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A REVIEW ON THE FACTORS AFFECTING CONSPICUITY OF A TWO-WHEELER ON ROAD

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ABSTRACT

There are number of factors responsible for collisions/crashes between a two-wheeler and another four wheeled automobile on road. Out of these factors, low conspicuity has been found as one of the major factor in most of the studies. Hence, this review paper has tried to enlist the factors affecting conspicuity of a two-wheeler (abbreviated as TW) on road. In this paper, previous literature has been studied for the extraction of relevant information and after a thorough analysis of related research papers from various databases, conspicuity of two-wheelers (Motorcycles/Scooters/Powered two-wheelers) has been divided into three types. In discussion part possible solutions for the enhancement of the same has been discussed. Further, this study will be useful for research and development in manufacturing of two-wheelers/TWs, helmets, clothing of a rider and the material that can help in the enhancement of conspicuity/visibility. Also, the results of this study can be used to aware both the TW riders and other drivers to avoid collisions due to conspicuity issues of a TW on road.

Keywords: Conspicuity, Two-wheeler, Collision, Rider

INTRODUCTION

The number of vehicles are increasing day by day on roads and studies from different countries have revealed that with the upliftment in the number of vehicles there is also an increase in the risk associated with accidents on roads. The yearly report of Ministry of Road Transport and Highways (Transport Research Wing), Road Accidents in India, 2022 presented the increase in road accidents by 11.9% when compared to the statistics of previous year. On the same hand, as a result of road accidents the stats for number of deaths raised by 9.4% and that of injuries by 15.3%. Further, according to the report, the number of motorised vehicles in India increased as a result of stable economic growth and raised per capita income and between 2010 and 2020, growth of 9.8 percent in CAGR i.e. Compound Annual Growth Rate has been recorded. Hence, as of March 31st, 2020, there were 326 million automobiles registered nationwide with the highest segment of 74.7 % of two-wheelers followed by other four wheeled vehicles. In this report, out of the total accidents the accidents of two wheelers has been recorded at the highest which numbered to be 63,115 and 25,228 deaths in 2022 followed by other four wheelers (Road accidents in India 2022, 2023). According to World Health Organization (2004), It was estimated that for per kilometre travel, risk of being killed is ten times more and it's twenty times more dangerous than driving a car for per travel hours on a motorcycle. Also, in a report by "National Highway Traffic Safety Administration (NHTSA), Department of Transportation U.S.", in the period from 2000 to 2008 the figure of TW riders' demises in crashes raised by 83% while those who got injured was raised by 66% (NHTSA, 2011). Similarly, about 14% of all serious injuries in Great Britain were recorded for powered two-wheelers where their population was less than 1% (Clarke et al., 2004). Hence, the vulnerability of the riders and the increase in the accidents involving TWs all together contributes to the concern for the safety of the TW riders (Shinar, 2007). Also, in a deep study "MAIDS" which was piloted in Europe reported that 73% of powered two-wheeler's accidents happened in the daytime out of which 90% were in clear weather conditions and also 85% were in light to medium traffic density (ACEM, 2004). Similar inferences were procured from New Zealand also which revealed that 64% of the TW collisions took place in daylight and 72% of them happened in optimal conditions of weather (Wells et al., 2004). Also, according to the annual report of Ministry of Road Transport and Highways (Transport Research Wing), Road Accidents in India, 2022, data of road accidents for 2022 in India showed that three-fourth of the accidents and fatalities occurred in bright or clear weather in contrast to the unfavourable weather circumstances including rain, fog, hail or sleet, which accounted for 16.6% of all traffic incidents in 2022 (Road accidents in India 2022, 2023).

After going through the above data, one must think of that why these accidents took place in such a clear weather conditions and what could be the possible factors contributing for these collisions?

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In European countries like France, Spain, Itay, Germany and other, the characteristics of 921 accidents were studied that were including motorised two wheelers recorded between 1999 and 2001 (Roge et al., 2010) and a sample of 923 motorcyclists were taken as a control group and analysed under in-depth study MAIDS i.e. "Motorcycle Accidents In Depth Study" (ACEM, 2004). The accident causes were categorized under three different categories after the analyses of data from the mentioned sources as "Environmental Causes, Mechanical Causes and Human Related Causes" (Gershon et al., 2009; Shinar, 2007). Out of these accident causes, the third category of human related causes was identified as the prominent cause in most of the collisions and 35.6% of them occurred as a result of attentional failure or misperception of the car driver. Here, although the view of the car driver was not blocked and still the detection failure was there that crossed the threshold time in which the crash could have been prevented (Roge et al., 2010). Further, studies have confounded it to be due to the "low visibility" of TWs on roads resulted due to their inconspicuous features (Olson, 1989; Wulf et al., 1989). In the MAIDS study also, 87.9% of accidents were found to be happened due to the human factors (ACEM, 2004) and about 70% of these accidents has been recorded to happen due to delays in TW's detection. This study was required in order to figure out the possible factors responsible for conspicuity of a two-wheeler on road as no comprehensive study was identified for the same purpose till now except the study by Wulf et al. which was conducted in the year 1989 and due to time gap, it was found with lacking in the aspects and dimensions which were covered further after it.

METHODOLOGY

Extensive literature review was done using systematic literature review and the PRISMA technique and TCCM (Theory, Context, Characteristics and Methodology). The databases consulted were SCOPUS, ScienceDirect, JSTOR, Google Scholar, Emerald and Springer Journals and the Journals specific to transportation. Finally, about 110 papers were considered for analysis.

LITERATURE REVIEW

Researches have revealed that conspicuity depends on many factors like size of a vehicle, outfit of the rider, distance from the observer, road and infrastructure conditions, weather, background of a two-wheeler, interaction with other road users, luminance etc (Damani and Vedagiri, 2021; Gershon et al., 2012; Hole et al., 1996; Thomson, 1980; Wulf et al., 1989), and the absence of significant factors can lead to reduction in conspicuity and thus the two-wheeler become less visible causing the other driver to look but not able to "see or comprehend" well. Thus, this paper has tried to enlist such possible factors with the following classification.

TABLE 1. CLASSIFICATION OF FACTORS AFFECTING CONSPICUITY OF A TWO-WHEELER

Physical factors of a TW	Size of a TW Colour Use of headlight and its configuration
Environmental factors	Surrounding luminance Luminance contrast TW contrast with the background
Human related physiological and psychological factors towards a TW on road	Impact of alcohol or drugs Position in other driver's field of vision Field dependent and independent drivers Information overload Unexpected places of TW in traffic stream and familiarity with a TW Stages of perceiving a TW Attention failures Highway hypnosis Speed and distance judgement errors

Source: Authors own creation

PHYSICAL FACTORS OF A TWO-WHEELER

Under the category "Physical factors" first attribute studied is the "Size" of a two-wheeler. In a comparative study by Shinar (2007), the small size of a TW as compared to other automobiles get concealed at blind areas or by other vehicles in the driver's field of view coming from the other side or at intersection. In a study by Williams and Hoffmann (1977, 1979a), increase in the anterior part of a TW with the use of white fairing raised the chances of detectability. Second attribute is the

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"Colour" which has been studied under three categories in which first is the colour associated with the helmet of the rider. In an experimental study by Wells et al. (2004), wearing white helmet was associated with 24% lower risk when compared to black helmet and light-coloured helmet was associated with 19% lower risk compared to dark coloured helmets. Also, the simulated study by Shaheed et al. (2012) found longest (earlier) detection distance for TW riders wearing "bright yellow clothing and helmets" for both young and old drivers of other automobiles in urban and rural environments which indicates safety for riders wearing bright colours. Also, in order to increase conspicuity on part of the helmet, in an experimental study by Pinto et al. (2014), the light on helmet was found to be significantly effective as compared to the standard lighting pattern as the presence of light at the highest point of the motorcyclist provides distinguished visual pattern for the presence and detection of a TW. It was found to be more significant when they were more difficult to be perceived due to small angular size and distant location. This also helped in optimal visibility of the TW when it is hidden or blocked by other vehicles on road. Next is the colour of rider's clothing. Under this, various studies have shown that fluorescent clothing results in enhancing conspicuity as compared to the dull ones (Dahlstedt, 1986; Donne et al., 1985; Fulton et al., 1980; Stroud and Kirkby, 1976; Williams and Hoffmann, 1977). On the other hand, under optimal viewing conditions, Woltman and Austin (1974) found no difference between fluorescent and non-fluorescent pigmented clothing but at dusk time fluorescent clothing were found to be superior. Also, Watts (1980) found that in a very light background conditions a dark blue coloured jacket was found to be more efficient as compared to a fluorescent yellow jacket. So, these finding pointed the importance of contrast of rider's clothing with the background. Also, Kwan and Mapstone (2004) found that fluorescent materials are dominant in enhancing conspicuity during day time while retroreflective materials and lights are effective in enhancing conspicuity at night. At daytime, riders wearing reflective or fluorescent clothing were found to be having 37% lower risk of collision (Wells et al., 2004). According to Wood et al. (2013) when light from a source like headlight falls on retroreflective material then it is reflected back to the light source hence more effective at night or low light conditions. On the other hand, invisible ultraviolet light is converted to visible light under natural daylight by fluorescent material hence resulting in effective conspicuity during daytime (Joint Technical Committee, 1999). Under the study of TW colour, no association was found in a case control study with the frontal colour of the TW and crash related risk in the study by Wells et al. (2004) while William and Hoffman (1979b) have argued that the frontal and side-on conspicuity of a TW is of significant importance than the rear one. Also, Abdur et al. (2021) in a study on bicycles found that white strips on red colour tyre provides an earlier detection in all light conditions. Third attribute studied under the physical factors is the use of "Headlights at daytime and its configuration". Turning "on" of the frontal headlight at day time was found to be responsible for providing 27% lower risk (Wells et al., 2004). In an experimental investigation using both simulated and actual driving by Brooks et al. (2005), use of headlights was found to be beneficial in an inclement weather compared to bright sunny days which are present with reflections from other automobiles and material of reflective nature. Further, simulated study by Shaheed et al. (2012) found that for drivers of both young as well as old age of vehicles other than a TW, modulating headlights were having extended recognition distances than high beams or daytime running lights in both urban and countryside environments. When talking about the headlight configuration, computer simulations results by Gould et al. (2012) who worked on discrimination of speeds with different light configurations found that at night, individuals were closely able to judge the speed of a TW with tri-headlight configuration. Similarly, in a laboratory experiment Roger et al. (2012) found that in visual competition with other vehicles on road, TWs with T shaped headlight configuration was quickly detected. While Pinto et al. (2014) in an experimental study found that the yellow light was significantly distinct in presence of surrounding white and other light sources.

ENVIRONMENTAL FACTORS

Second category studied in this paper are the "Environmental factors" affecting the conspicuity of a two-wheeler on road. Under this category "Surrounding luminance". is the first attribute which revealed that although the rate of cycling is quiet low at night but the data from various countries showed that cyclists' injury rates are high at night (Henley and Harrison, 2009; Jaermark et al., 1991) and cyclists and pedestrians are at higher risk of being injured due to collision with vehicle as a result of poor conspicuity due to lack of luminance at night (Kwan and Mapstone, 2004; Owens and Sivak, 1996). Further, the likelihood of involvement of pedestrians in car crashes at night is three to seven times higher than during the day hours (Sullivan and Flannagan, 2002). This data shows that surrounding luminance is an essential factor for the conspicuity of an object. Thus, surrounding luminance is responsible for better conspicuity of a cyclist as well as a motorcyclist. Next attribute is the "Luminance contrast". Under this, the measure of "luminance difference between a target and its background is called as 'contrast' and 'luminance' is the amount of light per unit area either reflected or emitted by the surface and higher value of contrast will result in greater probability of detection of a target" (Grether and Baker, 1972; Thomson, 1980). Also, Hole et al. (1996) found that conspicuity cannot be enhanced just by wearing bright and retroreflective clothes and using headlights but it also depends upon the brightness contrast with the background. On the other hand, results by Blackwell's research on vision

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says that the background constantly changes and is beyond the control of the rider (CIE, 1982). Over this an experimental study using video clips by Gershon and Shinar (2013) shows that use of alternating blinking light system (ABLS) i.e. a system of two mounted lights placed on the helmet that blinks in an alternative manner and creates an impression of motion which is also called as "PHI phenomenon" is found to be an exclusive and innovative display over the helmet was very successful in the scenario of changing background system. It was very useful in enhancing attentional as well as search conspicuity specially at dusk and in urban environments. It also helped in decreasing reaction time and detection distance specially when level of surrounding luminance decreased. Last attribute studied under this category is the "TWs contrast with the background". Williams (1976) suggested that for a dull coloured TW, blending with its checkered background during daylight conditions is very possible even when it is adjacent to its other road users. Camouflaging effect was also found with the increase of surrounding density (Monk and Brown, 1975). In the MAIDS study it was found that in 14.4% of the collisions of TWs, the background had undesirable impact on conspicuity as compared to the other automobiles which was 5.6% which shows that background responsible for a TW's conspicuity is more critical than for other vehicles like cars, buses, trucks etc (Shinar, 2007).

HUMAN RELATED PHYSIOLOGICAL AND PSYCHOLOGICAL FACTORS TOWARDS A TW ON ROAD

Under third categorization "Human related physiological and psychological factors towards a TW on road" has been studied that affects the conspicuity of a two-wheeler on roads. Under this, first attribute studied is the "Impact of alcohol or drugs". According to studies, increased blood alcohol concentrations resulted in the deterioration of the peripheral vision and hampered perceptual process (Buikhuisen and Jongman, 1972). Also, Cohen (1984) highlighted that under the impact of alcohol, the visual behaviour varies in many ways in which "visual field" compacts resulting in the reduction of the "visual search area". The second attribute studied under this category is the "Position of the TW in the other driver's field of vision". Considerable probability to be get noticed by an observer depends on where an object is in the observer's range of vision. Visual acuity has been found to be less sensitive towards periphery in daylight conditions which shows that any object approaching from an angle will have less probability of earlier detection as compared to the object coming straightforwardly towards the observer. Also, there is low variance in the sensitivity of central and peripheral vision at night and twilight conditions and both are less sensitive when compared to the central daylight vision conditions (Thomson,1980; Williams,1976). Thus, for a less conspicuous object like TW, the probability of non-detection increases when approaching from an angle or at intersection and under night and twilight conditions. Third attribute is the "Field dependent and Independent drivers". Witkin et al (1972) originally developed this concept. A field independent person has the ability to distinct salient features from background as compared to the field dependent person who faces problem in doing so and takes longer to distinguish accurately which shows that field independent person will be more efficient at driving than the other. Field dependent drivers need more time for the processing of the visual information and while driving are found to be less effective in visual search behaviour (Shinar et al., 1978). Smaller variability in eye fixation has been found among field-dependent drivers which indicates that they possess low capability to adapt their visual search behaviour to their immediate environment while driving (Cohen, 1980). Thus, driver's field dependency can influence the detection of a low conspicuous objects on roads like TWs. Next attribute under this category is the "Information overload". Some visual inputs like a TW in the peripheral visual field may not be perceived by the driver due to information overloads on the road particularly at intersections (Cumming, 1972). Term "tunnel vision" has been given by Mackworth (1965) for the decreased functional visual field due to information overload. Fifth attribute is the "Unexpected places of a TW in the traffic stream and familiarity with TW". Various studies have depicted the role of expectancy of a TW on road responsible for its cognitive conspicuity i.e. it depends upon the experience of the driver that when he/she can encounter a TW on the road. Expectancy further influences the distance detection time for an object or TW on road. So, it is likely for a driver to respond well in time for the presence of a TW on road when it is expected to be there (Harano, 1970; Olson and Sivak, 1986). More attention was given to the oncoming traffic by the TW rider driving a car than the other car drivers (Mortimer and Jorgeson, 1975). Therefore, these findings indicates the importance of familiarity factor of an automobile driver with TWs. Also, in a study by Brooks and Guppy (1990), the four-wheeler drivers who were also having the experience of riding a TW was more conscious towards detecting a motorcycle in traffic than other drivers who used to drive a car only and had a less chance of collision with them. Sixth attribute is the "Stages of perceiving an object (TW here)". Perception is the detection or realization of an object in the environment which is thoroughly examined in the foveal region after the eye saccade is stimulated due to detection of the object in the periphery of retina. So, object with strong conspicuity will be detected earlier than the other in this process as foveal attention is more for strong conspicuous objects (Wulf et al., 1989). Similar cause has been mentioned by Herslund and Jorgensen (2003) for LBFS type accidents. Also, Langham and Hole (1998), Mourant and Rockwell (1972) have found difference in the visual search strategies of experienced and inexperienced drivers. With the increase in experience the drivers

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use to focus their visual field at the centre of the traffic hence filtering out less information based on their experience from the environment while the inexperienced ones start their search ambiently. In retina the light receptors' physiological efficacy remains unchanged but due to limitations in information processing the useful visual field varies and only the fixated targets will be processed further in a situation of information overload. Consequently, at the cost of peripheral vision foveal vision takes precedence (Cohen, 1986; Wulf et al., 1989). Also, Miura (1987) in a field study found that with the increase in situational demands the automobile drivers' response was reduced unusually that resulted in narrow down of the functional field of view and with the increase in the complexity of the traffic, reaction time to stimulus present peripherally was increased. The eye tends to fix targets with the increase of distracting stimuli in the visual scene of the rider which can lead to the refusal of those objects that would not have been otherwise "rejected" in low traffic conditions like TWs. Further, the relevance of an object may lead to its rejection or it may be overlooked by the observer (Wulf et al.,1989). Therefore, distinction between sensorial and cognitive conspicuity has been highlighted by Engel (1976) which is visual prominence due to physical features of the object for the former and conspicuity due to interests and experiences of the observer for the later one. Next attribute in this line is the "Attention failure". Kahnemen, Ben-Ishai and Lotan (1973) has demonstrated correlation between overall accident involvement and performance on a selective attention test. Also, in driving performance, driver's reorientation capability to the relevant stimulus is important specially under the conditions of high overload. For sustained attention or vigilance, the event rate has been defined to be an important factor. Lack of frequent encounter with a TW on road may lead to decreased perception for a car driver (Fulton et al., 1980; Nagayama et al., 1980). At places with a smaller number of TWs, conditioning towards large sized automobiles may get high which road users encounter more often. The cost of detection failure also plays an important role. As the cost of detection failure in the terms of getting injured for large automobiles like trucks, buses is high for car drivers and low for TWs so, it is reasonable to suggest from a rational viewpoint for less priority being given for the detection of a TW compared to large automobiles on road that further can influence the driver's trait for the detection of TWs efficiently (Wulf et al., 1989). Also, in the MAIDS study the attentional level of TW rider was found to be more as compared to other more stable vehicles which was attributed to the fact of more attention required to ride a TW. Eighth attribute is the "Highway hypnosis" which is the lowered state of alertness which could be due to drowsiness, unchanging visual surroundings that results in decreased ability to detect movement which is common in long stretches of highways and predictable stretches of roads (Wertheim, 1978). Ninth and the last attribute here is the "Speed and distance judgement errors". According to Olson (1989) the inconspicuous character due to small size of a TW can be a probable cause of judging its approximate speed and distance which can also lead to collision.

DISCUSSION AND CONCLUSIONS

The above studies have revealed the importance of conspicuity of two-wheelers on road. In order to reduce the accidents due to low conspicuity a case control study by Wells et al. (2004) suggested the use of white or light-coloured helmets, wearing fluorescent or reflective clothes and voluntary use of headlight at daytime were found to be associated with decreased risk of crashes. On the other hand, Fylan et al. (2020) has suggested that at night time measures like use of retroreflective clothing or outfits with retroreflective strips positioned at the moveable joints must be used in order to increase conspicuity. Also, it has been found that riders take the concept of conspicuity to be not essential for their safety. So, the garment designers and manufacturers must ensure to stich the garments such that the retroreflective strips get positioned at the moveable joints so that when the rider moves, the biomotion also leads to the identification of the rider on road at nighttime easily. Even this concept of "biological Motion" has given rise to the mandatory wear of such clothes for those working at night on roads in Australia and New Zealand (King and Wood, 2013). According to Wood, Tyrrel and Carberry (2005), use of retroreflective striped clothing at night time resulted in the detection of a TW by 20 times of the distance at which the motorcyclist or cyclist was earlier perceived. Researchers have found that riders do not wear such clothes or accessories because they do not appeal to be attractive, stylish or is unusual and uncomfortable for them on road (Hagel et al, 2007; Hollenberg et al., 2018). Thus, awareness must be created among the TW riders through campaigns, advertisements, policies etc from the side of appropriate authorities. Additionally, different headlights and DRL designs and colours have been researched to make the TWs more noticeable (Pinto et al., 2014; Roger et al., 2012). Also, in order to be distinctly visible, it is required to be in sharp contrast with the background against the road environment (Gershon et al., 2012; Shaheed et al., 2012). Study by Shaheed et al. (2012) suggested the practice of modulating headlights in order to upsurge the visual conspicuity of two-wheelers. In order to increase contrast with background and for increasing attention, an attracting feature of "Daytime Running Lights (DRL)" became obligatory for two-wheelers in various countries. Also, the use of headlight can increase the conspicuity but with the changing background it may not be useful (CIE, 1982) thus, a novel system developed by Gershon and Shinar (2013) consisting of "Alternative Blinking Light System (ABLS)" was found useful in the changing environment. It consists of "56 light emitting diodes" each in two clusters with the distance of 12.5 cm between two clusters and a total height of ABLS with 24 cm. Less

space required for the installation of this set up with low power demand batteries or LEDs can be easily installed on the helmet without much extra weight (Muller et al., 2011).

As conspicuity is an important factor on road, a module specific on importance of conspicuity must be included in licensing procedure for both two-wheelers and other vehicles in order to acquaint the riders and drivers with the concept of conspicuity and the ways of enhancing it on road under different conditions. Further thought can be given on framing rules specific to day light use of headlight by TWs on road and colours specific for helmets and upper torso as per conspicuity requirements under different conditions of day and night. Also, further research can be done on how to increase conspicuity with the changing background. Conspicuity tape can be used in TWs at specific points of its irregular shape in order to enhance visibility. Further, industries on tapes, material and garments based on conspicuity specific to TWs under different conditions can be developed.

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