the corresponding percentage distribution of crashes for the different crash types in the output 3 D pie chart that has been presented herein.

For the sake of clarity, the color coded output of the 3 D pie chart data may be enlisted as follows:

1. **Blue** for **Head On type collisions**

2. **Red** for **Side Hit type collisions**

3. **Green** for **Back Hit type collisions**

Glancing at the 3 D pie chart reveal the following percentage distribution of incidences of road crashes for each of the 3 major types of collisions:

1. Head On collisions - 66% of the total number of road crashes

2. Side Hit collisions - 22% of the total number of road crashes

3. Back Hit collisions - 12% of the total number of road crashes

Perusing the data revealed by the 3 D pie chart, we find that the Head On or full frontal type of collisions are the most predominant type of collisions which occurred on Group A1 type of roads, being responsible for a whopping 66% of the total number of reported crashes. This is followed by the Side Hit or lateral impact type of collisions, which accounted for exactly a third of the collisions reported under the Head On type, namely at 22% of the total crash incidences. Finally, the Back Hit or rear impact category of collisions accounted for a relatively lower, but still significant proportion, namely 12% of the overall reported crash incidences.

In order to aptly comprehend the reasons behind the different type of crashes occurring on the Group A1 category of roads, we must be conversant with the nature and physical traits of the Group A1 roads. Group A1 roads are the ones found on major traffic routes, which witness the highest and densest transit of traffic and are usually located in the precincts or neighborhoods with the busiest vehicular transit like major crossroads, downtown junctions, highways etc. On Group A1 roads, the only considerations from a lighting perspective are the safety and speed of the traffic and the comfort of the drivers. Looking at the data represented by the 3 D pie chart, we find that the Head On or full frontal collisions were the predominant types of collisions on Group A1 roads. On Group A1 roads, the speed of vehicular transit is the highest and the lighting needs to be adequate to provide proper visual guidance to the drivers & motorist while executing sharp turns or navigating bends, crossing roads or even changing the course of travel. During our field surveys, it was often found that the lighting at key focal and movement points on Group A1 roads was either deficient in terms of the level of illumination or in cases where the requisite levels were met, they were often overshot, resulting in unwarranted glare and visual impairments due to excessive light levels and also poor shielding of the luminaire housings. Also, in many of the busiest traffic routes, adequate traffic monitoring was found lacking and greater emphasis needs to be put on automated monitoring aided by the latest technology, instead of just manual monitoring. Consequently, a large number of Head On or full frontal collisions were reported on Group A1 roads between oncoming vehicles traveling at opposite or transverse directions due to the relative high speed of travel, the traffic density and the severely lacking efficiency of the road lighting, whenever available at all.

The physical alignment, traffic density and speed of vehicular transit on the Group A1 roads also predispose them to substantial incidences of lateral impact crashes, As a matter of fact, lateral impact or Side Hit type of collisions accounted for close to a quarter of the total number of crash incidences, 22% to be precise. Side Hit or lateral impact category of collisions usually are the ones which transpire when a vehicle, person or object is usually moving in a direction transverse to the colliding vehicle, person or object. Group A1 category of roads are usually the major traffic roads and include the busiest downtown thoroughfares, national, state and interstate highways and expressways. These roads, especially the ones in urban and suburban locales are often intricately connected with several other major and minor roads and lanes, which divert traffic away or bring traffic into the major roads. As a result, this creates multiple points and portals of inflection for lateral movement of traffic. Also, when traffic diverts from the major roads to the minor roads and vice versa, often drastic changes in speeds are noticed. These movements require the lighting at the side entry points to be adequate for providing proper visual guidance. However, it was found on most locations that the lighting was not up to the mark and failed to provide even the minimum requisite levels of illumination laid down for the Group A1 category of roads. Also, the alignments of the poles and luminaires was inappropriate, which failed to provide the necessary visual guidance for timely detection and identification of potential obstacles while crossing over in a lateral position. All these factors appear to have significantly contributed to the high number of Side Hit crashes on Group A1 roads.

Concerning the Back Hit or rear impact type collisions, we find that they accounted for 12% of the total crash incidences on the Group A1 category of roads. Back Hit or rear impact type of crashes are more prevalent when the vehicles are traveling in the same direction or one vehicle is approaching another from a transverse direction and collides with the rear end of the other vehicle at a crossing or intersection point between two roads which themselves are in a transverse alignment with respect to each other. During our field surveys it was observed that on various instances of major Group A1 and aligned as well as connected roads, there was a dearth of adequate traffic monitoring and often in utter disregard of all traffic rules and etiquettes, vehicles would travel at significant speeds even in areas where specified speed limits had been stipulated. The lighting on such roads, as has been discussed was far from satisfactory, save for a few notable exceptions, and as such the vehicles were often found to dash against stationary or moving objects and vehicles, including even parked vehicles from the rear side on both continuous stretches of road as well as turnings and sharp bends, where the visual guidance and thus, the identification of objects upfront was considerably due to the severely lacking nature of the available road lighting and under many circumstances, the total non-existence of any form of lighting. Consequently, a substantial amount of rear impact or Back Hit type of collisions were found to have transpired and recorded on the Group A1 category of roads.

Analysis of collisions by road position on Group A1 type roads

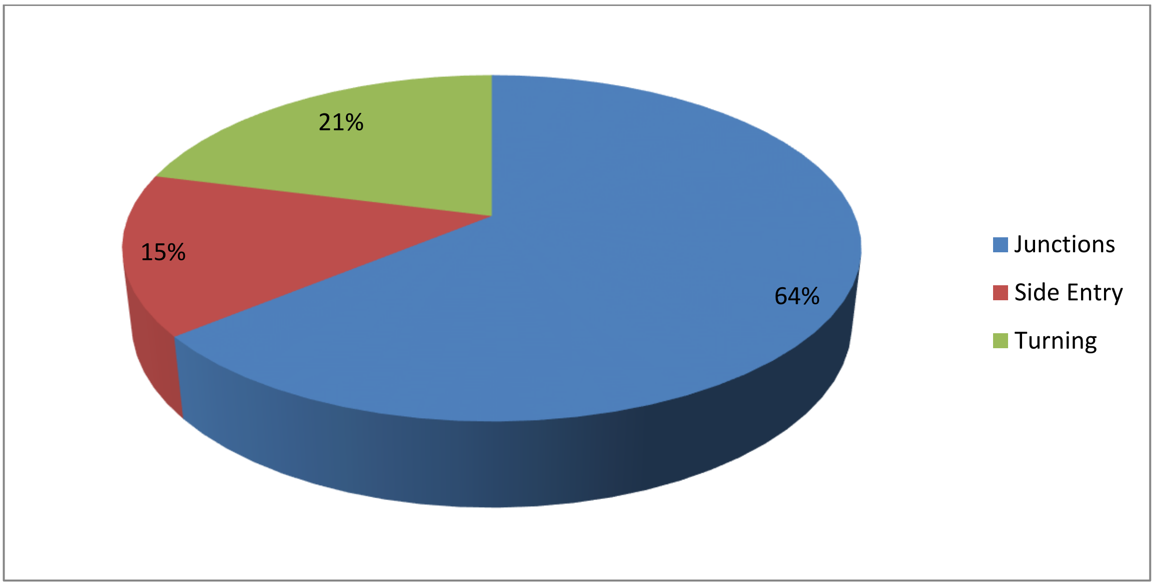


Fig. 22: Road crashes distribution by road position on Group A1 type roads

In the preceding segment, we have assessed the nature and categories of road collisions on the Group A1 type roads. In the present segment, we shall attempt to evaluate and analyze the physical position of collisions on Group A1 roads, depicting the area of the road whether a major crossroads or junction or intersection of several key local roads or streets or a midway turning point, representing a specified area of intersection of two or more roads or a portal of side entry, signifying a threshold of entry or egress to or from the concerned roadway, highway or expressway would provide us with crucial insights and in-depth information about the nature and mechanism of the road crashes and the impact played by the available road lighting installation on the precipitation of the same. The sequestered data pertaining to the crashes that transpired according to the various road and traffic positions on the Group A1 category of roads were examined by computing the sum total of the number of crashes reported at each road position and entering the same as inputs for the 3 D pie chart graphic tool in the Microsoft Excel software, which then produced the corresponding percentage distribution of crashes for the different road traffic positions in the output 3 D pie chart that has been presented herein.

For the sake of clarity, the color coded output of the 3 D pie chart data may be enlisted as follows:

1. **Blue** for **Junction**

2. **Red** for **Side Entry**

3. **Green** for **Turning**

Glancing at the 3 D pie chart reveal the following percentage distribution of incidences of road crashes for each of the 3 major types of collisions:

1. Junctions - 64% of the total number of road crashes

2. Side Entry - 15% of the total number of road crashes

3. Turning - 21% of the total number of road crashes

Scrutinizing the data revealed by the 3 D pie chart, we find that the Junctions or major crossroads, which witness the highest density of traffic and speed of vehicular transit were the sites that recorded the highest incidences of crashes on the Group A1 type of roads, being responsible for 64% of the total number of reported crashes. This is followed by the points of Side Entry, which accounted for precisely 15% of the total number of the road crashes. Finally, the areas of Turnings, but accounted for more than a fifth of the total number of -crashes, precisely 21% of the total crashes.

We shall now strive to unravel the mechanism of the crashes at the different road positions and traffic sites on the Group A1 roads and the causes thereof. Group A1 roads are the roads traversing the major traffic routes, which are the hosts of the densest flow of traffic and are usually located in the precincts or neighborhoods with the busiest vehicular transit like major crossroads, downtown junctions as well as national, state and interstate highways etc. From a photometric perspective, on Group A1 roads, the only considerations are the safety and speed of the traffic and the comfort of the drivers. As such, at the major crossroads, Junctions and important multilane intersection points and crossings, the density and speed of transit of vehicular traffic is the highest, which by extension also require the most demanding lighting to prop the heavy and rapid transit of traffic.

As reflected in the recorded and tabulated data and also witnessed firsthand during our field surveys, it was often found that the lighting at key focal points, junctions and major road intersections on Group A1 roads was wanting in terms of the level of illumination, resulting in vast swatches of darkness with poor or almost nil visibility. Au contraire, in cases where the recommended minimal levels were indeed met, they were often exceeded by large degrees, resulting in unwarranted glare and visual impairments due to excessive light levels and also poor shielding of the luminaire housings. Also, in many of the most vital junctions and traffic intersections, adequate traffic monitoring was found lacking and greater stress needs to be laid on the usage of smart and automated monitoring systems aided by the latest technology, rather than just manual monitoring, which can become inefficient due to the sheer bulk of traffic flow and the rapid transit of the vehicles. Consequently, a large number of crashes and collisions, be it full frontal or lateral or even rear impact collisions were reported at the major junctions, crossroads and large traffic intersection points on the Group A1 roads between oncoming vehicles traveling at opposite or transverse or same direction due to the relative high speed of travel, the sheer density and bulk of such traffic in conjunction with the abjectly shoddy quality and efficacy of the road lighting, if present at all.

The alignment of the Group A1 category of roads is often such that they form interlocking and interconnecting mesh or grid like structures. These roads, especially the ones in urban and suburban locales are often intricately connected with several other major and minor roads, lanes, alleys, streets and lanes, which divert traffic away or bring traffic into the major roads. and also highways and interlinks between regional roads and major expressways of mass movement of traffic and goods carrying vehicles. As a result, this creates multiple points and portals of inflection for lateral movement of traffic. Also, when traffic diverts from the major roads to the minor roads and vice versa, often drastic changes in speeds are noticed. These movements require the lighting at the side entry points to be adequate for providing proper visual guidance. Points of Side Entry or lateral intersections are often among the most vulnerable areas on road surfaces due to the angular nature of the movement of vehicles and other objects relative to each other, which renders mutual visibility a daunting task and the lack of proper road lighting makes this task an endeavor of gargantuan proportions. However, it was found on most locations that the lighting was not up to the mark and failed to provide even the minimum requisite levels of illumination laid down for the Group A1 category of roads. Also, the alignments of the poles and luminaires was inappropriate, which failed to provide the necessary visual guidance for timely detection and identification of potential obstacles while crossing over in a lateral position. All these factors appear to have significantly contributed to the relatively substantial number of crashes at the points of side entry, which accounted for 15% of all the crashes on the Group A1 category of roads.

Turning our analytical attention to the road crashes on Turnings, bends, U turns and other similar points of vehicular movement which usually involve the change of direction of transit, we find that on Group A1 roads crashes at such locations accounted for more than a fifth or precisely 21% of the total crash incidences. It is imperative for the lighting in such areas to be absolutely up to scratch due to the sharp turns, bends and curvatures on the road surface which by their very nature preclude the proper visibility of oncoming or traveling traffic on the other side.

In the vast majority of observed cases, traffic signs and signals were either absent or poorly visible. The presence of quality road lighting was inconsistent even on the same stretch of road surface with multiple turnings, wherein they would be present at one point of turning and absent on the rest, This led to the present of large swathes of road areas where visibility would be very poor. On occasions where high mast lighting was available, it was often found to be too bright or poorly shielded, which led to unwarranted glare and visual distraction. The high mast poles were also misaligned and mis-oriented with respect to the provision of good visual guidance and thus, visual fatigue and discomfort was pretty prevalent under such lighting conditions. Also, the substantial speeds of vehicular movement on such roads exacerbated the prevalent lighting and road conditions and made the situation ripe for possible crashes and may be attributable to the very high frequency of crashes observed at Turnings and U turns on Group A1 roads.

Analysis of type of collision on Group A2 category of roads

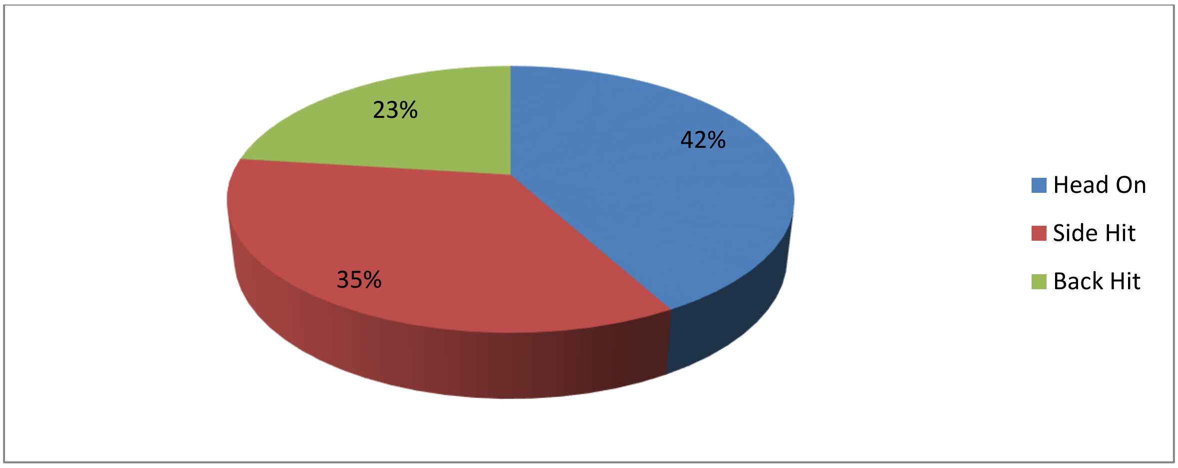


Fig. 23: Proportion of Road Crashes by Collision Types on Group A2 roads

In this segment of our ongoing analyses of the road crashes recorded over a decade at various locations across India, we shall venture to assess the types of collisions which occurred on the Group A2 category of roads. As observed over the course of this dissertation, the major types of collisions which were recorded on the different categories of roads in this study are Head On or full frontal collisions, Side Hit or lateral impact type collisions and the Back Hit or rear impact type of collisions. The streamlined data corresponding to the crashes that transpired on the Group A2 category of roads were appraised by computing the sum total of the number of crashes reported under each type of collisions, which were then entered as inputs for the 3 D pie chart visual graphic tool in the Microsoft Excel software. The 3 D pie chart displayed the output percentage distribution of crashes for the collision types in distinctive color coded format, that has been presented herein.

For clarity and convenience, the color coding scheme of the 3 D pie chart data may be enumerated as follows:

1. **Blue** for **Head On type collisions**
2. **Red** for **Side Hit type collisions**
3. **Green** for **Back Hit type collisions**

Glancing over the 3 D pie chart reveal the following percentage distribution of incidences of road crashes for each of the 3 major types of collisions:

1. Head On collisions - 42% of the total number of road crashes
2. Side Hit collisions- 35% of the total number of road crashes
3. Back Hit collisions - 23% of the total number of road crashes

It is evident from the above percentage figures, distilled meticulously from the tabulated datasets by the 3D pie chart, that the full frontal Head On collisions accounted for the highest incidences of road crashes on the Group A2 category of roads, representing 42% of the total number of road crashes. This was followed by the Side Hit or lateral impact type of collisions, which signify 35% of the total incidences of road crashes. Finally, the Back Hit or rear impact type of collisions were responsible for nearly a quarter of the total incidences of the road crashes, 23% of the overall crashes to be precise. A cursory perusal of the presented data tells us that the distribution of the crashes according to the collision types bears resemblances to the ones observed for the Group A1 category of roads.

The Group A2 category of roads are the ones which are primarily meant for other type of main roads with considerable mixed traffic like main city streets, arterial roads and large thoroughfares. While the Group A2 category of roads witness somewhat lesser density and flow of traffic in comparison with the Group A1 category of roads, the bulk of traffic flow and also the rapidness of vehicular transit on such roads is nonetheless quite substantial. Scrutinizing the visual information represented by the 3D pie chart, we find that the Head On or full frontal collisions were the predominant types of collisions on Group A2 roads, which is very much akin to what was observed on the Group A1 category of roads. As mentioned, on Group A2 roads, the speed of vehicular transit is quite considerable, especially in the urban and suburban locales and as such the lighting needs are meant to be rigorous in order to provide proper visual guidance to the drivers & motorists while executing sharp turns or navigating bends, crossing roads or even changing the course of travel. During our field surveys, it was often found that the lighting at pivotal junctures and points of rapid traffic transit on Group A2 roads was either deficient in terms of the absolute level of illumination, thereby resulting in dark patches on substantial area of the road surface and also poor uniformity of illumination. On the contrary, in cases where the recommended lux levels were met, poor designing and the lack of proper shielding and screening of the housing bays of the luminaires led to stray light seeping onto the Field of Vision of the motorist and causing unwarranted glare and considerable visual discomfort.

Furthermore, in some of the most significant Group A2 routes, it was often observed during our surveys that adequate traffic monitoring was found lacking. Consequently, a large number of Head On or full frontal collisions transpired on the Group A2 roads amongst oncoming vehicles which were traveling at opposite or transverse directions due to the considerable rapidness of transit, the traffic density, lack of proper traffic monitoring which leads to violation of traffic regulations and above all the highly deficient and inadequate quality of the road lighting, if at all present.

Much as in the instance of the Group A1 category of roads, the physical alignment as well as traffic density and rapidness of vehicular transit on the Group A1 roads also make them susceptible to considerable numbers of lateral impact crashes or Side Hit collisions. In fact, lateral impact or Side Hit type of collisions contributed to a significant chunk of the total incidences of crashes, 35% of the total crashes to be exact. Side Hit or lateral impact category of collisions usually are the ones which transpire when a vehicle, person or object is usually moving in a direction transverse to the colliding vehicle, person or object. Group A2 category of roads traverse some of the most important city streets, arterial roads and busiest urban thoroughfares and are often intricately connected with several other major and minor roads, streets, lanes and alleys which divert traffic away from or bring traffic into the major roads. As a result, this creates multiple points for lateral movement of traffic, which flows in and out of the principle roads and routes. Also, when traffic diverts from the major roads to the minor roads and vice versa, drastic speed variations are usually noticed. These movements require the lighting at the side entry points to be adequate for providing proper visual guidance. However, during our data collecting field surveys, it was found on most locations that the lighting was inadequate and failed to provide even the minimum recommended levels of illumination laid down for the Group A2 category of roads. Furthermore, the alignments of the poles and luminaires was inappropriate and misaligned, which did not provide the necessary visual guidance for timely detection and proper identification of potential obstacles while ambulating the roads in a lateral position. The culmination of all these factors significantly contributed to the large number of reported Side Hit or lateral impact collisions on the Group A2 category of roads.

Glancing at the 3D pie chart we also observe that the Back Hit or rear impact type collisions were responsible for 23% of the cumulative crash incidences on the Group A2category of roads. This figure is substantially higher than the corresponding figures for Back Hit collisions on Group A1 type roads. Group A2 category of roads are usually located on principal urban and suburban traffic areas. While the speed of vehicular transit is quite considerable on such roads on many occasions, due to inefficient traffic monitoring traffic bottlenecks are created in many areas, especially during evening rush hours. Consequently, an odd type of traffic behavior was observed in many places. Once the traffic bottleneck was removed and flow resumed, there was a tendency amongst motorists to recklessly speed up in order to atone for the lost time. As a result, such abrupt speeding on roads with specified speed limits led to a significant crashes with mobile and stationary objects, including but not limited to parked vehicles on the roadsides. This situation was greatly exacerbated by the poor quality of the available road lighting, if present at all on such roads. The lighting on many of the concerned roads was pretty inadequate in terms of all the relevant lighting parameters and was often either too low as to render the areas completely dark or excessively bright which caused visual disability and discomfort, which led to the significant incidences of rear impact collisions on these type of roads.

Analysis of collisions by road position on Group A2 type roads

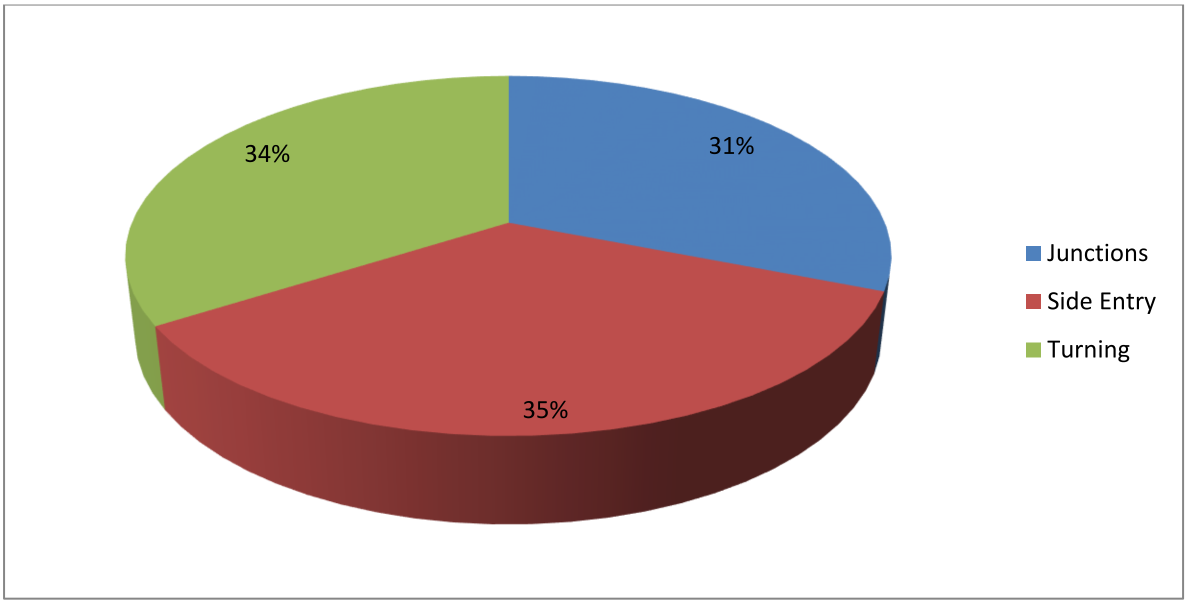


Fig. 24: Road crashes distribution by road position on Group A2 type roads

In the last segment of our ongoing discussion, we had assessed the categories of road collisions and their causes and mechanisms on the Group A2 type roads. Presently, we shall venture to evaluate and comprehend the physical position and orientation of collisions on the surface of Group A2 roads, signifying the area of the road be it a major junction, crossroads or intersection of several key local roads or streets or a midway turning point or indentation along a continuous road stretch, representing a specified area of intersection of two or more roads or a portal of side entry, signifying a gateway of entry or egress to or from the concerned roadway, onto adjoining lanes, streets and roads and would provide us with essential insights and in-depth information about the traits, characteristics and mechanism of the road crashes and the effect of the available road lighting installation on the precipitation of the same. The streamlined data pertaining to the crashes that transpired according to the various road and traffic positions on the Group A2 category of roads were scrutinized by computing the sum total of the number of crashes reported at each road position and entering the same as inputs for the 3 D pie chart graphic tool in the Microsoft Excel software, which then produced the pertinent percentage distribution of crashes for the different road traffic positions in the output 3 D pie chart that has been presented above.

For the ease of our comprehension, the color coding scheme of the 3 D pie chart data may be enumerated as follows:

1. **Blue** for **Junction**
2. **Red** for **Side Entry**
3. **Green** for **Turning**

Glancing at the 3D pie chart reveal the following percentage distribution of incidences of road crashes for each of the major road positions:

1. Junctions - 31% of the total number of road crashes
2. Side Entry - 35% of the total number of road crashes
3. Turning - 34% of the total number of road crashes

Examining the data revealed by the 3D pie chart, we find an approximately even distribution of the road crashes on Group A2 category of roads according to the positions of the road area where the crashes transpired. The major crossroads and junctions accounted for almost one third of the total incidences of crashes, 31% to be precise. The highest incidences of crashes was at the points of Side Entry or lateral movement of vehicles, which recorded 35% of the total crashes, which is followed extremely closely by the crashes at the Turnings, which recorded 34% of the total crash incidences.

Group A2 category of roads are the ones which are primarily meant for other type of main roads (vis a vis the Group A1 category of roads) with considerable mixed traffic like main city streets, arterial roads and large thoroughfares. The mixed traffic on Group A2 roads implies the presence of different types and categories of vehicles from the small private cars, sedans and Sport Utility Vehicles (SUVs) to manual pedal cycles and also large goods carrying vehicles like trucks, lorries, vans and other miscellaneous categories of vehicles. Although, the Group A2 category of roads witness somewhat lesser volume and flow of traffic relative to the Group A1 category of roads, the bulk of traffic flow and also the speed of vehicular transit on such roads is nonetheless quite considerable.

From a photometric perspective, the quality and efficacy of road lighting on such roads needs to be impeccable in order to ensure the safety and security of all road users. However, during our field surveys, it was observed that under most circumstances in the Group A2 categories of roads, the quality and nature of the road lighting highlighted either of two extremes - either too low or excessively high, which led to the presence of Dark patches or Glare respectively, which are amongst the most crucial and decisive factors in the precipitation of road crashes and possible casualties.

The level of illumination available on the road surface is the de facto prime factor in determining the level of visibility and visual comfort and visual guidance which the driver of the vehicle is afforded by the available road lighting and in aiding object detection, identification and in-time decision making. In many instances, the level of illumination is also a determinant in the presence of glare or dark patches. However, glare is usually caused by the improper alignment of the luminaires and the usage of Non Cut-off or Semi Cut-off luminaires. Glare may also be caused by the unshielded or improperly focused headlights of oncoming cars and vehicles.

Furthermore, in most of the Group A2 category of roads at different points and positions of the road surfaces like the major crossroads or traffic junctions as well as points of adjacent Side Entry and sharp Turnings, bends and U turns it was observed that there was no system of personnel for traffic monitoring and regulation. As such, very often there was unbridled traffic violations and over speeding even on roads with stipulated speed limits. Also, in many of the Group A2 roads, the defunct lamps and luminaires were neither repaired nor replaced or updated for several years and in some cases even for decades. Consequently, the cumulative effect of all these factors led to the significant number of road crashes at all the different road positions on the Group A2 category of roads.

Analysis of type of collision on Group B1 category of roads

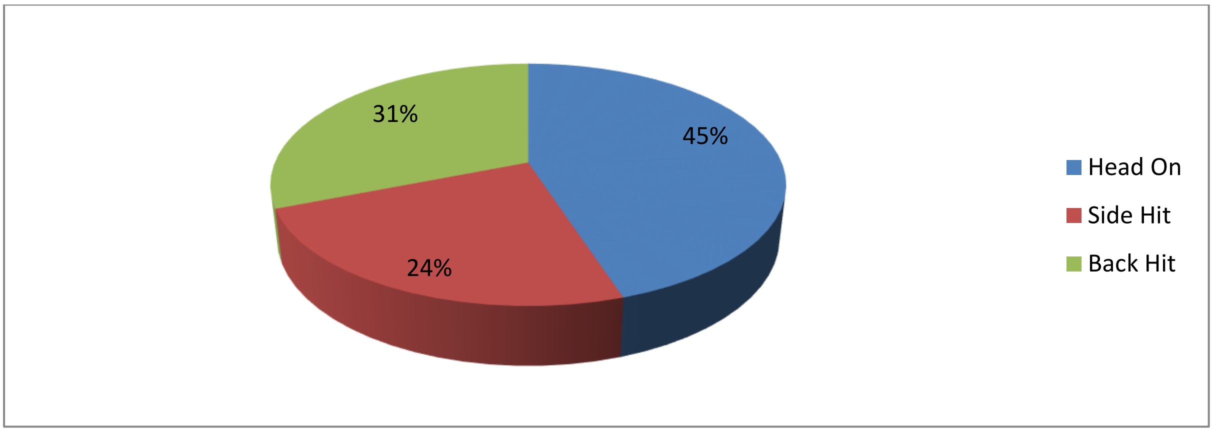


Fig. 25: Proportion of Road Crashes by Collision Types on Group B1 roads

Over the course of our discussion in the foregone segments, we have studied and analyzed the road crashes occurring on Group A1 and Group A2 category of roads vis a vis different parameters. Presently, we would venture to assess and comprehend the incidences of road crashes by the type and nature of collisions on the Group B1 category of roads. Group B roads are the secondary roads which have lesser traffic density than Group A type roads, which ply some of the busiest traffic routes and represent the principal roads in urban and semi urban areas. Group B1 type of roads still witness substantial flux of urban and intercity traffic at speeds which are quite considerable, given the fact that such roads are usually located in vital business and commercial centers, shopping areas or areas of heavy public transportation and transit. Thus, the nature and amount of road lighting needs to be commensurate with and adequate for the requirements of such types of roads for mitigating and preventing road crashes and mishaps

In this segment, the streamlined data pertaining to the crashes that transpired according to the types of collisions on the Group B1 category of roads were scrutinized by computing the sum total of the number of crashes reported at each road position and entering the same as inputs for the 3D pie chart graphic tool in the Microsoft Excel software, which then produced the pertinent percentage distribution of crashes for the different road traffic positions in the output 3D pie chart that has been presented above.

For the ease of our comprehension, the color coding scheme of the 3 D pie chart data may be enumerated as follows:

1. **Blue** for **Head On type of collisions**
2. **Red** for **Side Hit type of collisions**
3. **Green** for **Back Hit type of collisions**

Leafing through the 3D pie chart reveals the following percentage distribution of incidences of road crashes for each of the 3 major types of collisions:

1. Head On collisions - 45% of the total number of road crashes
2. Side Hit collisions - 24% of the total number of road crashes
3. Back Hit collisions - 31% of the total number of road crashes

The above percentage figures revealed by the pictorial distribution of the 3 D pie chart clearly illustrate the fact that the Head On collisions were the most damaging type of collision on the Group B1 roads, accounting for close to half of all the crashes, 45% of the total crash incidences to be precise. This was followed by the Back Hit or rear impact type of collisions which represent 31% of the total number of crashes. Finally, the Side Hit or lateral impact type of collisions represent close to a quarter of all the crashes on Group B1 roads, accounting for 24% of all the reported crashes.

To accurately evaluate and examine the precise causes and mechanisms behind these crashes, we firstly need to be well versed with the physical and photometric characteristics of the Group B1 roads. The Group B1 roads are the ones which witness lighter and lesser traffic as compared to the standards of Group A1 and Group A2 categories of roads. However, the Group B1 type roads being primarily located in high priority business and commercial districts, shopping centers and market areas or areas of heavy public transportation and transit usually witness substantial flux of urban and intercity traffic at speeds which are quite considerable. The prevalent road lighting and traffic monitoring situation on these roads is often deplorable to put it mildly. Such roads are quite frequently plagued with acute dearth of traffic personnel and/or traffic monitoring systems, which results in unrestrained traffic violations and crossing the threshold speed limits, stipulated on many such roads. Also, a major problem on such roads, especially in suburban shopping districts and market areas is that of vandalism and encroachment on public property. It was often found on such roads that the lamps, luminaires and accessories used for public lighting had been vandalized or pilfered and were being used by roadside peddlers and purveyors as light sources. Consequently, the already inadequate nature of the prevalent road lighting installations were rendered further effete. Thus, a large number of Head On or full frontal collisions were reported on Group B1 roads between oncoming vehicles traveling at opposite or transverse directions due to the relative high speed of travel, the traffic density and the severely lacking efficiency of the road lighting, whenever available at all.

The physical orientation, relatively high traffic density and pace of vehicular transit on the Group B1 roads also makes them susceptible to significant incidences of lateral impact crashes. Lateral impact or Side Hit type of collisions accounted for close to a quarter of the total number of crash incidences, 24% to be precise. Side Hit or lateral impact category of collisions usually are the ones which transpire when a vehicle, person or object is usually moving in a direction transverse to the colliding vehicle, person or object. Group B1 category of roads are usually the major types of secondary roads and traverse some of the most cramped and chockablock full areas of business and commercial activity. These roads, especially the ones in urban and suburban locales are often intricately connected with several other major and minor roads and lanes, which divert traffic away or bring traffic into the major roads. As a result, this creates multiple points and areas for lateral movement of traffic, adjacent to the concerned Group B1 roads. Furthermore, when traffic diverts from the major roads to the minor roads and vice versa, it is usually accompanied by drastic variations in speed. These movements require the lighting at the side entry points to be adequate for adequate visual guidance and visual comfort. However, it was found on many of the surveyed crash sites that the lighting levels were pretty poor which resulted in visual fatigue and poor visual performance.. All these factors working in unison appear to have significantly contributed to the high number of Side Hit crashes on Group B1 roads.

As regards the Back Hit or rear impact type collisions, we find that they accounted for a weighty 31% of the total crash incidences on the Group B1 category of roads, second only to the number of full frontal or Head On collisions reported on such roads. Back Hit or rear impact type of crashes usually are found to occur when the colliding vehicles are traveling in the same direction or one vehicle is approaching another from a transverse direction and collides with the rear end of the other vehicle at a crossing or intersection point between two roads which themselves are in a transverse alignment with respect to each other.

During our field expeditions, it was often observed that on various instances of vital Group B1 and aligned roads, there was a severe paucity of adequate traffic monitoring and consequently vehicles would travel at significant speeds even in areas where specified speed limits had been stipulated. The level and quality of road lighting was severely shoddy and inadequate on most occasions and as such the vehicles were often found to dash against stationary or moving objects and vehicles, parked vehicles, roadside booths and kiosks and even pedestrians from the rear side on both continuous stretches of road as well as turnings and sharp bends, where the visual guidance and thus, the identification of objects upfront was considerably due to the severely lacking nature of the available road lighting and under many circumstances, the total non-existence of any form of lighting. Consequently, significant incidences of Back Hit or rear impact type of collisions were found to have transpired and recorded on the Group B1 category of roads.

Analysis of collisions by road position on Group B1 type roads

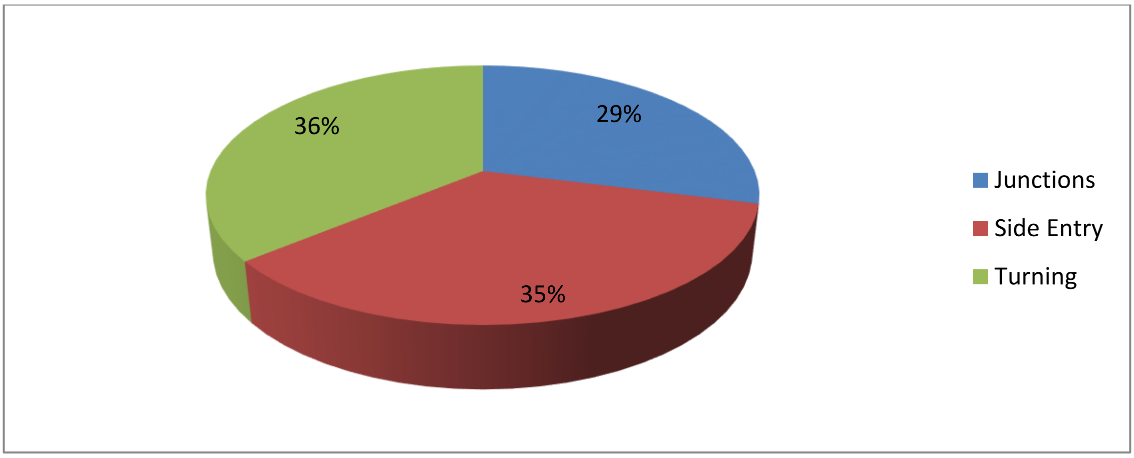


Fig. 26: Road crashes distribution by road position on Group B1 type roads

In the prior segment, we had assessed the categories of road collisions and their causes and mechanisms on the Group B1 category of roads. In this section, we shall endeavor to evaluate and comprehend the physical position and orientation of collisions on the surface of Group B1 roads, signifying the area of the road where the crash transpired. Such road positions could be a major junction, crossroads or intersection of several key roads or streets or a midway turning point or area of indentation along a continuous road stretch intended for the egress or exit of vehicular traffic. Such analysis would provide us with intricate and in-depth information about the traits, characteristics and mechanism of the road crashes and the effect of the available road lighting installation on the precipitation of the same. The segregated road crash data pertaining to the categories of the various road and traffic positions on the Group B1type roads were evaluated by computing the sum total of the number of crashes reported at each road position and entering the same as inputs for the 3 D pie chart graphic tool in the Microsoft Excel software, which then produced the pertinent percentage distribution of crashes for the different road traffic positions in the output 3 D pie chart that has been presented above.

For the ease of our comprehension, the color coding scheme of the 3 D pie chart data may be enumerated as follows:

1. **Blue** for **Junction**
2. **Red** for **Side Entry**
3. **Green** for **Turning**

Poring over the 3D pie chart reveals the following percentage distribution of incidences of road crashes for each of the 3 major types of collisions:

1. Junctions - 29% of the total number of road crashes
2. Side Entry - 35% of the total number of road crashes
3. Turning - 36% of the total number of road crashes

From the percentage figures presented above corresponding to the visual representation of the 3D pie chart, it is apparent that position of Turnings represent the highest incidences of road crashes on Group B1 type of roads, which is followed closely by the points of Side Entry or lateral and adjacent traffic movement, which accounted for 35% of the total number of crashes. The Junctions and major crossroads and intersections on such roads accounted for 29% of the overall incidences of road crashes.

While attempting to unravel the mechanism of the crashes at the different road positions and traffic sites on the Group B1 roads and the causes thereof, we first need to be conversant with the physical and photometric traits of such roads. Group B1 roads are the ones which witness lighter and lesser traffic as compared to the standards of Group A1 and Group A2 categories of roads. However, the Group B1 type roads being primarily located in high priority business and commercial districts, shopping centers and market areas or areas of heavy public transportation and transit usually witness substantial flux of urban and intercity traffic at speeds which are quite considerable. The prevalent road lighting and traffic monitoring situation on these roads is often deplorable to put it mildly. Such roads are quite frequently plagued with acute dearth of traffic personnel and/or traffic monitoring systems, which results in unrestrained traffic violations and crossing the threshold speed limits, stipulated on many such roads. Also, a major problem on such roads, especially in suburban shopping districts and market areas is that of vandalism and encroachment on public property. It was often found on such roads that the lamps, luminaires and accessories used for public lighting had been vandalized or pilfered and were intersection points and crossings, the density and speed of transit of vehicular traffic is the highest, which by extension also require the most demanding lighting to prop the heavy and rapid transit of traffic.

It was often found that the lighting at key focal points, junctions and major road intersections on Group B1 roads was severely lacking in terms of the level of illumination, resulting in vast swatches of darkness with poor or almost nil visibility. Au contraire, in cases where the recommended minimal levels were indeed met, they were often exceeded by large degrees, resulting in unwarranted glare and visual impairments due to excessive light levels and also poor shielding of the luminaire housings. Consequently, a large number of crashes and collisions, be it full frontal or lateral or even rear impact collisions were reported at the major junctions, crossroads and large traffic intersection points on the Group B1 roads between oncoming vehicles traveling at opposite or transverse or same direction due to the relative high speed of travel, the sheer density and bulk of such traffic in conjunction with the abjectly shoddy quality and efficacy of the road lighting, if present at all.

The alignment of the Group B1 category of roads is often such that they form interlocking and interconnecting grid like networks between different types of roads. These roads, especially the ones in urban and suburban sites are often intricately connected with several other major and minor roads, lanes, alleys, streets and lanes, which divert traffic away or bring traffic into the major roads. and also highways and interlinks between regional roads and major expressways of mass movement of traffic and goods carrying vehicles. As a result, this creates multiple points for lateral movement of traffic onto and from adjacent roads and streets. These movements require the lighting at the side entry points to be adequate for providing proper visual guidance. Points of Side Entry or lateral intersections are often among the most vulnerable areas on road surfaces due to the angular nature of the movement of vehicles and other objects relative to each other, which renders mutual visibility a daunting task and the lack of proper road lighting makes this task an endeavor of gargantuan proportions. Also, the alignments of the poles and luminaires was inappropriate, which failed to provide the necessary visual guidance for timely detection and identification of potential obstacles while crossing over in a lateral position. All these factors appear to have significantly contributed to the relatively substantial number of crashes at the points of side entry, which accounted for 35% of all the crashes on the Group B1 category of roads.

As regards the road crashes on Turnings, bends, U turns and other similar points of vehicular movement which usually involve the change of direction of movement of the vehicles, we find that on Group B1 roads crashes at such locations accounted for the highest incidences of road crashes, precisely 36% of the total crash incidences. It is imperative for the lighting in such areas to perform in an absolute impeccable manner due to the sharp turns, bends and curvatures on the road surface which by their very nature preclude the proper visibility of oncoming or traveling traffic on the other side. However, in the vast majority of observed cases, traffic signs and signals were either absent or poorly visible. The presence of quality road lighting was inconsistent even on the same stretch of road surface with multiple turnings, wherein they would be present at one point of turning and absent on the rest, This led to the presence of large swathes of road areas where visibility would be very poor. In the instances where high mast lighting was available, it was often found to be too bright or poorly designed and shielded, which led to inadvertent glare and visual distraction being present in the Field of View of the drivers and motorists. The high mast poles were also misaligned and improperly oriented and thus unable to provide proper visual guidance and consequently, visual fatigue and discomfort were significantly high on such roads. Furthermore, the lack of proper traffic monitoring implied that the vehicles often traveled at higher than recommended speeds and violated traffic norms. All these factors were exacerbated by the prevalent shoddy lighting installations and poor road conditions which made these roads fertile grounds for potential crashes and may be accountable for the very high incidences of road crashes observed at turnings, bends and U turns on Group B1 roads.

Analysis of type of collision on Group B2 category of roads

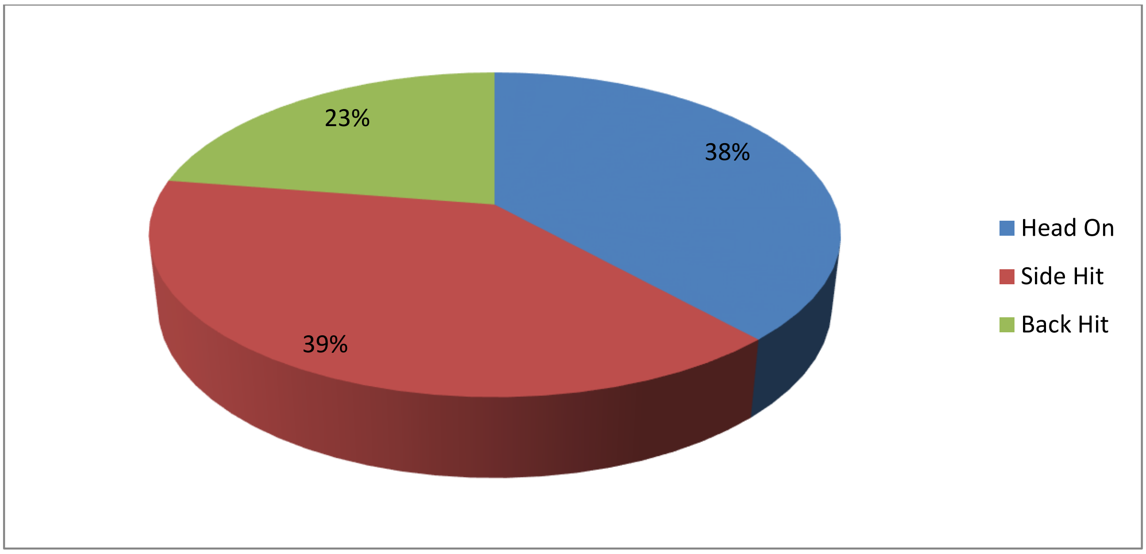


Fig. 27: Proportion of Road Crashes by Collision Types on Group B2 roads

In the previous sections we have studied the road crashes according to the type of collisions and position of occurrence on Group B1 type of roads. Presently, we would venture to assess and comprehend the incidences of road crashes by the type and nature of collisions on the Group B2 category of roads. Group B2 roads are the type of secondary roads which have considerably lower rate of traffic flow than those of the Group B1 type of roads, which ply some of the busiest traffic routes and represent the principal roads in urban and semi urban areas. In this segment, the segregated data pertaining to the crashes that transpired according to the types of collisions on the Group B2 category of roads were scrutinized by computing the sum total of the number of crashes reported at each road position and entering the same as inputs for the 3 D pie chart graphic tool in the Microsoft Excel software, which then produced the pertinent percentage distribution of crashes for the different road traffic positions in the output 3D pie chart that has been presented above.

For the ease of our comprehension, the color coding scheme of the 3 D pie chart data may be enumerated as follows:

1. **Blue** for **Head On type of collisions**

2. **Red** for **Side Hit type of collisions**

3. **Green** for **Back Hit type of collisions**

Leafing through the 3D pie chart reveals the following percentage distribution of incidences of road crashes for each of the 3 major types of collisions:

1. Head On collisions - 38% of the total number of road crashes
2. Side Hit collisions - 39% of the total number of road crashes
3. Back Hit collisions - 23% of the total number of road crashes

The above percentage figures revealed by the pictorial distribution of the 3D pie chart clearly illustrate the fact that the Side Hit or lateral impact collisions were the most damaging type of collision on the Group B2 roads, accounting for 39% of all the crashes. This was followed by the full frontal Head On collisions, which represent 38% of the total number of crashes. Finally, the Back Hit or rear impact type of collisions represent close to a quarter of all the crashes on Group B2 roads, accounting for 23% of all the reported crashes.

To understand the precise reasons and rationale behind these crashes, we firstly need to be well versed with the physical and photometric characteristics of the Group B2 roads. The Group B2 roads are the type of secondary roads which have considerably lower rate of traffic flow than those of the Group B1 type of roads. Secondary streets which connect intermediate areas between busy commercial hubs, downtown areas and sprawling shopping districts, roads between moderately sized city, boroughs and blocks and connecting different neighborhoods are some examples of Group B2 category of roads. The full frontal or Head On collisions on Group B2 roads accounted for a substantial 39% of the total number of crashes. It is pertinent to observe here that the adherence to strict design standards as regards road lighting and alignment, arrangement or orientation of luminaires on these roads is often pretty lax and also on such roads there is usually lesser number of traffic personnel employed, who are often tasked with manning larger roads in greater numbers. As a consequence, there is greater propensity among drivers, motorists, pedestrians and other road users to flout and defy traffic norms and regulations, which results in increased probability of crashes on such roads. On many occasions it was observed that there were no clear demarcating refuges or physical separation in case of dual carriageways for dividing the streams of traffic on such roads. Also, the prevalent road lighting on such roads was found to be pretty deficient in most of the essential criteria for defining the quality and efficacy of lighting, which only worsened the existing road conditions and caused greater crash propensity. Consequently, a high number of full frontal Head On collisions and crashes between oncoming traffic were reported on such roads.

At points of Side Entries, lateral and adjacent conduits as well as turnings, bends near adjoining the Group B2 type of roads, it was also found on multiple occasions during the field study that proper traffic signals were either absent, defunct, inadequate or located in very non-descript and inconspicuous locations, which made it extremely hard for them to be located and properly used in conjunction with the flow of traffic. From the perspective of photometric parameters and the road lighting installation, it is also pertinent to note that very often on secondary roads, especially on Group B2 type roads, the Lighting Maintenance plan, if any, is not rigorously maintained or executed by the civic and municipal authorities. As such, it was found that in many instances, age-old luminaires and light sources which are in dire need of retrofitting, re-lamping and upgrading are still being used as workhorses on a regular basis. Such light sources and luminaires greatly degrade the quality of available road lighting and provide very low and poor levels of illumination, which in turn can be a very vital contributing factor in the transpiring of road crashes and mishaps.

Furthermore, the alignment of the Group B2 category of roads is amenable to the formation of grid like networks between different types of roads. These roads, especially the ones in urban and suburban sites are often intricately connected with several other major and minor roads, lanes, alleys, streets and lanes, which divert traffic away or bring traffic into the major roads. and also highways and interlinks between regional roads and major expressways of mass movement of traffic and goods carrying vehicles. As a result, this creates multiple points for lateral movement of traffic onto and from adjacent roads and streets Thus, for the Group B2 type of roads, all the above physical photometric factors in conjunction with the poor repair and maintenance schedules and re-lamping of lamps and retrofitting of luminaires appears to have a significant effect on breaching the requisite standards of road safety on such roads, which consequently leads to greater number of Side Entry and lateral crashes and mishaps.

Regarding the Back Hit or rear impact type collisions, we find that they accounted for a sizeable 23% of the total crash incidences on the Group B2 category of roads. Back Hit or rear impact type of crashes usually are found to occur when the colliding vehicles are traveling in the same direction or one vehicle is approaching another from a transverse direction and collides with the rear end of the other vehicle at a crossing or intersection point between two roads which themselves are in a transverse alignment with respect to each other.

It was frequently found during our fieldwork that the level and quality of road lighting was severely inadequate on most occasions and as such the vehicles were often found to dash against stationary or moving objects and vehicles, parked vehicles, roadside booths and kiosks and even people, pets and walking pedestrians from the rear side on both continuous stretches of road as well as turnings and sharp bends, where the visual guidance and thus, the identification of objects upfront was considerably due to the severely impaired nature of the available road lighting and often the complete unavailability of all forms of road lighting. Consequently, significant incidences of Back Hit or rear impact type of collisions were found to have transpired and recorded on the Group B2 category of roads.

Analysis of collisions by road position on Group B2 type roads

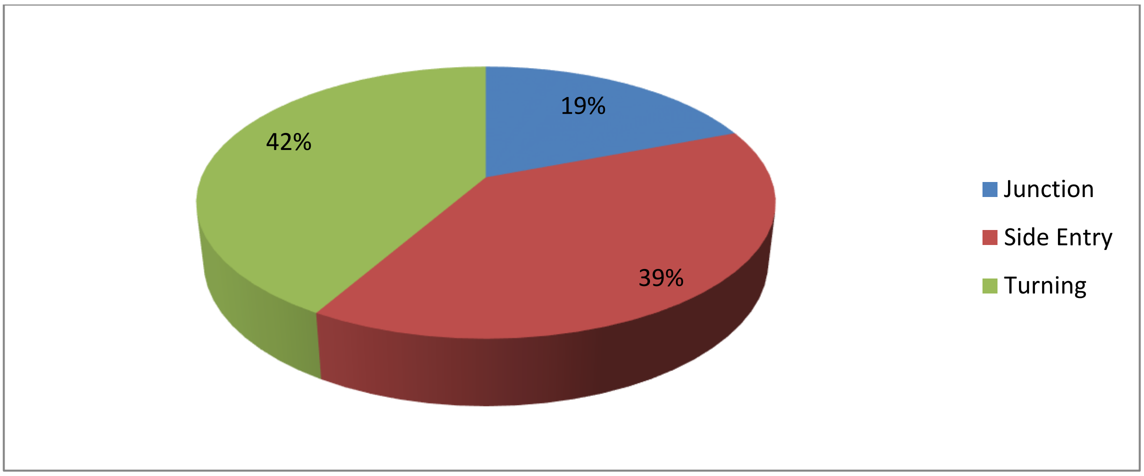


Fig. 28: Road crashes distribution by road position on Group B2 type roads

In the previous segment of the study, we had assessed the categories of road collisions and their causes and mechanisms on the Group B2 category of roads. In this segment, we shall venture to evaluate and analyze the physical position and orientation of collisions on the surface of Group B1 roads, signifying the area of the road where the crash transpired. Such road positions could be of various types, including major junctions, crossroads or intersections of several key roads or streets or a midway turning point or area of indentation along a continuous road stretch intended for the egress or exit of vehicular traffic. Such evaluation would enable us to garner intricate and in-depth information about the traits, characteristics and mechanism of the road crashes and the effect of the available road lighting installation on the precipitation of the same. The segregated road crash data pertaining to the categories of the various road and traffic positions on the Group B1 type roads were evaluated by computing the sum total of the number of crashes reported at each road position and entering the same as inputs for the 3D pie chart graphic tool in the Microsoft Excel software..

For the ease of our comprehension, the color coding scheme of the 3 D pie chart data may be enumerated as follows:

1. **Blue** for **Junction**
2. **Red** for **Side Entry**
3. **Green** for **Turning**

Gazing over the 3D pie chart reveals the following percentage distribution of incidences of road crashes for each of the 3 major types of road positions:

1. Junctions - 19% of the total number of road crashes
2. Side Entry - 39% of the total number of road crashes
3. Turning - 42% of the total number of road crashes

From the above figures, it is pretty lucid that the positions of Turnings and bends on the Group B2 roads were responsible for the most number of crashes, namely 42% of the total incidences of all the crashes that transpired. This was followed by the positions and points of Side Entry and lateral movement of traffic which accounted for a pretty hefty 39% of the total number of crashes. Finally, the major crossroads and junctions and multi road intersections accounted for nearly a fifth of the cumulative number of crashes, contributing to exactly 19% of the overall recorded crashes.

We shall now attempt to unravel the underlying causes and contributing factors which led to the transpiring of the crashes and mishaps at the different road positions on the Group B2 category of roads. In order to do so, we need to be well versed with the physical and photometric characteristics of such roads. The Group B2 roads are the type of secondary roads which have considerably lower rate of traffic flow than those of the Group B1 type of roads. Some examples of Group B2 category of roads are secondary streets connecting the intermediate areas between busy commercial hubs, downtown areas and sprawling shopping districts, roads between moderately sized city blocks and boroughs and also connecting different neighborhood areas. On Group B2 roads, due to their very nature, major intersections of multiple roads, large crossroads and junctions are relatively lesser in number, especially in suburban areas and areas bordering smaller towns and townships, as well as outskirts of larger urban areas. It is pertinent to observe here that the adherence to strict design standards as regards road lighting and alignment, arrangement or orientation of luminaires on these roads is often pretty lax and also on such roads there is usually lesser number of traffic personnel employed, who are often tasked with manning larger roads in greater numbers. From a photometric perspective, the quality and condition of road lighting at such junctions and cross roads was also found to be very deficient, resulting in poor visual comfort and guidance. As such, a significant number of crashes were reported in such areas on the Group B2 type of roads.

At points of Side Entries, lateral and adjacent conduits adjoining the Group B2 type of roads, it was also found on multiple occasions that traffic signs, signals and other relevant markers were either conspicuously absent, defunct, inadequate or located in very non-descript and inconspicuous locations, which made it extremely hard for them to be sighted and properly used in conjunction with the flow of traffic. From the perspective of photometric parameters and the road lighting installation, it is also pertinent to note that very often on secondary roads, especially on Group B2 type roads, the Lighting Maintenance plan, if any, is not rigorously maintained or executed by the civic and municipal authorities. As such, it was found in many instances that age-old luminaires and lamps which are in dire need of retrofitting, re-lamping and upgrading are still being used as workhorses on a regular basis. Such light sources and luminaires greatly degrade the quality of available road lighting and provide very low and poor levels of illumination, which in turn can be a very vital contributing factor in the transpiring of road crashes and mishaps. It is perhaps not very surprising then to observe that the points of Side entry and lateral traffic movements on such roads recorded a substantial number of road crashes, notably 39% of the total number of crashes.

Finally, focusing our eyes of evaluation on the road crashes transpiring on Turnings, bends, U turns and other similar points of vehicular movement which usually involve the change of direction of movement of the vehicles, we find that on Group B2 roads crashes at such locations accounted for the highest incidences of road crashes, namely 42% of the total crash incidences. It is imperative for the lighting in such areas to perform in an absolute impeccable manner due to the sharp turns, bends and curvatures on the road surface which by their very nature preclude the proper visibility of oncoming or traveling traffic on the other side. However, in the vast majority of the sites that were surveyed during our on field investigations, traffic signs and signals were either absent or poorly visible. The presence of quality road lighting was inconsistent even on the same stretch of road surface with multiple turnings, wherein they would be present at some points of turnings and bends and be non-existent at the rest, This led to the present of large swathes of road areas where visibility would be very poor. In the instances where high mast lighting was available, it was often found to be too bright or poorly designed and shielded, which led to inadvertent glare and visual distraction being present in the Field of View of the drivers and motorists. The high mast poles were also misaligned and improperly oriented and thus unable to provide proper visual guidance and consequently, visual fatigue and discomfort were significantly high on such roads. Also, the lack of adequate traffic monitoring implied that the vehicles often traveled at higher than recommended speeds and violated traffic norms. All these factors were exacerbated by the prevalent shoddy lighting installations and poor road conditions which made these roads fertile grounds for potential crashes and may be accountable for the very high incidences of road crashes observed at turnings, bends and U turns on Group B2 roads.

Analysis of type of collision on Group - D type roads

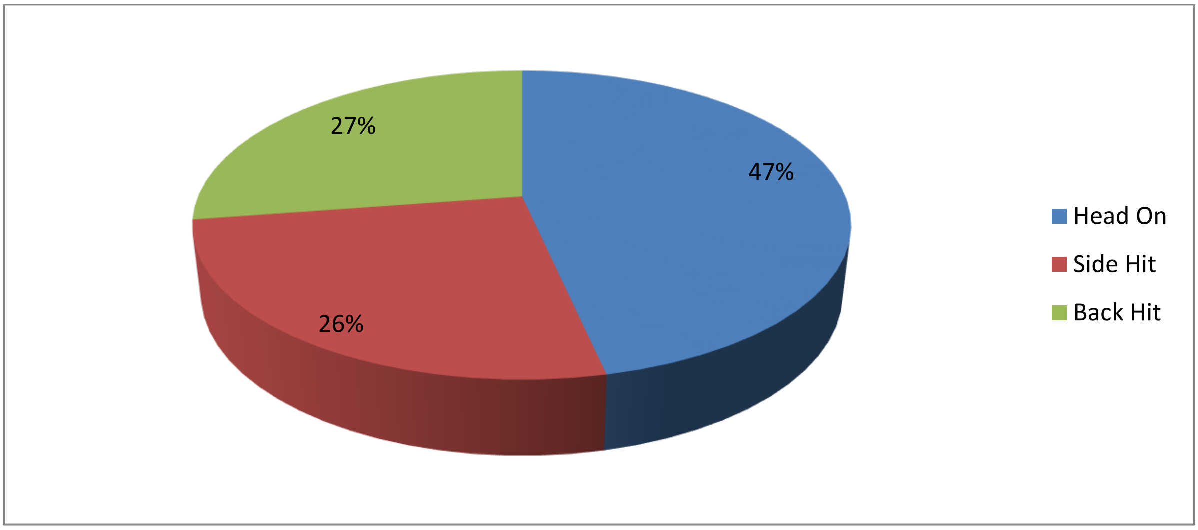


Fig. 29: Proportion of Road Crashes by Collision Types on Group D roads

Hitherto in our study and analysis of the road crashes according to the different road categories (as per the IS 1944 classification) we have studied and analyzed the road crashes occurring on the Group C type of roads, which were responsible for the highest number of crashes s well as those on the busiest and densest traffic routes on Group A1 and Group A2 category of roads and the secondary roads categorized under the Group B1 and Group B2 type of roads. We shall now focus our attention to the other types of specialized roads which are classifiable under the remnant categories. In the present segment, we would attempt to assess and comprehend the incidences of road crashes by the type and nature of collisions on the Group D category of roads. Group D category of roads are the roads which form the public passageways for transit on bridges, flyways, flyovers, skyways and other such structures and have their own unique characteristic traits.

In this segment, the arranged and segregated data pertaining to the crashes that transpired according to the types of collisions on the Group D category of roads were scrutinized by computing the sum total of the number of crashes reported at each road position and entering the same as inputs for the 3D pie chart graphic tool in the Microsoft Excel software, which then produced the pertinent percentage distribution of crashes for the different road traffic positions in the output 3D pie chart that has been presented above.

For our convenience and ready reference, the color coding scheme of the 3 D pie chart data may be enumerated as follows:

1. **Blue** for **Head On type of collisions**
2. **Red** for **Side Hit type of collisions**
3. **Green** for **Back Hit type of collisions**

Leafing through the 3D pie chart reveals the following percentage distribution of incidences of road crashes for each of the 3 major types of collisions:

1. Head On collisions - 47% of the total number of road crashes
2. Side Hit collisions - 26% of the total number of road crashes
3. Back Hit collisions - 27% of the total number of road crashes

The above percentage figures distilled from the visual representation of the 3D pie chart clearly elucidate the fact that the Head On collisions were the ones responsible for the highest number of collisions on the Group D category roads, accounting for close to half of all the crashes, precisely 47% of the total crash incidences. This was followed by the Back Hit or rear impact type of collisions which represent 27% of the total number of crashes. and the Side Hit or lateral impact type of collisions were also responsible for the crash incidences in almost equal measure, accounting for 26% of the total incidences of road crashes.

. Group D category of roads are the roads which form the public passageways for transit on bridges, flyways, flyovers, skyways and other such structures. Group D roads have their own unique characteristic traits and challenges. Under most circumstances, Group D roads, due to their very nature and purpose of eliminating traffic bottlenecks and ensuring smooth and relatively rapid transit are often located at a substantial elevation from the normal street level, appearing to be almost juxtaposed into the landscape alongside the roads and streets and buildings which are at a normal elevation. Bridges, flyways, skyways and similar constructions are all suspended structures being propped up by pillars or similar constructs, careful consideration needs to be made to ensure that the road lighting design factors in all the requisite elements. During our field surveys, it was often observed on Group D category of roads, bridges, flyways and skyways, particularly the ones located in suburban areas and outskirts that there were no physical refuges or makers for segregating the streams of traffic. Also, in most of the surveyed bridges and flyways, traffic monitoring be it manually or through automated modalities was essentially non-existent. The condition of the road lighting was found to be pretty inadequate in terms of all the relevant lighting parameters and was often either too low as to render the areas completely dark or excessively bright which caused visual disability and discomfort, which led to the significant incidences of rear impact collisions on these type of roads. Consequently, a lot of the vehicular transit of traffic on such roads was found to be at much higher speeds than warranted on such types of roads, where caution needs to be exercised while driving not only to prevent crashes, but, also to maintain the integrity of the structure itself. Without proper physical segregation between the streams of traffic and hindered by the abject nature of the available road lighting, significant numbers of full frontal or Head On collisions were reported on such roads, accounting for close to half of all the recorded crashes and mishaps.

At points of Side Entries, lateral and adjacent conduits as well as turnings, bends near or adjoining the Group D type of roads, especially on large or multilane flyways and skyways, it was found on multiple occasions during the field study that proper traffic signals were either absent, defunct, inadequate or located in very non-descript and inconspicuous locations, which made it extremely hard for them to be located and properly used in conjunction with the flow of traffic. From the perspective of photometric parameters and the road lighting installation, it is also pertinent to note that on Group D category of roads, which have some of the most demanding lighting requirements, for unfathomable reasons the Lighting Maintenance plan, if any, was barely maintained or executed by the civic and municipal authorities. On many occasions, it was found that the lamps and luminaires had not been repaired for many years and even several decades. Such lamps and luminaires greatly degrade the quality of available road lighting and provide very low and inadequate levels of illumination, which in turn proves to be a very vital contributing factor in the transpiring of road crashes and mishaps during hours of darkness. As mentioned earlier, the flyways and skyways, especially the multilane and larger ones often lacked any form of traffic surveillance and monitoring. Sideways and lateral traffic movements require the lighting at the bends, turning and connecting points to be adequate for providing proper visual guidance. However, it was found on many locations that the lighting was not up to the mark and failed to maintain even proper visibility, much less be a beacon of proper visual guidance. All these factors appear to have significantly contributed to the high number of Side Hit crashes on the Group D category of roads.

Regarding the Back Hit or rear impact type collisions, we find that they accounted for a sizeable 27% of the total crash incidences on the Group D category of roads, ranking second only to full frontal type of collisions in their frequency of occurrence. Back Hit or rear impact type of crashes usually are found to occur when the colliding vehicles are traveling in the same direction or one vehicle is approaching another from a transverse direction and collides with the rear end of the other vehicle at a crossing or intersection point between two roads which themselves are in a transverse alignment with respect to each other. During our field expeditions, it was frequently found that the level and quality of road lighting was severely inadequate on most occasions and as such the vehicles were often found to dash. Also, a new trend which has emerged on some of the major Group D roads in recent years, particularly in urban and metropolitan areas is the fact that due to inefficient traffic monitoring, traffic bottlenecks are created in many areas, especially during evening rush hours. Consequently, an odd type of traffic behavior emerged. Once the traffic bottleneck was removed and flow resumed, there was a tendency amongst motorists to recklessly speed up even on the bridges, flyways and multilane skyways in order to make up for the lost time. As a result, such abrupt speeding on roads with relatively poor illumination which causes visual discomfort led to significant crashes with mobile and stationary objects,. The lighting on many of the concerned roads was pretty inadequate in terms of all the relevant lighting parameters and was often either too low as to render the areas completely dark or excessively bright which caused visual disability and discomfort, which led to the significant incidences of rear impact collisions on these type of roads. Consequently, significant incidences of Back Hit or rear impact type of collisions were found to have transpired and recorded on the Group D category of roads.

Analysis of collisions by road position on Group D type roads

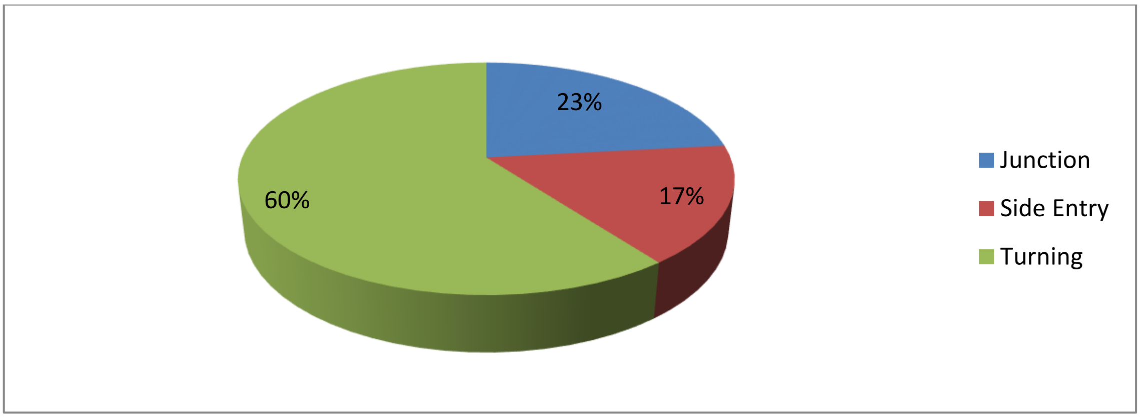


Fig. 30: Road crashes distribution by road position on Group D type roads

In the preceding segment of our ongoing discussion on the road crashes occurring on the different categories of roads, we had assessed the categories of road collisions and the probable reasons and rationale behind their occurrences on the Group D category of roads. In this segment, we shall venture to evaluate and analyze the physical position and orientation of collisions on the different spots or physical spots of bridges, flyways, skyways and other elevated roads. The relevant road positions could be of various types, including major junctions, crossroads or intersections of several key roads or streets or a midway turning point or area of indentation along a continuous road stretch intended for the egress or exit of vehicular traffic. Such evaluation would enable us to obtain intricate and in-depth information about the traits, characteristics and mechanism of the road crashes and the effect of the available road lighting installation on the precipitation of the same. The segregated road crash data pertaining to the categories of the various road and traffic positions on the Group D type roads were evaluated by computing the sum total of the number of crashes reported at each road position and entering the same as inputs for the 3D pie chart graphic tool in the Microsoft Excel software, which then produced the pertinent percentage distribution of crashes for the different road traffic positions in the output 3D pie chart that has been presented above.

For the ease of our comprehension, the color coding scheme of the 3D pie chart data may be enumerated as follows:

1. **Blue** for **Junction**
2. **Red** for **Side Entry**
3. **Green** for **Turning**

Gazing over the 3D pie chart reveals the following percentage distribution of incidences of road crashes for each of the 3 major types of road positions:

1. Junctions - 23% of the total number of road crashes
2. Side Entry - 17% of the total number of road crashes
3. Turning - 60% of the total number of road crashes

From the above figures, it is cogent that the positions of Turnings and bends on the Group D roads were responsible for the predominant majority of the crashes, an incredible 60% of the total incidences of all the crashes that transpired on such roads. This was followed by the major crossroads and intersections and junctions between the bridges, flyways, skyways and roadways as well as other elevated thoroughfares, which accounted for 23% of the crashes, followed finally by the positions of Side Entry or lateral traffic movement, which contributed to 17% of the overall crashes recorded on such roads.

We shall now attempt to unravel the underlying causes and contributing factors which led to the transpiring of the crashes and mishaps at the different road positions on the Group D category of roads. Group D category of roads are the roads which form the public passageways for transit on bridges, flyways, flyovers, skyways and other such structures. Group D roads have their own unique characteristic traits and challenges as well as lighting requirements. While perusing the crash statistics, we find that the highest incidences of road crashes on the Group D category of roads occurred at the positions of turnings, bends, U turns and other allied positions. It is pertinent to observe here that on most Group D roads, due to their very nature, the pace and speed of traffic flow and also driver behavior is relatively on the conservative side and usually slack. However, at turnings and bends, especially on crossings over to and interconnects between elevated and normal level roads, there are drastic variations in speed and the pace of vehicular transit. As such, the lighting needs for such points and areas needs to be commensurate to provide the appropriate visual guidance to the motorists. However, on most such roads, it was found during our field surveys that the quality and nature of lighting was either excessive as to cause glare and visual discomfort or it was so low as to render the visibility to be extremely poor. Consequently, a significant majority of the crashes were recorded at such locations on the Group D category of roads.

A similar picture emerged as regards the points of conjunction and crossroads between elevated highways, flyways and bridges and the corresponding points of progression onto roads of surface elevation. Here too, substantial variations in speed of transit were observed and due to the widespread lack of almost any form of traffic monitoring and surveillance on such roads, vehicles often ran amok as soon the threshold between the elevated and normal elevation roads was reached. The problem was greatly exacerbated by the severely constrained lighting installations on such roads. Furthermore, it is germane to note that very often on these roads, the Lighting Maintenance plan, if any, was not rigorously maintained or executed by the civic and municipal authorities. As such, it was found that in many instances, years and even decades old luminaires and light sources which are in dire need of retrofitting, re-lamping and upgrading are still being used as workhorses on a regular basis. Such light sources and luminaires greatly degrade the quality of available road lighting and provide very low and poor levels of illumination, which in turn can be a very vital contributing factor in the transpiring of road crashes and mishaps. Consequently, these spots accounted for nearly a quarter of all crashes on the Group D roads, 23% of the total number of crashes.

Finally, focusing our eyes of evaluation on the road crashes transpiring on the points of side entry or lateral traffic movement, it is imperative for the lighting in such areas to perform in an absolute impeccable manner due to the sharp turns, bends and curvatures on the road surface which by their very nature preclude the proper visibility of oncoming or traveling traffic on the other side. The points of side entry, even though relatively less frequent on Group D roads, nonetheless have stringent lighting needs. However, in the vast majority of the sites that were surveyed during our on field investigations, traffic signs and signals were either absent or poorly visible. The presence of quality road = In the instances where high mast lighting was available, it was often found to be too bright or poorly designed and shielded, which led to inadvertent glare and visual distraction being present in the Field of View of the drivers and motorists. The high mast poles were also misaligned and improperly oriented and thus unable to provide proper visual guidance and consequently, visual fatigue and discomfort were significantly high on such roads. Also, the lack of adequate traffic monitoring implied that the vehicles often traveled at higher than recommended speeds and violated traffic norms. All these factors were exacerbated by the prevalent shoddy lighting installations and poor road conditions which made these roads fertile grounds for potential crashes and may be accountable for the very high incidences of road crashes observed at points of lateral movement of traffic on Group D roads.

Analysis of type of collision on Group E type roads

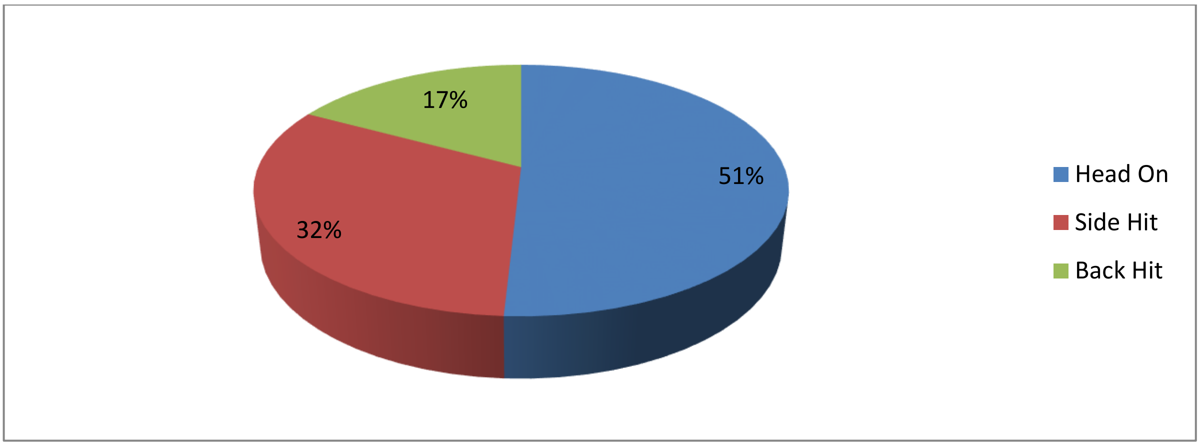


Fig. 31: Proportion of Road Crashes by Collision Types on Group E type roads

In the present segment of our study, we would endeavor to assess and comprehend the incidences of road crashes by the type and nature of collisions on the Group E category of roads. Group E roads are the ones which are found to traverse through towns and city centers, downtown urban and semi urban areas, high streets in suburban and rural areas and townships, which are often the nerve centers of commercial and popular activity in such locations. In this segment, the segregated data pertaining to the crashes that transpired according to the types of collisions on the Group E category of roads were scrutinized by computing the sum total of the number of crashes reported at each road position and entering the same as inputs for the 3D pie chart graphic tool in the Microsoft Excel software, which then produced the pertinent percentage distribution of crashes for the different road traffic positions in the output 3D pie chart that has been presented above.

For the ease of our comprehension, the color coding scheme of the 3D pie chart data may be enumerated as follows:

1. **Blue** for **Head On type of collisions**

2. **Red** for **Side Hit type of collisions**

3**. Green** for **Back Hit type of collisions**

Leafing through the 3D pie chart reveals the following percentage distribution of incidences of road crashes for each of the 3 major types of collisions:

1. Head On collisions - 51% of the total number of road crashes

2. Side Hit collisions - 32% of the total number of road crashes

3. Back Hit collisions - 17% of the total number of road crashes

Perusing the percentage distribution figures distilled from the infographic of the 3D pie chart, we find that the Head On collisions were the ones responsible for the highest number of collisions on the Group D category roads, accounting for more than half of all the reported rashes, precisely 51% of the total crash incidences. This was followed by the Side Hit or lateral impact type of collisions which represent 32% of the total number of crashes and finally the Back Hit or rear impact type of collisions were responsible for the 17% of the total number of the reported road crashes.

We shall now try to assess and analyze the distinct physical and photometric traits prevalent on the Group E category of roads which led to the precipitation and distribution of the crashes as demonstrated by the 3D pie chart. The Group E category of roads are the ones which usually traverse through towns and city centers, downtown urban and semi urban areas, high streets and major marketing hubs in suburban and rural areas and townships, which are often the nerve centers of commercial and popular activity in such locations. Group E category of roads are often found to connect shopping hubs and epicenters of downtown business and activity in urban settings and in suburban and rural areas they serve as major district roads, linking production centers and markets where the exchange of commodities can take place. During our field surveys, it was found on many occasions that the Group E category of roads, especially the ones in the outskirts of major cities, suburban areas and also in small townships had no proper physical segregations or refuge structures for separating the streams of traffic. Also, as has been found to be a recurring event in many categories of roads, even manual traffic monitoring on such roads was a pretty rare phenomenon. The condition of the road lighting was found to be pretty inadequate in terms of all the relevant lighting parameters and was often either too low which large swathes and patches of darkness on the road surfaces where vehicular transit transpired or excessively bright and over illuminated which caused visual disability and discomfort, which led to the significant incidences of rear impact collisions on these type of roads. Consequently, a lot of the vehicular transit of traffic on such roads was found to be at much higher speeds than warranted on such types of roads. Without the presence of any proper physical segregation or barrier between the streams of traffic and the relatively rapid transit of vehicles from opposing and oncoming directions and also severely constrained by the abject nature of the available road lighting, significant numbers of full frontal or Head On collisions were reported on such roads, accounting for more than half of all the recorded crashes and mishaps.

Group E roads usually experience mixed traffic, both in terms of speed of vehicular movement and also the density and volume of traffic. Oftentimes, especially in suburban or rural townships, such roads are chock-a-block with various types of vendors, hawkers and sundry tradesmen plying their trades and selling goods and merchandise on the roadsides. Such activity, which usually takes place during specific periods of the daytime and evening often impedes with the flow and motion of vehicular traffic and also the transit of pedestrians. Also, most Group E category of roads are connected to local streets, roads and other trading routes through which the local tradesmen and purveyors bring in their goods and wares for merchandizing. This creates numerous points and portals of Side Entry and lateral traffic movement as well as turnings, bends, sharp turns and U turns. Thus, by their very nature, many types of Group E roads can cause a bottleneck for vehicular transit and also pose serious physical obstacles in the path of vehicular movement, which can be a contributing factor to road crashes and accidents. In conjunction with the shoddy quality of the prevalent road lighting, if, available at all, this contributed significantly to the high number of Side Hit collisions as well as Back Hit or rear impact type collisions on such roads.

Analysis of collisions by road position on Group E type roads

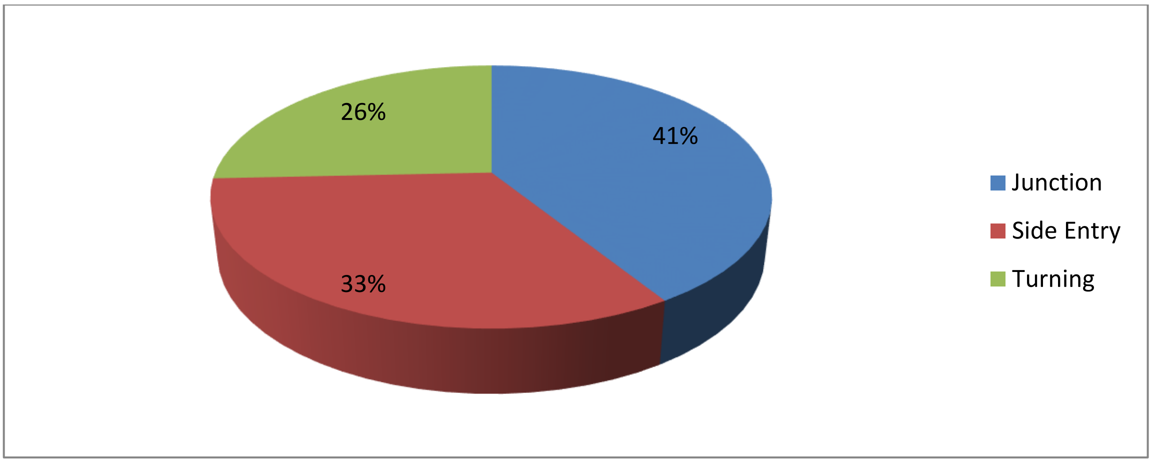


Fig. 32: Road crashes distribution by road position on Group E type roads

In the preceding segment of our ongoing discussion, we had assessed the categories of road collisions and the probable reasons and rationale behind their occurrences on the Group E category of roads. Presently, we shall examine the physical position and orientation of collisions on the different spots and traffic positions on such roads. The relevant road positions could be of various types, including major junctions, crossroads or intersections of several key roads or streets or a midway turning point or area of indentation along a continuous road stretch intended for the egress or exit of vehicular traffic. Such evaluation would afford us the opportunity to obtain intricate, in-depth and detailed information about the traits, characteristics and mechanism of the road crashes and the effect of the available road lighting installation on the precipitation of the same. The segregated road crash data pertaining to the categories of the various road and traffic positions on the Group E type roads were evaluated by computing the sum total of the number of crashes reported at each road position and entering the same as inputs for the 3D pie chart graphic tool in the Microsoft Excel software, which then produced the pertinent percentage distribution of crashes for the different road traffic positions in the output 3D pie chart that has been presented above.

For the ease of our comprehension, the color coding scheme of the 3 D pie chart data may be enumerated as follows:

1. **Blue** for **Junction**
2. **Red** for **Side Entry**
3. **Green** for **Turning**

Gazing over the 3D pie chart reveals the following percentage distribution of incidences of road crashes for each of the 3 major types of road positions:

1. Junctions - 41% of the total number of road crashes
2. Side Entry - 33% of the total number of road crashes
3. Turning - 26% of the total number of road crashes

From the above figures, it is cogent that the major crossroads, intersections and junctions accounted for the highest number of crashes on the Group E roads totaling 41% of all the crashes. The points of Side Entry or lateral traffic movement recorded exactly a third of the total number of crashes at 33%, followed by the positions of Turnings and bends, which contributed to 26% of the overall crashes recorded on such roads.

We shall now strive to unravel the mechanism of the crashes at the different road positions and traffic sites on the Group E roads and the causes thereof. Group E category of roads are often found to connect shopping hubs and epicenters of downtown business and activity in urban settings and in suburban and rural areas they serve as major district roads, linking production centers and markets where the exchange of commodities can take place. Junctions, crossroads and intersections of both major and minor roads are very frequent on Group E category of roads, due to their very nature. As such, at the major crossroads, Junctions and important multilane intersection points and crossings, the density and speed of transit of vehicular traffic is the highest, which by extension also require the most demanding lighting to prop the heavy and rapid transit of traffic. Group E roads, as discussed are very often the nerve centers of commercial activity and barter. During our field surveys, it was found frequently that the Group E roads usually experience mixed traffic, both in terms of speed of vehicular movement and also the density and volume of traffic. At most of the locales study, the quality and efficacy of the available lighting was utterly inadequate. if available at all! Oftentimes, especially in suburban or rural townships, such roads are chock-a-block with various types of vendors, hawkers and sundry tradesmen plying their trades and selling goods and merchandise on the roadsides. Such activity, which usually takes place during specific periods of the daytime and evening often impedes with the flow and motion of vehicular traffic and also the transit of pedestrians. Consequently, a large proportion of the crashes were reported at or near the busy crossroads and junctions on such roads, witnessing the highest vehicular transit and also the greatest hustle and bustle.

Furthermore, most Group E category of roads are connected to local streets, roads and other trading routes through which the local tradesmen and purveyors bring in their goods and wares for merchandizing. This creates numerous points and portals of Side Entry and lateral traffic movement as well as turnings, bends, sharp turns and U turns. Thus, by their very nature, many types of Group E roads can cause a bottleneck for vehicular transit and also pose serious physical obstacles in the path of vehicular movement, which can be a contributing factor to road crashes and accidents. During the fieldwork phase of the study, it was observed on many occasions and in multiple locations that vehicles had to steer and veer significantly off their intended course in an attempt to avoid hitting vendors, peddlers and other purveyors of roadside merchandise and in so doing greatly augmented their risk of colliding with other objects or crashing against oncoming vehicles or kerbs or other impediments and obstacles on the road surface.

Over the course of our fieldtrips it was also found that in many of the Group E roads and locations, the overall lighting infrastructure was pretty poor and in many instances completely non-existent. The arrangement and siting of luminaire poles was also very shoddily planned and executed in a substantial number of the sites, which led to very poor levels of uniformity of lighting and consequently poor visual guidance for the driving motorists. In fact, the poor lighting design, alignment and orientation of the luminaires and corresponding light sources were a cause of significant visual fatigue for the drivers and other road users, instead of augmenting their visual comfort. On some occasions, it was even found that some of the roadside lamps had been taken off their housing luminaires by local tradesmen and were being improvised and used as light sources for their impromptu shops for selling merchandise on the roadsides. Such reckless vandalism and civic violations severely undermine the efficacy of the road lighting installation in maintaining the safety and security of the roadside and surrounding environs on such roads and localities. In conjunction with the shoddy quality of the prevalent road lighting, if, available at all, this contributed significantly to the high number of collisions at the points of Side Entry as well as Turnings, Bends and U turns on such roads.

Analysis of type of collision on Group F type roads

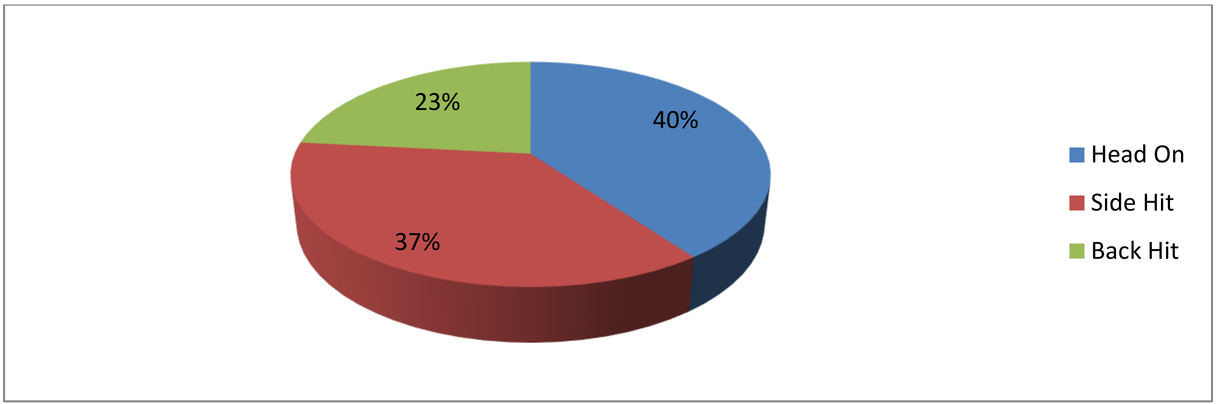


Fig. 33: Proportion of Road Crashes by Collision Types on Group F type roads

Over the course of our ongoing analyses we have been able to study, evaluate, assess and gain in-depth insights into the nature as well as the probable causes and contributing factors which precipitated in road crashes and accidents on the different categories of roads as per the IS 1944 guidelines, including the Group C roads, which reported the highest incidences of crashes and also the major road types Group A1, Group A2, Group B1, Group B2 and some of the specialized roads classifiable under Groups D and E. Presently, we shall study the crashes that occurred on the remnant Group F roads, which represent some of most specific categories of roads that traverse specialized areas near the major transport hubs.

To begin with, the streamlined and segregated data pertaining to the crashes that transpired according to the types of collisions on the Group F category of roads were scrutinized by computing the sum total of the number of crashes reported at each road position and entering the same as inputs for the 3D pie chart graphic tool in the Microsoft Excel software, which then produced the pertinent percentage distribution of crashes for the different road traffic positions in the output 3D pie chart that has been presented above.

For the ease of our comprehension, the color coding scheme of the 3 D pie chart data may be enumerated as follows:

1. **Blue** for **Head On type of collisions**
2. **Red** for **Side Hit type of collisions**
3. **Green** for **Back Hit type of collisions**

A look at the 3 D pie chart reveals the following percentage distribution of incidences of road crashes for each of the 3 major types of collisions:

1. Head On collisions - 40% of the total number of road crashes
2. Side Hit collisions - 37% of the total number of road crashes
3. Back Hit collisions - 23% of the total number of road crashes

Perusing the percentage distribution figures obtained from the visual graphic of the 3D pie chart we find that the Head On collisions were the ones responsible for the highest number of collisions on the Group D category roads, accounting precisely 40% of the reported total number of crashes. This was followed by the Side Hit or lateral impact type of collisions which represent 37% of the total number of crashes and finally the Back Hit or rear impact type of collisions were responsible for 23% of the total number of the reported road crashes.

We shall now venture to evaluate the reasons and mechanisms of the collisions that occurred on the Group F type of roads. The Group F category of roads are the ones which usually ply the routes near the major transport and public transit hubs like rail stations, airports, airfields, docks, ports, piers etc. They are often the transporters of some of the heaviest and most massive cargo payloads, large convoys and cavalcades of goods which may be ferried along on large trucks, flat-bed trucks for outsized payloads and specialized machinery and equipment and multi-wheeled "road train" trucks for carrying interstate and also international cargo. Group F roads near public transportation hubs like rail stations and airports often witness some of the heaviest and densest traffic due to the constant entry and egress of passengers and travelers to and from the stations and airports around the clock. On the other hand roads near docks and large ports as well as major airports are often the sites and routes through which large fleets of heavy and voluminous cargo vessels often carrying international and intercontinental heavy goods, machinery, equipment, food grains, oils, minerals and even hazardous and inflammable chemical substances are transported to various centers of commerce, distribution, refinement as well as export. From the ongoing discussion, it is pretty evident that Group F category of roads have some of the most onerous and demanding lighting requirements of all types of categories of roads in order to ensure the safe and hazard free transit of not only people, motorists and drivers, but, also of such high value, voluminous and under many circumstances also high-risk and hazardous cargo materials.

While surveying various Group F category of roads on site during our field inspections, it was often found that the levels of lighting on such roads, especially the ones near major rail stations and also ports and docks were often woefully inadequate. The presence of large swathes of darkness or dark patches was noticeable on many circumstances due to the pretty low levels of illumination, which rendered it very difficult to attain any sort of proper visual comfort or provide any visual guidance to the drivers or motorists. On some other instances like near airports and airfields, the lighting levels were found to be excessively high. Often, the luminaires were often found to be poorly designed or oriented which led to unnecessary, stray and excessive light being emitted from the luminaires and obscuring the motorist's vision, motorist or other observer which gives rise to unnecessary and visually disconcerting effects like glare as well as alarming levels of visual fatigue and discomfort, which can be major contributing factors to potential road crashes. The so called "Zebra Effect" was also observed frequently. Furthermore, the roads particularly near rail stations in some of the suburban and outskirt areas of major cities and townships and also near the ports were often found to be devoid of any physical refuges or demarcations for segregating the flow of traffic and consequently oncoming traffic traveling at substantial rates of speed on such roads with far from ideal lighting conditions led to the occurrence of a large number of Head On crashes.

Group F roads, especially the ones found in suburban areas or rural townships, are often chock-a-block full with various types of vendors, hawkers and sundry tradesmen plying their trades and selling goods and merchandise on the roadsides, particularly near rail stations and local or interstate bus terminals. Such activity usually impedes with the flow and motion of vehicular traffic and also the transit of pedestrians. Also, many of the Group F category of roads are connected to local streets, roads and other trading routes through which the local tradesmen and purveyors bring in their goods and wares for merchandizing. This creates numerous points and portals of Side Entry and lateral traffic movement as well as turnings, bends, sharp turns and U turns. Vandalism and pilferage of lamps and luminaires is also a frequent problem found on such roads, which is a great detriment to the already shoddy quality of lighting found on such roads. From a photometric perspective, due to the poor nature of the prevalent lighting the contrast of objects on such roads was also pretty poor which can be a vital deterrent to visibility and object identification, due to the low levels of uniformity of the lighting distribution. Consequently, a large number of Side Hit & Back Hit type crashes were reported on such roads, often while trying to avert other obstacles, people and vendors.

Analysis of collisions by road position on Group F type roads

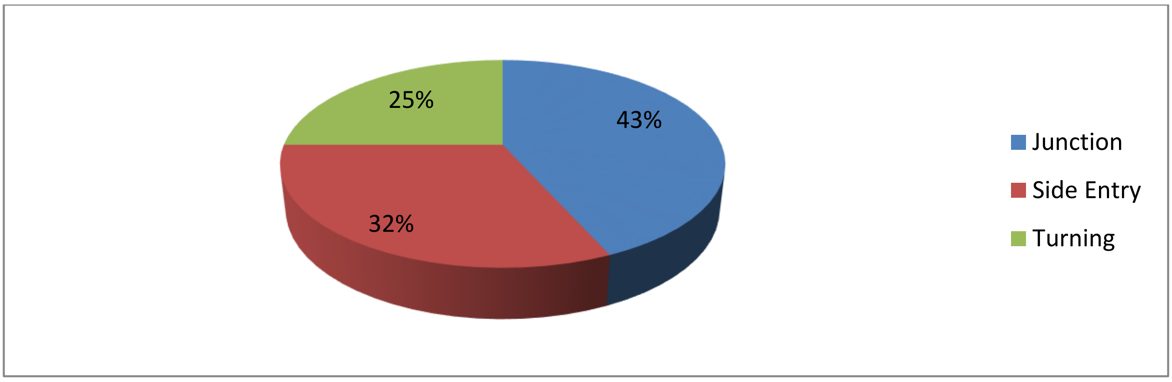


Fig. 34: Road crashes distribution by road position on Group F type roads

Finally, we shall examine the physical position and orientation of collisions on the different spots and traffic positions on such roads. The relevant road positions could be of various types, including major junctions, crossroads or intersections of several key roads or streets or a midway turning point or area of indentation along a continuous road stretch intended for the egress or exit of vehicular traffic. Such evaluation would afford us the opportunity to obtain intricate, in-depth and detailed information about the traits, characteristics and mechanism of the road crashes and the effect of the available road lighting installation on the precipitation of the same. The segregated road crash data pertaining to the categories of the various road and traffic positions on the Group F type roads were evaluated by computing the sum total of the number of crashes reported at each road position and entering the same as inputs for the 3 D pie chart graphic tool in the Microsoft Excel software, which then produced the pertinent percentage distribution of crashes for the different road traffic positions in the output 3 D pie chart that has been presented above.

For the ease of our comprehension, the color coding scheme of the 3 D pie chart data may be enumerated as follows:

1. **Blue** for **Junction**
2. **Red** for **Side Entry**
3. **Green** for **Turning**

Gazing over the 3 D pie chart reveals the following percentage distribution of incidences of road crashes for each of the 3 major types of road positions:

1. Junctions - 43% of the total number of road crashes
2. Side Entry - 32% of the total number of road crashes
3. Turning - 25% of the total number of road crashes

From the above figures, it is evident that the major crossroads, intersections and junctions accounted for the highest number of crashes on the Group E roads totaling 43% of all the crashes. The points of Side Entry or lateral traffic movement recorded approximately a third of the total number of crashes at 32%. This was followed by the positions of Turnings and bends, which contributed to 25% or exactly a quarter of all the crashes reported on the Group F category of roads.

We shall now venture to unravel the mechanism of the crashes at the different road positions and traffic sites on the Group F roads and the causes thereof. The Group F category of roads are the ones which are usually found near the major transport and public transit hubs like rail stations, airports, airfields, docks, ports, piers, local and interstate bus terminals etc. Certain types of Group F roads often carry the onerous burden of some of the heaviest and most massive cargo payloads, large convoys and cavalcades of goods which may be transported on large trucks, flat bed trucks for outsized payloads and specialized machinery and equipment and multi-wheeled "road train" trucks for carrying interstate and also international cargo.

Junctions, crossroads and intersections of both major and minor roads are very frequent on Group F category of roads, due to their very nature. Consequently, at the major crossroads, Junctions and important multilane intersection points and crossings, the density and speed of transit of vehicular traffic is the highest, which by corollary also require the most demanding lighting to buttress the rapid transit of bulk traffic. During our field surveys, at most of the locales that were investigated, the quality and efficacy of the available lighting was found to be pretty abject often utterly inadequate for the demands of such roads. On many occasions, lighting was totally non-existent, which in itself can be a major contributing factor to crashes as the motorists are literally and practically driving blind on such roads. Also, the vitally necessary exercises of repair, replacement and re-lamping of defunct lamps, luminaires and other associated accessories was found to be pretty lax and in fact on most of the surveyed locales, even upon inquiry, we were hard pressed to find the existence of any proper Lighting Maintenance Plan for such crucial roads. Consequently, a large number of crashes were reported at the major crossroads, intersections and junctions which witness the heaviest and fastest traffic.

Furthermore, especially in suburban or rural townships and in particular near rail stations and bus terminals, such roads are chock-a-block with various types of vendors, hawkers and sundry tradesmen plying their trades and selling goods and merchandise on the roadsides. Also, in such areas, most Group F category of roads are connected to local streets, roads and other trading routes through which the local tradesmen and purveyors bring in their goods and wares for merchandizing. This creates numerous points and portals of Side Entry and lateral traffic movement as well as turnings, bends, sharp turns and U turns.

During our on location surveys, it was observed on many occasions and in multiple locations that vehicles had to steer and veer significantly off their intended course in an attempt to avoid hitting vendors, peddlers and other purveyors of roadside merchandise and in so doing greatly augmented their risk of colliding with other objects or crashing against oncoming vehicles or kerbs or other impediments and obstacles on the road surface. The arrangement and siting of luminaire poles was also very poorly planned and shoddily executed in a significant proportion of the sites, which as a result led to very poor levels of uniformity of lighting and consequently poor visual guidance for the driving motorists, especially when navigating tricky areas like sharp bends and executing difficult driving maneuvers in such locations. In fact, the poor lighting design, alignment and orientation of the luminaires and corresponding light sources were a cause of significant visual fatigue for the drivers and other road users, instead of augmenting their visual comfort. On some occasions, it was even found that some of the roadside lamps had been taken off their housing luminaires by locals. Such unbridled acts of vandalism and civic violations severely undermine the efficacy of the road lighting installation in maintaining the safety and security of the roadside and surrounding environs on such roads and localities. In conjunction with the despicable quality of the prevalent road lighting, if, available at all, this contributed significantly to the high number of collisions at the points of Side Entry as well as Turnings, Bends and U turns on the Group F category of roads.

Analysis of Road Crashes according to Lamp type

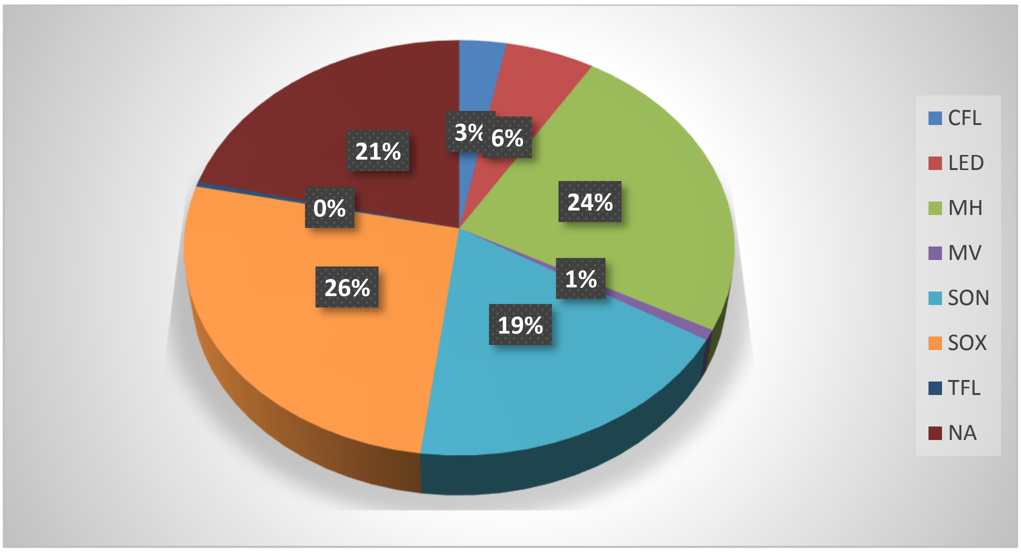


Fig. 35: Distribution of Road Crashes according to Lamp type

In the previous sections of our study, we have analyzed and evaluated the road crashes which transpired on the different categories of roads as per the IS 1944 classification, according to the nature and types of collisions that occurred as well as the position of road or traffic area which bore witness to the precipitation of the said crashes. In the present phase of our ongoing analysis, it will be our endeavor to comprehend the role played by and degree of impact of the available road lighting on the precipitated crashes in terms of the lamps and light sources that were used. As has been our modus operandi throughout the data analysis and evaluation phase of our dissertation, the collected and tabulated data was segregated in the Microsoft (MS) Excel software, according to the type and category of lamps and light sources which were available at the crash locations where the specific crashes and accidents transpired.

The sum total number of the crashes as per the type of lamp and light source used was then computed using appropriate commands in the Microsoft Excel software. The resultant data was then plotted using the 3 D pie chart graphic tool in the Microsoft Excel software. Consequently, Microsoft Excel generated the pertinent percentage distribution of crashes for the different lamps and light sources used as has been represented in the 3 D pie chart produced herein. For aiding visual evaluation, the Microsoft Excel software plotted the data in color coded form, corresponding to the different types of lamps which were found to have been used in the road areas where the crashes transpired.

For the sake of clarity and the ease of our comprehension, the color coding scheme of the 3 D pie chart data may be enumerated as follows:

1. **Blue** for **Compact Fluorescent Lamps (CFL)**
2. **Red** for **Light Emitting Diodes (LED) lamps**
3. **Green** for **Metal Halide (MH) lamps**
4. **Violet** for **Mercury Vapor (MV) lamps**
5. **Cyan** for **SON** lamps
6. **Orange** for **SOX** lamps
7. **Deep Blue** for **TFL** lamps
8. **Maroon** for **NA** implying No Available Lighting

Gazing over the 3 D pie chart reveals the following percentage distribution of incidences of road crashes for each of the light sources or lamps:

1. Compact Fluorescent Lamps (CFL) - 3% of the total number of road crashes

2. Light Emitting Diodes (LEDs) – 6% of the total number of road crashes

3. Metal Halide (MH) lamps - 24% of the total number of road crashes

4. Mercury Vapor (MV) lamps – 1% of the total number of road crashes

5. SON or High Pressure Sodium lamps – 19% of the total number of road crashes

6. SOX or Low Pressure Sodium lamps – 26% of the total number of road crashes

7. TFL or Tubular Fluorescent lamps – 0% (actually negligible numbers less than 1%) of the total number of road crashes

8. NA or No Available Lighting – 21% of the total number of road crashes

While evaluating the data as outlined above, we find that the Compact Fluorescent Lamps (CFL) lamps were present in a measly 3% of the locations where the crashes occurred. CFL lamps have been a popular choice in road lighting installation as they offer good energy savings and decent levels of illumination and can generate significant cost savings. In many areas where they are used for road lighting, especially in suburban and rural areas, it was found on many occasions that single CFL lamps were used to supplant and replace much larger and higher wattage lamps, which had become defunct or had reached the end of their usable lives. However, CFL lamps, usually do not generate sufficient levels of illumination for sustainable road lighting purposes over long periods. Consequently, their usage for road and street lighting needs to be relegated to roads with lesser traffic density and in more offbeat locations. However, during our field surveys, it was often found that CFL lamps were employed in important roads and routes with relatively dense and rapid transit of traffic, in order to generate cost savings. Also, the Color Rendering Index (CRI) of CFLs is approximately 80, which makes it far from ideal for proper color rendition of objects in the hours of darkness and also fails to provide adequate Visual Comfort and Visual Performance for motorists and other road users. It is pertinent to note that CFLs fail to illuminate sufficiently large swathes of road surfaces, where they are often used for generating cost savings. In such instances, Tubular Fluorescent Lamps (TFL)s are generally a better choice as they can provide higher levels of illumination. The TFL lamps, which may come in various variants like T5, T8 or T12 were found to be used very rarely in the areas surveyed which had reported crash occurrences and consequently accounted for only a handful (less than 1%) of the total number of reported crashes.

In our field surveys, it emerged that the Light Emitting Diodes (LEDs) were present only in 6% of the total number of areas for which crashes were recorded in the collected data spanning over a decade. This figure is significant, as in India we are by and large we are still in a phase of transition where different municipal authorities are gradually retrofitting old, existing and defunct lamps and light sources with LED lamps due to their myriad benefits. LEDs quintessentially represent the future of lighting in a global perspective and are being used in almost all fields and spheres of lighting. It is only a matter of time before LEDs revolutionize the realm of road lighting also in a larger Indian context. It is also imperative to note that most of the LED luminaires which were found during our field surveys, were predominantly recorded on streets in various crash locations in Gujrat. West Bengal is yet to fully transition to and avail the benefits of LED lamps.

Although LEDs have countless benefits in terms of energy and cost savings and also negating the need for frequent lamp replacements and retrofits, owing to their substantially high life times and rugged durability, we need to be reminded of the fact that LEDs are still an emerging and developing technology, especially in the perspective of road lighting. As such, it was found on many occasions during our field surveys that the LEDs which were used in many of the crash locations and sites had poor levels of illumination and also less than desirable levels of color rendition (CRI), which in turn led to dark patches being found on the road surface and also poor object identification and visibility. Conversely, in some areas it was also found that the misdirected and poorly oriented LED lamps were a significant source of glare in the observer's Field of View (FOV). The problems are often exacerbated by the usage of cheap and inferior quality LED sources, which are purchases in bulk for effecting cost savings. Such LEDs also suffer from Temperature Sensitivity, whereby the quality of the produced lighting is highly dependent on the ambient operating temperature. At high temperatures there are changes in the parameters of the current passing through the semiconductor elements, which can lead to burning out of the LED module. Also, the biggest disadvantage of LEDs at present is their relatively high cost, which has a prohibitive impact on their widespread usage as road lighting sources in different localities. However, with the ever improving quality and reducing costs of LEDs, their adoption is expected to only grow by leaps and bounds with ever increasing usage in road lighting.

While perusing the data, we find that the Metal Halide (MH) type of lamps were present in nearly a quarter of the road crash sites, 24% to be precise, second only to the Low Pressure Sodium lamps or SOX lamps. The reason for this is primarily attributable to the fact that Metal Halide lamps are still being used in various roads, streets, highways, expressways and other significant roads and routes of vital importance. The prime advantages of Metal Halide lamp, which led to their popularity especially in the past few decades are their relatively compact designs, flexibility of usage in various positional orientations, lower run up times, long life time in terms of burning hours and availability in various wattages as well as high luminous efficacy ranging usually between 80-130 lm/W.

However, the Metal Halide lamps suffer from significant disadvantages which make them a far from ideal source for road lighting and a potential contributing factor in the significant number of road crashes reported on roads and crash sites where they were installed. Among the major cons of Metal Halide lamps is the excessive amounts of strong glare which they produce, which can have a temporarily blinding impact on drivers, motorists and other road users. Thus, Metal Halide lamps contribute substantially to unwarranted light pollution, which can be a prime cause of distraction and diversion for traveling motorists and other road users, impeding their visual capacity and capability and even causing sensations of temporary blindness due to their harsh glare. Furthermore, the color rendition (CRI) of such lamps ranges between 60 and 70, which is less than ideal for proper object identification, object contrast and visual guidance. All these factors appear to have had a significant impact on the number of reported crashes where MH lamps were installed.

In the visual representation obtained from the 3 D pie chart data, it is found that the Mercury Vapor (MV) lamps accounted for only 1% of the road crashes and were present in the corresponding locations. Mercury Vapor lamps were a very popular choice for road lighting source in their heydays during the 1980s and 1990s. However, they have been gradually replaced by other and much more improved light sources. Their major forte lay in their decent luminous efficiency during their heyday ranging between 35 to 60 lm /W as well as their relatively long life spans, which in many cases can extend to 40 years. However, in the present perspective they are being sparingly used especially for road lighting applications, due to the fact that other lamp technologies have higher and better luminous efficacies as well as their poor color rendition (CRI) of around 45, which causes human skin to appear with a greenish tinge and also renders the visibility and identification of objects to be very poor. Also, these lamps can be a cause of significant light pollution which can greatly predispose areas lit with such lamps to be crash prone.

We shall now attempt to evaluate the crashes occurring on the roads equipped with the High Pressure Sodium (HPS) lamps or the SON lamps. Perusing the graphical data of the 3 D pie chart, we find that the SON lamps were installed in nearly a fifth (19% exactly) of the roads, where the crashes were reported and recorded. This is primarily due to the fact that HPS or SON lamps still remain among the de facto stalwarts of road lighting sources. The HPS lamps were found in a large number of the areas and all categories of roads, be it in urban downtown areas or suburban and rural outskirts and offbeat areas during the field survey phase of our study. The major advantages of SON lamps is their high luminous efficacy of around 80-130 lm/ W which can go up to even 150 lm / W for certain variants of these lamps and also their relatively long burning hours. The major disadvantages of these lamps is the fact that the light produced is a golden white color, which can render color vision and proper object identification and visibility to be very low in most cases. These lamps were also found in many occasions to be a significant source of inadvertent and unwarranted glare. All these factors appear to have contributed to the large number of accidents reported at locations using the HPS or SON lamps.

Finally, we find that the Low Pressure Sodium (LPS) or SOX lamps were used in the highest number of crash locations, accounting for 26% of the total number of road crashes.

This is testament to the fact that SOX lamps are the preeminent and most popular light sources used for illuminating roads, streets, highways and carriageways all across India. The major reasons behind their enduring popularity is their high energy efficiency and luminous efficacy which can range around 200 lm /W, as well as their high burning life. Another significant advantage of the SOX lamps are that they can provide visibility even under inclement conditions like rain, fog, snow and other related weather phenomena and conditions which can greatly reduce visibility. However, the biggest con of these lamps is their abject lack of color rendition, which makes all objects appear yellow, gray or even black is a major cause of concern as it proves to be a huge detriment to visibility, identification and timely reaction of potential threats and obstacles to be extremely poor and consequently is a major potential contributor to the precipitation of such substantial numbers of road crashes reported on the numerous roads which had such lights installed. Furthermore, these lamps have relatively short life spans which necessitates frequent maintenance and re-lamping operations. In our field surveys, it was found that on many occasions that such maintenance operations were not performed for periods of several years and in some cases, even several decades in areas using LPS or SOX lamps. Consequently, such roads accounted for the highest number of road crashes reported when analyzed in the perspective of type of lamps used or available.

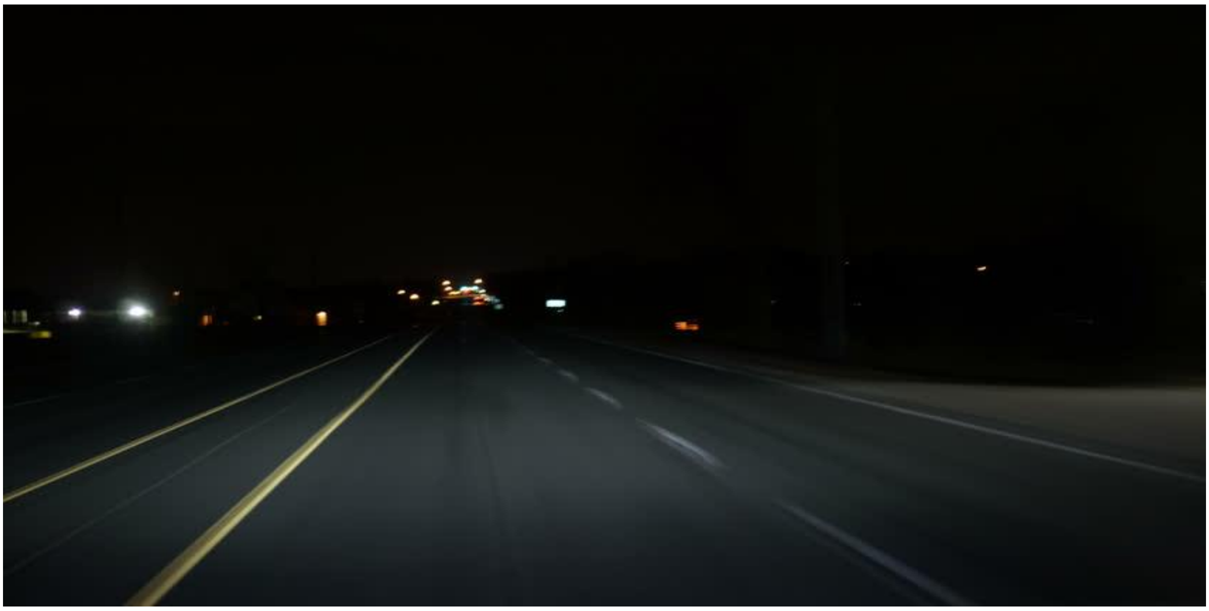


Fig. 36: Typical unlit Indian highway at night

Thus far, over the course of our ongoing discussion, we have evaluated the role played by the different types of lamps and light sources used in the various locations and road areas where the crashes and accidents were reported. However, our assessment would be utterly incomplete and deficient, if, we do not consider the areas where lighting was not at all available. It may perhaps sound odd to a 21st century audience that there are roads with no available night time illumination in major areas, but, it was found during our investigation that such areas were more than just an aberration. In fact, if, the No Available Lighting category were a light source in itself, it would account for no less than 21% of all the reported crashes, more than a fifth of the accidents that transpired. This is a rather concerning and worrying statistic. It was found during our field surveys, that various areas, be it in the heart of large cities or residential areas, suburban off beat areas as well as rural shopping and commercial hubs, large national and interstate highways or even specialized roadways near ports, rail stations and even airports in a few instances as well as bridges and flyways were completely devoid of any form or sort of lighting to illuminate the passage of vehicular traffic and pedestrians and dispel the gloom of darkness. Needless to say that the complete lack of illumination severely predisposed such areas to crashes, many of them fatal as the motorists were literally and practically being forced to drive blind, relying only on the illumination afforded by the vehicle headlights with no aid whatsoever from the roadways. Consequently, more than a fifth of all the recorded crashes were found to have transpired on such roads with absolutely no means of night time illumination.

CHAPTER-V

SUMMARY & CONCLUSIONS OF THE STUDY

SUMMARY & CONCLUSIONS OF THE STUDY

Over the course of this dissertation, we truly had the best seat in the house to witness road lighting and the intricate interplay of kindred parameters and phenomena in action. At the outset of the study we had endeavored to evaluate the paramount role played by road lighting in ensuring the safety and security of people and property in terms of averting accidents and crashes against immovable objects, especially during the hours of darkness. In essence, the present study has afforded us an expansive overview and pervasive perspective of the myriad facets, aspects and dimensions of the contemporary scenario of Road Lighting.

Delving deep into the realm of roads and road lighting, it emerged over the course of the study that the Group C category of roads witnessed the highest incidences of road crashes. It was often found on such roads that the lighting was far from adequate in terms of all the relevant parameters and in many instances completely absent. Furthermore, on Group C roads, factors like rampant pilferage and vandalism of lighting installations, presence of untrimmed foliage, trees and vegetation as well as flouting of speed limits together with the deplorable lighting conditions played a significant part in the precipitation of the crashes. The number of crashes on the Group C category of roads was closely followed by those on the major primary and secondary traffic routes on the Groups A1, A2, B1 and B2 category of roads, which witness some of the highest traffic densities as well as rapid vehicular transit and consequently have stringent lighting demands, which in practice are rarely met in India. It is therefore imperative for the road lighting design on such roads to be in strict accordance with the relevant guideline recommendations and also for civic authorities to preempt pilferage and vandalism as well as performing regular maintenance activities of the lighting installation and pruning of proximate foliage.

The collisions on most of the major categories of roads were found to be well distributed according to the type of collision, whether full frontal Head On, Side impact or Rear impact collisions, which occurred at different road positions including major crossroads and junctions, points of side entry as well as positions of turnings and bends.

The study also unearthed a treasure trove of information about the different light sources used for illuminating roads, streets and highways and what impact they had on the precipitation of the crashes. Our analysis revealed that the Low Pressure Sodium or SOX lamps accounted for the highest number of road crashes, which is largely attributable to the fact that they are still the predominantly used road lighting sources as well as due to their deplorable color rendering and consequently poor visibility, identification and timely reaction of potential threats and obstacles. The Metal Halide lamps as well as the High Pressure Sodium or SON lamps, with their respective limitations also were found to illuminate many of the crash sites. LEDs, which have been universally acclaimed as the future of lighting also accounted for many of the crashes, although most localities in India are yet to fully transition to and harness the benefits of LED lights. It is also pertinent to note that due to the high intensity beam of LED lights, it causes significant glare to the motorist, leading to crashes, especially if the Mounting Height of the lighting pole is low. However, the biggest surprise element was the fact that roads with No Available Lighting accounted for more than a fifth of all the reported crashes. This is a very appalling statistic as major roads, including national and interstate highways were found to be completely devoid of nighttime illumination, which contributed to the significant crash incidences on such roads. The situation on such roads needs to be immediately rectified not only through appropriate response from civic authorities, but, also through public awareness drives like the recent "**Roshan Dilli**" campaign, which aims to illuminate roads without any lighting in New Delhi. It also goes without saying that the faster localities transition to LED lights on roads, the sooner they will be able to reap its rich rewards in every aspect, including cost and energy savings.

CHAPTER - VI

A BEACON LIGHTING THE PATHWAY OF PROGRESS

- FUTURE AVENUES OF STUDY

FUTURE SCOPE OF RESEARCH

The current study and dissertation represents a substantial body of work upon the present perspective of roads and the transportation network and the role played by road lighting in ensuring the safety and security of all road users and maintaining the integrity of the roadways system. As an official of the public insurance sector, the author felt morally obligated to undertake this endeavor in the anticipation that it would serve as a comprehensive compendium for improving road safety and security and minimizing misdemeanors. The scope and span of this study has been extensive and as such the study has strived to address many vital aspects of the wide gamut of road lighting. However, it is our strong belief that this work would serve as a firm base for future studies, which may be geared toward establishing granular real-time correlation between enhanced Road Lighting and reduced mishaps and perpetrations of criminal acts. Novel technologies like Telematics, leveraging the benefits of Big Data, cloud computing and the nascent revolution of perpetually interconnected Internet of Things (IOT) devices may be employed for such in-depth monitoring and can greatly augment and improve the present scenario of road crashes and lead to safer pedestrian and driving environments. Furthermore, the study has unraveled many glaring loopholes in the present road lighting context of Indian roads and the purpose of the study would be well served if remedial actions and improvements are effected accordingly.

Ensuing research and field studies may also be focused on further fine-tuning the existing Road Lighting infrastructure by leveraging the benefits of LEDs and conventional light sources as well as integrating renewable energy sources like Solar Panels, wherever feasible. Avant-garde modern concepts like those of Smart Cities and Smart Streets are already de rigueur in a contemporary global perspective. The lighting requirements of such advanced, designer cities and urban agglomerations both in terms of ensuring public safety and security as well as embellishing and augmenting the esthetic appeal of such cities are opening up ever expanding vistas and newly fangled concepts for the future of Street Lighting , providing practically infinite possibilities and directions for future research.

Future research and surveys into the areas described hitherto as well as integration of innovations from other relevant technological fields would ensure that the road ahead is perpetually well illuminated. Road Lighting, thus, paves the way forward and shines a bright beacon on our pathway forward onto the world of tomorrow and beyond, with advances in Road Lighting also spawning ingenious innovation and development in allied fields of technology and research and vice versa, thereby creating a mutually cohesive ecosystem of advancement.

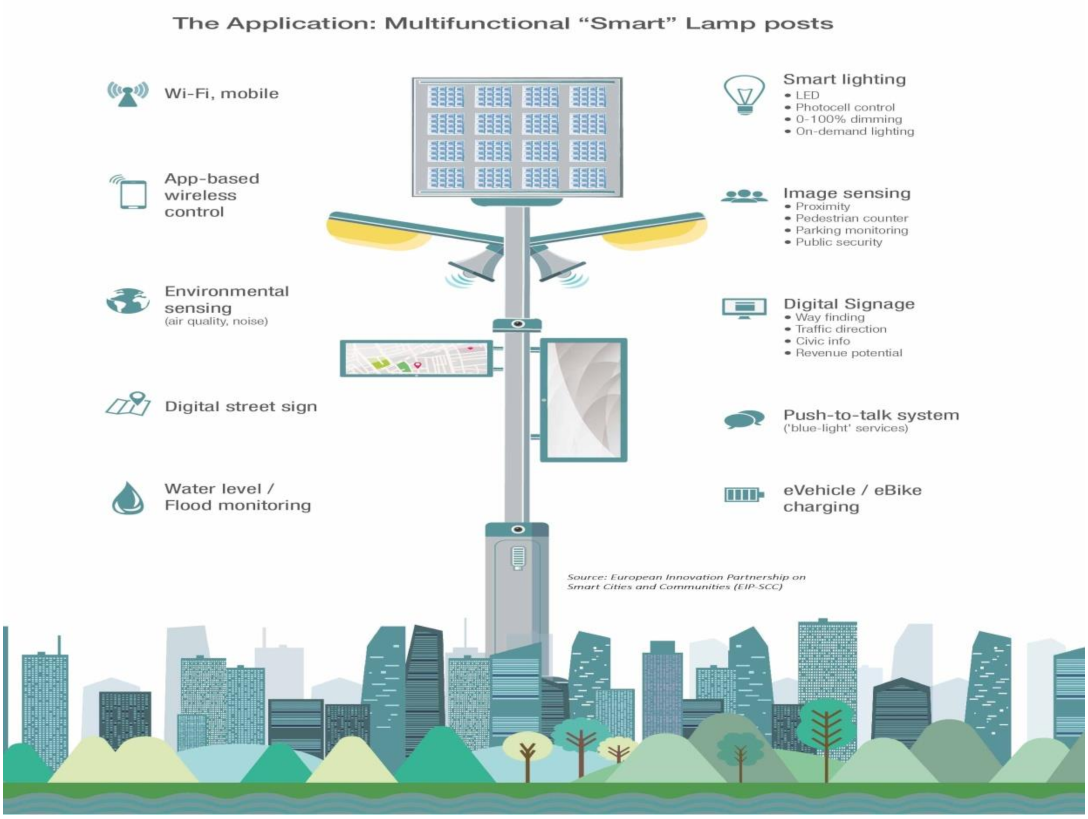


Fig. 37: Depiction of a Smart Lamp Post System using Solar Panels

CHAPTER -VII

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