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A SYSTEMATIC REVIEW ON MOTORCYCLISTS' AGGRESSIVE BEHAVIOR ANALYSIS USING COMPUTATIONAL MODELS: CURRENT STATE, CHALLENGES, AND RECOMMENDATIONS

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ABSTRACT

There is an increase in motorcycles traffic accidents, while the cause for such accidents has always been associated with aggressive driving behaviors. There has been considerable research attention on how to deal with such driving behavior that causes severe and fatal accidents from the academic perspective; these research works addressed technical, scientific, and social issues. This study systematically searches, reviews, and analyzes the literature associated with motorcycle accidents and driving behaviors. Between the years 2014 and 2021, the next four databases have been searched: ScienceDirect, Scopus, Web of Science, and IEEE Xplore. A total of 108 people were picked depending on certain inclusion and exclusion criteria. Approximately 68% (n=79/108) of the researchers looked at the challenges from a social science perspective, whereas 25% (n=26/108) concentrated on experimental research variables. Only 7% (n =3/108) explored the development of Apps & systems. Finally, our contribution comprehensively analyses most of the articles by highlighting challenges associated with motorcycle behavior, motivations, and recommendations. In addition, provide potential research gaps in current studies that require further investigation.

Keywords: *Accident Causation, Driving Behavior, Traffic Violation, Motorcyclists, Computational Models*

1- INTRODUCTION

In driving behavior research, exploring the literature shows different research dimensions. Motorcyclists have been a source of substantial concern in terms of road safety recently [1]. Motorcycles have also been linked to around 50% of all traffic fatalities [2]. In different nations, the rising frequency of road accidents is a severe problem. Accidents might cause harm to governments and individuals, especially in terms of economic and social loss, which has a societal impact [3]. Traffic road accidents cause over a million deaths every year around the world, and they are expected to be the 5th leading mortality cause by the year 2030 if no preventive steps are done [4].

Various nations have made enhancing traffic safety a key priority [5]. Knowing the most common causes of traffic accidents will aid in the development of solutions for preventing or reducing traffic accidents. In addition, accidents are primarily caused by human behavior, according to research. The most important aspect of determining road safety is behavior [6]. As a result, efforts and actions for mitigating a few of the dangers connected with

driving conduct are required [7]. Concepts connected to driving actions and behaviors are referred to as driving behavior [8]. As a result, researching and comprehending driving behavior is crucial to avoiding or reducing traffic accidents.

The primary objectives of this study are to examine past research, summarize findings associated with significant categorization requirements, develop techniques and estimation procedures, define motorcycle driving behavior, and propose taxonomic literature on motorcycle accidents. The following are the remaining parts of this work: Section 1 contains the research's introduction. The systematic review protocol is described in Section 2, whereas Section 3 examines the statistical outcomes of the associated reviewed articles. In Section 4, the taxonomy is described; in Section 5, the performance metrics, datasets, problems, recommendations, and assessment approaches are offered. Section 6 discusses the methodological characteristics of the publications that were reviewed. Section 7 outlines future research directions. The research's weaknesses are highlighted in Section 8. Finally, in Section 9, the research's conclusions are presented.

2- SYSTEMATIC REVIEW PROTOCOL

This section discusses how to conduct a systematic literature review (SLR) [9]. SLR promotes a thorough understanding of a topic of interest or phenomenon, as well as important specifics and insights for future policies and research [1]. This work provides an excellent method for identifying, interpreting[2], and evaluating the current literature associated with a specific phenomenon[3]. The method was widely identified for its effectiveness and adaptability to a variety of research methods [4]. This evidence-based technique is significant for improving quality and identifying gaps in the literature[5]. It also helps determine the topics that must be examined in detail and summarize the specific issues for future research. Primary studies are defined as the individual studies utilized in a systematic review[6]. SLR is often considered a secondary study[7].

2.1 Information Source

Figure 1 shows the search method, which was based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [16]. A total of four digital databases were selected; (1) Science-Direct provides access to publications from numerous fields, such as scientific, technical, and medical; (2) The IEEEXplore library contains a variety of technology and engineering journals; (3) The Scopus database contains journal articles in the fields of social science, physical science, health science, and life science; (4) arts, humanities, and social science journals can be found on Web of Science (WoS). The databases have been selected for their academic trustworthiness.

2.2 Search Strategy

We applied our search query on Scopus, Science Direct (SD), IEEE, and Web of Science (WOS) in the middle of November 2018 using search strings ("Driver Behaviour" OR "Driver-Behaviour" OR "Driver Behavior" OR "Driver-Behavior" OR "Driving Behavior" OR "Driver Style" OR "Driving Style") AND (Motor-cycle OR Motorbike) and the following keywords (motorcycle OR motorbike) to limit our scope of searches. The search query is shown in the upper part of Figure 1. In each one of the search engines, sophisticated search options have been used for selecting papers, excluding conference papers, book chapters, and other types of documents. We looked over the studies in the journal and found that there was enough recent and appropriate scientific data to support this investigation. The settings used to apply the search query are shown in Table 1.

Table1: Workflow procedure

Attributes	Digital Library			
	Science Direct	IEEE	Scopus	WOS
Year	2014 – 2021	2014 – 2021	2014 – 2021	2014 – 2021
Language	English Only	English Only	English Only	English Only
Subject Areas	All available	All available	All available	All available
Run-on	Full Text	Full Text	Full Text	Full Text
Date of running search string	2021	2021	2021	2021

2.3 Selection of Study

This phase begins with the 1231 articles that have been found in the initial search results. Filtering, screening, and initiating categorization are the three processes that follow this to determine if the created articles will be included in the review. Duplicated articles have been also eliminated from databases. Title scanning, along with abstract screening, identifies the relevant papers organized in distinct folders. The full-text reading regarding the screened articles from the first phase started the filtering phase. This phase entailed a thorough review of articles to determine the main and subcategories. During the process, numerous notes and comments were made. Each article was assessed separately, and various attributes have been recorded in an Excel file, all of the articles were subjected to the same technique.

2.4 Eligibility Criteria

The research has to be chosen based on a set of criteria. Also, any article that met the criteria that have been outlined in Fig. 1 was chosen. We set an initial goal of mapping the research space on motorcycle driving behavior into coarse-grained categories, and we used the pre-survey literature to develop a broad taxonomy of five categories. After the initial removal of duplicates, items that did not meet the eligibility criteria were eliminated in two cycles of screening and filtering. The following exclusion criteria have been used: (1) non-English articles and conference proceedings (2) experimental and empirical investigations that focused on an e-bike, a bicycle, or a scooter instead of a motorcycle.

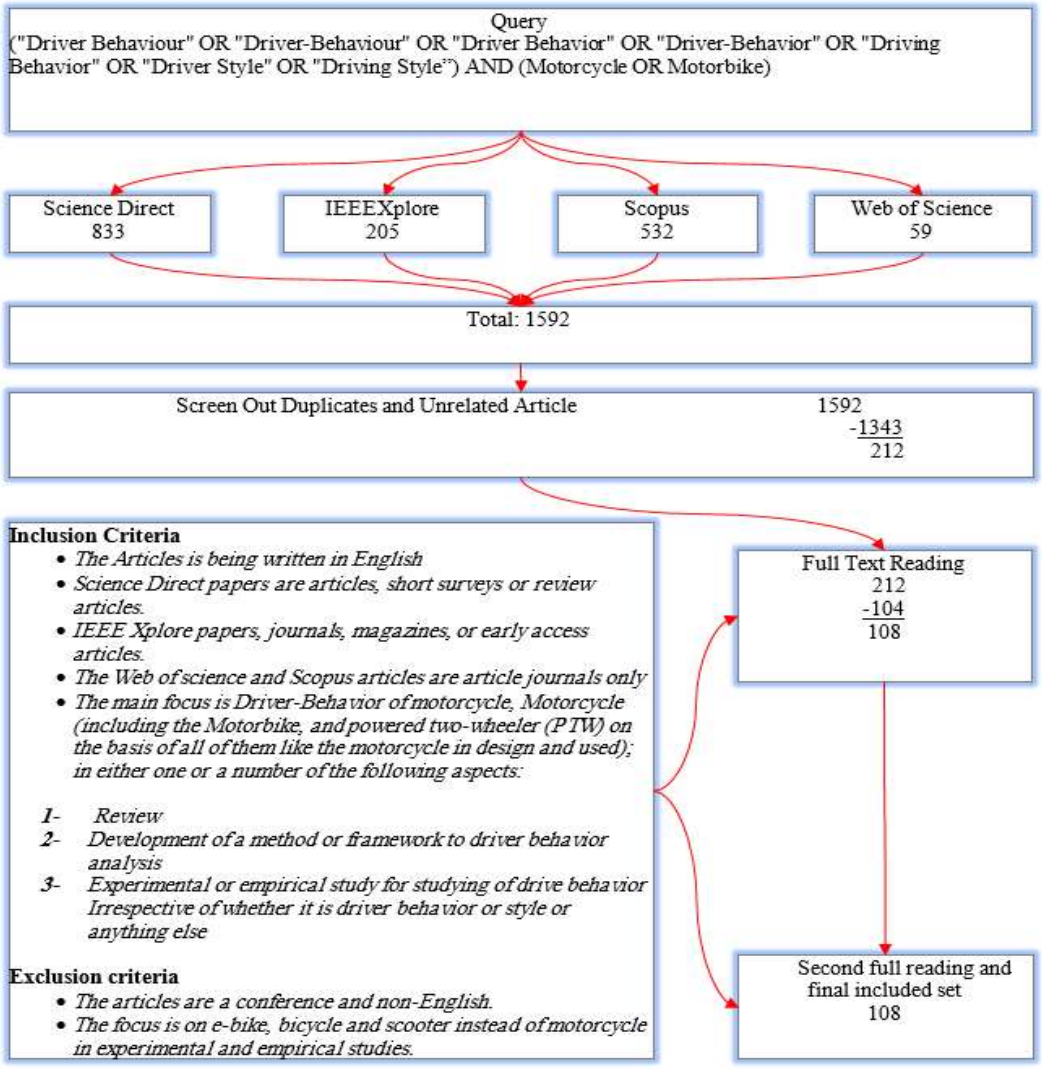

Figure 1: Selection of Study, Search Query, Inclusion, and Exclusion Criteria

3- TAXONOMY

This section contains a taxonomy that summarizes the findings of the search procedure. After finding, scanning, filtering, and reading the full text of chosen articles, this procedure began. All articles are divided into three primary categories, each with its own set of sub-categories. The first category includes social science studies (surveys depending on case-control studies and questionnaires). Experimental studies are the second category, which is associated with the factor of motorcycle driving behavior and contains two subcategories (experiment by using simulation, and real-time field tests). The 3rd category, Development Apps and Systems, has 2 sub-categories (which are Smart-phone Apps Develop and Systems). In the next sections, we'll go over the major categories and their subcategories (Figure 2).

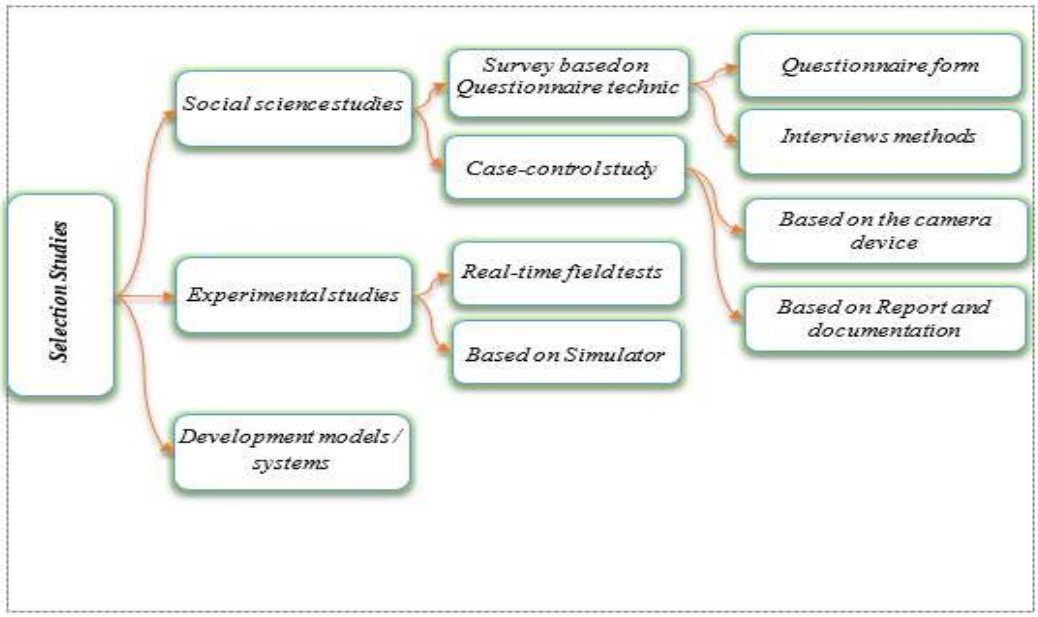

Figure2: Taxonomy Of Research Literature On Motorcycle Driving Behavior

3.1 Social Science Studies

The first taxonomic category indicates the type of study that involves data collecting, such as observations and surveys (n= 79/108). The studies in this section are divided into two groups:

first, Survey Based on Questionnaire Technic Studies involve datasets or data collection approaches (n=66/79 articles) the first sub-category of social science strategy research, namely survey depends on questionnaire technique. These studies using the Questionnaire designs and interviews were utilized in many of the articles (n=58/68). A few researchers utilized datasets by defining the associated features and examining research difficulties using statistical methods. The driving distractive compensatory beliefs toward driving distractions (DDCB)[19], and standard questionnaires were used in the studies [5]. Better cognitive assessments have been used, involving the Driving Behavior Questionnaire (DBQ) [1, 8-16], and Motorcycle Rider Behavior Questionnaire (MDBQ) [1, 17-22]. Few studies deployed web-based questionnaires [23-25] by accessing respondents via driver/rider forums and social media using the convenience sampling technique [26-28] and self-report questionnaires [29-34], Self-administered questionnaires [35-39], motorcyclists questionnaires [40, 41], Likert questionnaire[42], questionnaire basic demographic information [43, 44], the methodological developments regarding specific tools to assess the acceptability of motorcyclists of ITS, as part of motorcyclists profiling questionnaire (MOPROQ) [6], the interviews were held with the aid of a questionnaire administered using a probabilistic sample [45-48] online to collect data set and analysis [3]. One-to-one interview surveys [49], face-to-face interviews [50], house-to-house visits, and public areas, such as public halls [51] were also reported to have been used. An online survey was first designed using Google Forms [52]. In this subgroup, the last article described given telephone interviews [2] to identify

the context and their shortcomings during the reported events.

Second, Case-Control Study contains (n=13/79articles) about how to use observations to estimate the severity of traffic crashes, consequences of road accidents, hazards, and riding behaviors. Other papers [53-58] concentrated on the use of the camera for watching and recording factors that cause motorcycle accidents, as well as to identify motorcycle driving behavior. One research [59] focused on the use of the MetroCount MC5600 data loggers for collecting data on vehicle travel directions far or near minor roads. The author's initial article [60] included aggregate data from Schwartz's value dimensions, gross national income per capita, law enforcement's responses to five risk factors related to road safety, and traffic fatality rates for 97 countries. The enforcement of 5 laws that are related to safe road behavior (for example, national child restraint laws, motorcycle helmet laws, national speed laws, national seatbelt laws, and national drink driving laws), GNI per capita, and the traffic fatality rate for every nation were all mentioned by the second author [61-63].

3.2 The Experimental Studies

The second major taxonomy category includes (n= 26/108) research that takes an experimental method. Depending on data collection methods, this section is separated into two subcategories: The first sub-category of the experimental study, Real-Time Field Tests (n= 11/26), can be defined as research constructed an instrumented motorcycle employing a Honda motorcycle with a 100cc engine capacity for capturing participants' real-time riding behaviors [64] In field testing, the article looked at the relationship between reported riding behavior and riding pleasure [65]. Other experiments used an unobtrusive inconspicuous data acquisition system (DAS) created by Virginia Tech Transportation Institute (VTTI) on each motorcycle for capturing data in real-time [66], as well as an instrument-equipped helmet [67]. other articles used, On-board diagnostic (OBD) [66], accelerometers [68-70], gyroscopes [70], and GPS sensing [71, 72], The second sub-category of the experimental study is Experiment by using simulation (n=15/26) refers to articles in which a sort of simulator is used for data collecting to evaluate a factor that is associated with driving behavior, like images of a driving situation taking up 90% of the screen Dell Precision laptop, [73-76]. Other researchers utilized chassis dynamometers with standard driving cycles and on-board portable systems of emission measurements in the real-world driving conditions [77-79], as well as intelligent agent-based simulations [80, 200, 201, 202, 203, 204, 205], and a moving-based motorcycle simulator that included a motion platform, screen projection, sound system, and image-generation software [81-85]. Using a sophisticated motorcycle riding simulator, one study had the attempt to quantify the effect of low blood alcohol content on motorcycle riders' performance of riding. Another paper attempted to model seepage with the use of Cellular Automata (CA) simulation. Furthermore, those interactions amongst the vehicles have an impact on facility safety and capacity. This behavior has been observed in CA-based models in a few studies. The study [86] estimates the lateral and longitudinal gaps between adjacent side and front vehicles to find forward movement possibilities, and it has been compared to VISSIM (a simulation software). [87].

3.3 Development models/systems

The third main category regarding taxonomy is associated with the motorcycle domain's driving behavior, including (n= 3/108) of the remaining articles, namely Development Apps & system. The section is devoted to various aspects of the literature, which suggested the Development of Apps & systems associated with the motorcycle. Moreover, several systems have been proposed for overcoming data delivery problems, like the tracking postal system for overcoming message delivery issues. Postal motorcyclist monitoring system [88], development [89] Postal motorcycle Driving Monitoring System (PDMS), in which PDMS was designed on Windows CE 5.0 with Visual C++. Also, the system was installed on the CATCHWELL CW-31 in [90]. Partial proportional odds (PPO) logistic regression model has been introduced for examining the impact of explanatory variables on the ordered dependent one, which is the severity of the injury.

4- DISCUSSIONS

The phase, which follows the taxonomy and complete reading phase, attempts to discuss key attributes and fine-tune the prior literature. The motivations, recommendations, and obstacles linked to driving behavior studies are summarized in this section. This is significant because it demonstrates to future academics the challenges and concerns linked to driving behavior on which they might focus to develop policy responses. In addition, the concluding section of the discussion includes recommendations that indicate connections between new and previous research. Because the

early researchers are aware of their constraints, they will be able to translate their findings into recommendations for other researchers working on comparable projects. As a result, fresh researchers are supplementing the work of previous ones in this area.

4.1 Issues and Challenges

As noted in the previous taxonomy, the presented section covers the key issues defined in the research of driving behavior across multiple domains (Figure 3).

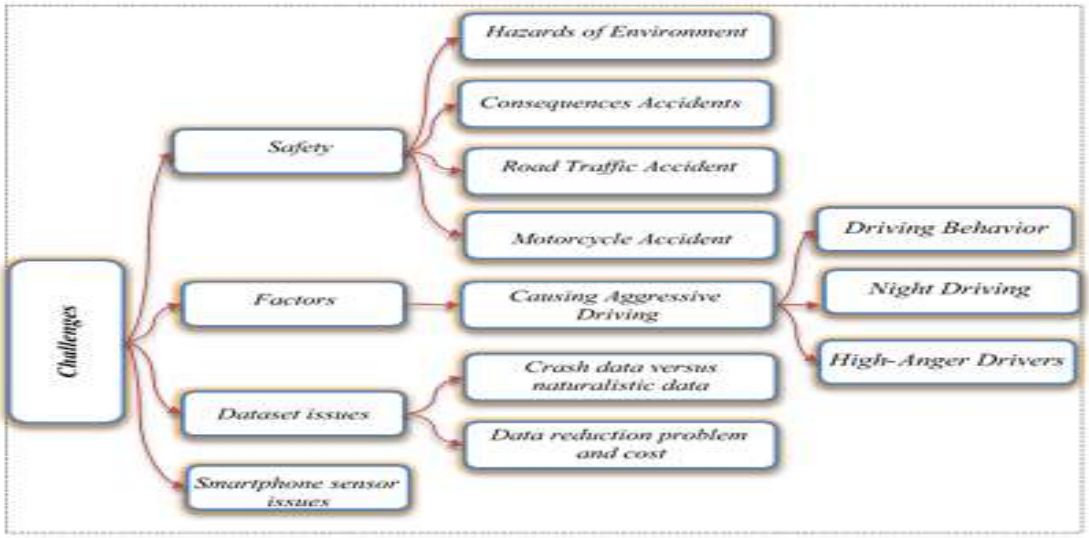

Figure 3 Issues and Challenges Overview

The issues listed in this section are discussed since they are drawn from a variety of research, and separating them in the suggested study would be too difficult.

4.1.1 Challenges Related to the safety

The provided difficulty is examined together with primary issues that are related to past studies' safety concerns; the two most essential ones are The hazard of accidents and the consequences of road accidents. Utility hole covers, which pose a risk of accidents, are placed in traffic lanes. The consequences of road accidents might represent unexpected risks on roads, like the negative effect on all society levels. Accidents are not only harming individuals and frustrating their families, and their impact transcends the general society[25]. Road traffic injuries (RTIs), such as motorcycle-related injuries, were one of the worldwide health problems [9, 90-92]. It is reported that social and economic road collision costs are about 5% of the Gross Domestic Product (GDP) in terms of low- and middle-income nations [10]. The serious body injuries and health risks for two-wheelers drivers were considerably high compared to drivers of cars[93].

Injuries to the head and neck are the main cause of death and severe disability among accident victims. It also affects the prevalence of maxillofacial injuries[94]. Road Traffic Accidents and Concerns On Motorcycle Accidents: Various researches have focused on motorcycle-related traffic crashes, which have resulted in a rise in motorcycle-related fatalities [47, 89, 95-97], crash frequency [98], and several have reported an upward trend in the accident rate [36, 67, 70, 99, 100]. Generally, their rate keeps growing in cities with significant traffic congestion problems, featuring medium to high urban densities, limited public transport, and road infrastructures [101]. Another focus on traffic-related traffic flow [77, 103, 136] is the lack of adequate road infrastructure in developing countries. As a result of the lack of separate lanes for different vehicle classes, almost all cities in developing countries like India are experiencing severe traffic congestion. As a result, public and private transportation driving patterns are influencing each other [102]. The next challenge concerns Motorcycle Street Racing, which the prevalence of motorcycle street racing is occurring more and more in Malaysia and is the main concern for the public [103].

4.1.2 Smart-phone sensor issues

Smartphones are used to collect data on the behavior of motorcycle driving. These devices have resource limits, such as insufficient energy, low sensor precision, and limited computing capability. Additionally, the raw data from smartphone sensors is sparse [89]. The use of smartphones as well as other systems, such as OBD, requires more effort and requires connecting or fitting additional devices, making the system scalable, less secure, and practical [66]. Smartphone-based research deals with single-perspective driving behavior features, resulting in integrity issues and bias evaluation [104]. Furthermore, due to the use of embedded inexpensive and unreliable sensors, the data collected from smartphones has concerns with dependability, integrity, and validity. The huge amounts of data collected necessitate offline numerical study and data mining [105].

4.1.3 Dataset issues

One of the unique issues that are faced by traffic-movement researchers has been the absence of needed and enough experiential intact for examining motorcycle driving behavior, resulting in only experimental models being developed. As a result, the slow advancement of such a study subject remains a problem [106], Insufficient style representations are provided by expired data and incomplete, short street/periods [73, 74]. The accuracy of the correction procedure is harmed by incomplete datasets. It's difficult to create an accurate model to explain the driving behavior. The factors that influence driving behavior were not identified. Real-time monitoring includes numerous errors [6, 38, 66, 68, 107-110]. However, the methods for carrying out such activities were prohibitively expensive, restricting the experimental study's time, distance, and location [60].

4.2 MOTIVATION

The literature on adjusting the motorcycle's driving behavior across diverse contexts are described in this section. General-purpose motivations and similarities were used to classify the motivations (Table 2)

Table 2 Motivations Overview

Motivations Related to Improve Safety	
1- Attitudes / drivingstyle	The previous research emphasized the importance of understanding the negative effects of attitude (driving style) and the underlying reasons for motorcyclists' behavior to decrease risky driving tendencies and improve young driving' safety attitudes toward risky riding behavior among motorcycle riders.
2- Motorcyclists' safety and reduce road accidents	Researchers are encouraged to conduct such studies for a variety of reasons, including decreasing road accidents, enhancing motorcyclist driving performance, detecting the causes of motorcycle accidents, enhancing motorcyclist safety, promoting road safety, driving safety optimization, and safety legislation, and lowering motorcycle fatalities.,
3- Enhance awareness of driving for safety and reducing factors causing an accident	Some studies are encouraged by the significance of such types of studies for improving awareness of driving for safety and decreasing the factors resulting in accidents like developing the measures of injury prevention and protection devices of motorcyclists, Identifying potential safety hazards in their early stage before they lead to accidents, decrease the probability of severe injuries, thus warning the driver, to reduce the teen crashes besides severity of their injuries improvements in the self-motion perception and proper road delineation and street lighting, strict enforcements for the red light, speeding violations, promote the use of the helmets, enhancing the conspicuity of the motorcyclists.

Knowing and analyzing motorcycle driving behavior is a significant factor in motorcycle safety. For a variety of reasons, researchers are encouraged to pursue this type of research. To begin, it is necessary to comprehend motorcyclists' attitudes about their safety as well as the safety of others on the road. Second, to better understand why young motorcyclists are engaged in so many incidents [24], and to decrease road accidents [48, 89, 111]. Third, knowing the causes of motorcycle accidents [19, 89], decreases motorcycle fatalities [64, 97], increases road safety education among all motorcyclists [112], gives a good measure of traffic safety [113], and reduces the risk of serious injuries [4, 59, 90, 114] Other researchers [2, 13, 47] look into the serious effects of attitude (driving style) and the underlying reasons for motorcyclists' behavior. Identifying risky riding behavior among motorcycle riders is critical [115] for reducing dangerous driving inclinations and improving the safety attitude toward young driving [70]. A few studies focused on increasing driving safety awareness and minimizing accident-causing causes. One solution is to provide injury prevention and protection systems for motorcycle riders [99] and decrease teen crashes as well as the severity of their injuries [116].

4.3 Recommendation

As stated in the previous research, this section examines the literature part with recommendations for future directions as shown in (Figure 4).

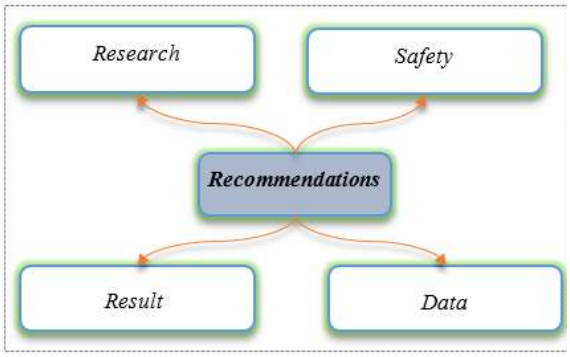

Figure 4: Recommendations Overview

2.3.1 Recommendations about Related Data

Data is an important part of any research project. A few suggested collecting more data by combining databases of road geometry, and traffic violations, and employing various statistical techniques [73, 74]. Data could be collected through a web- or application-based survey [27], which uses GPS devices for tracking actual distances [101] and provides more information about driving. [124], Other researchers [67, 98, 100, 125] urged more longitudinal data research and using other data sources.

2.3.2 Recommendations Related to Result

This section contains suggestions for verifying the results. The validation of results must be the focus of future studies [92, 126]. In some research [98], it can be important to investigate how temporal and spatial-temporal dimensions affected overall results, and the conclusions must be considered with extreme caution [20, 59] And Comparable outcomes were among the other Recommendations [85, 127].

5- METHODOLOGICAL ASPECTS OF PREVIOUS RESEARCH

The methodological methods that have been utilized in past studies are explained in this section. This section addressed a lot of different traits; all of them will be considered (Figure 5).

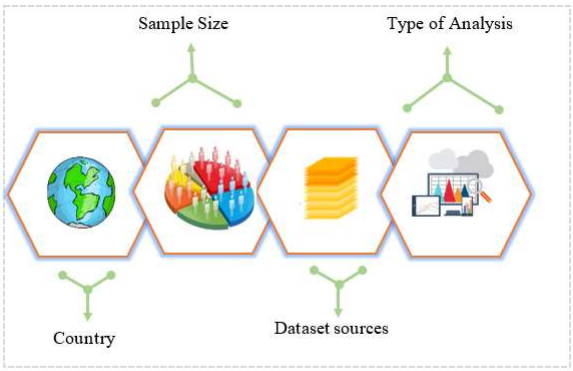

Figure 5: Methodological Aspects Overview

The previous research proposal highlighted the need of examining previous research modeling methodologies. Future research on motorcycle driving behavior, for example, must be conducted by defining well-defined locations and using the correct sample size analysis method. Future studies must also compare results from other nations. The analysis tools and data sources used, along with the approaches presented, must be well-designed.

5.1 Country

Motorcycle riders have received a lot of attention around the world. As a result, research institutes and agencies that use such studies for research, medical, social, and other purposes are

very interested in such studies. Almost all studies on motorcycle driving behavior are from 32 nations, according to the current study, with the US, Malaysia, and Australia having the most published works (Figure 6).

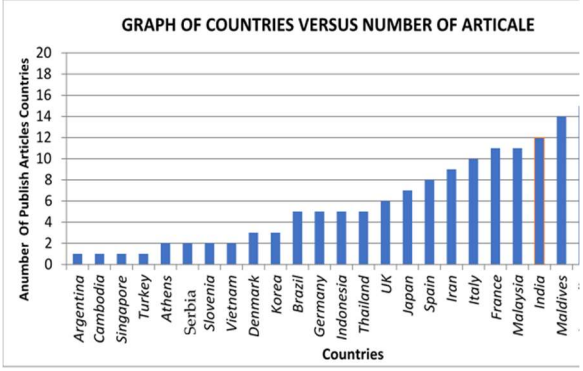

Figure 6. The number of articles that have been included is based on countries of origin.

Figure 6 shows the author's country of affiliation (in research with several authors, the author's country is provided). The majority of motorcycle research was conducted in China, Australia, and the United States. Other countries receiving one item each were Denmark, Greece, Argentina, Maldives, Cambodia, Serbia, Norway, Nigeria, Turkey, Singapore, Venezuela, and Colombia. Brazil, China, Malaysia, Germany, and Vietnam, for example, have studies ranging from 2 to 15. Table 3 offers a list of nations with links to more information.

Table3. Countries, with references.

Country	References
Australia	[31, 73, 81, 84, 100, 119, 128-133]
Athens	[107]
Argentina	[134]
Serbia	[93, 135]
Brazil	[46, 98, 111, 136, 137]
USA	[1, 7, 40, 108, 116, 124, 138-144]
Cambodia	[145]
China	[12, 14, 55, 63, 71, 113, 122, 142, 146-155]
Denmark	[156]
France	[23, 68, 76, 82, 85, 125, 157-160]
Germany	[57, 97, 161-163]
India	[15, 20, 56, 66, 92, 109, 164-166]
Indonesia	[5, 74, 121, 167]
Italy	[10, 81, 90, 112, 168-172]
Japan	[37, 83, 118, 173-175]
Korea	[88, 176]
Maldives	[3]
Malaysia	[27, 39, 64, 95, 120, 177-179]
Slovenia	[25]
Singapore	[180]
Spain	[11, 19, 75, 104, 117, 181-183]
Thailand	[13, 18, 77, 184]
Turkey	[61]
UK	[8, 24, 45, 114, 185, 186]
Vietnam	[115, 123, 144]
Iran	[17, 33, 36, 69, 70, 79, 187, 188]

Only 32 out of 195 countries researched motorcycle driving behavior. As a result, in the remaining countries, particularly in Southeast Asia, there are major gaps in academic endeavors. Models comparing motorcyclists' driving behavior are another field of academic study that has received little attention [134, 145]

5.2 Sample Size

The sample size represents a subject that has been drawn from the entire population, which is considered a sub-set of the whole specific research endeavor population. This section highlights sample sizes and methodological aspects of earlier research on the behavior of motorcycle driving. Additionally, the summation of participants differed among the researchers. This section provides all of the last sample sizes that have been applied by the respective researchers, which have been categorized into 3 classes, as follows:

✓ In the 1st category, sample size based upon the social science approaches is focused upon the use of different 4 sample size groups, the size of 1st group ranges from 10 to 99 participants [47, 61, 79, 101, 118, 132, 133, 167, 189]. The 2nd group is in hundred and ranges from 100 to 999 participants [1, 11, 12, 14, 23, 24, 27, 74, 96, 112, 134, 159, 188, 190]. The 3rd group is in thousands and varied from 1000 to9999 participants [17, 18, 35, 48, 56, 90, 92, 98, 99, 108, 109, 125, 166]. The fourth group is in hundreds of thousands and varies from 10000 to 99999 participants [59, 107, 115, 116, 182].

✓ *The 2nd class has been based on the* sample size based on the simulator approaches. It is divided into 2 sub-groups of the sample size; the first one has been referred to as Tens and ranges from 10 to 99 participants [78, 81, 82, 115] The 2nd one is Hundreds, which uses the samples from 100 to 999 participants [15, 172, 179].

✓ The 3rd class is sample size based upon real-time field tests. There are two subgroups of the sample size, the first one used 0 to 9 participants [31, 64]. The 2nd one consists of a study that utilized samples from 10 to 99 participants [84]. All of the samples were utilized across different studies. A few of such researches were used more than the other groups of the participants.

The large size of the sample presents accurate and reliable data and reflects more information about the behavior of the driver. However, it's related to the selection of accurate tools for data collection and the time that is required to conduct experimental studies and preprocessing of data.

5.3 Dataset sources

Data represents a fundamental high-quality research element for all of the research about the behaviors of motorcycle driving and were considered as one of the main significant aspects because they were a liaison between the findings and analyses. Authors have utilized numerous data sets the determination the behaviors of motorcycle driving as well as their correlation with road accidents. The data source was indicated as well in a variety of the researches with the use of previous literature in the studies of the driving behavior in the following table 4.

The first resource is a *survey through questionnaires and interviews,* as has been shown in the literature. Others have obtained data from the *medical and healthcare centers and institutions*, which include medical systems, hospitals, records, clinics, and centers. Some of the researchers have received the data from the *Dept. of the Transportation (NMDOT) Traffic Safety Division and police reports.* Other researchers have depended upon the data that have been provided through *experimental ways and observation*. Some of the research has depended upon the number of data sources for the behavior of motorcycle driving in real-time, like the video cameras, recruitment, and trials. The last set of the research has been outsourced from *other* places that involve online sources, which include the scientific databases, websites, panel data, and Safety and Information Systems. Knowing data sources provides researchers with the ability to understand the way that the data has been obtained from academic literature. The researchers can understand their options of the data sources and determine whether or not the available one at disposal is academically suited.

Table 4: References of previous sources of data

Ref#	Data source			
	the survey, which has been followed by a questionnaire and interviews	*Medical and care centers institutions*	*Traffic Safety Division and police reports*	*experimental means and observation*
[1, 5, 6, 11, 12, 17-20, 23, 24, 27, 33, 35-37, 39, 40, 45, 79, 91, 92, 101, 110, 112, 115, 121, 166, 167, 178, 188]	√			
[62, 94, 97, 99, 109, 111, 118, 133, 134, 141, 191]		√		
[90, 92, 107, 177, 190, 192, 193]			√	
[4, 10, 13, 15, 28, 31, 32, 54, 55, 60, 63, 64, 66-71, 73, 78, 81-85, 88, 102, 105, 113, 114, 119, 125, 127, 131, 172, 179, 180, 186, 194, 195]				√

5.4 TYPE OF ANALYSIS

This section provides an overview and types of analyses that are utilized in research on driving behaviors. Many articles used descriptive Statistics [18, 28, 55, 64, 91, 109, 178, 182], bivariate analyses [61, 91], sensitivity analysis [48, 60, 61, 74, 79, 91, 133, 155], empirical analysis [54, 92, 105, 107, 143, 196], Qualitative analysis [31], various analysis types have been utilized, such as the binary logistic regression [111], multivariate linear regression analysis [75], multiple regression analysis[3, 20, 178] headway

analysis[74],, exploratory analysis[14, 20, 25, 98, 110]. Detailed motorcycle accident data analyses have been conducted by statistical analysis [15, 20, 23, 48, 62, 85, 101, 111, 121, 125, 134, 141, 166, 167, 179, 187, 190, 193] and odds ratios analysis [99] was implemented to explore impacts of single variables on the cycling and driving aggressions, at the same time as regulating impacts of the other variables, such as the frequency of driving and cycling. The following approaches are less frequently utilized Linear regression analysis [35], automated video-based analysis techniques [113], and reference analysis [4]. The last group will be associated with other types of analysis which have a small number of occurrences in literature and include vibration analysis[71], [117].

6- OUR REVIEW VS OTHER REVIEWS

The present research provides a detailed review that is carried out on the topics of the related research about the behaviors of motorcycle driving. No reviews or surveys cover the model about the behaviors of the motorcycle driving from a viewpoint of the data sources or present detailed analyses that are associated with the data collection using instrumented motorcycles that drive in the real-time fields. Available resources do not provide a sufficient level of knowledge for the evaluation of the performances of the currently suggested/used models of classification. Additionally, the number of researchers who explore the functionality of the classification models, their complexity, and cost efficiency has been insufficient. Selecting the optimal cost-effective/practical DAS has been complex, due to a lack of clear criteria for the assessment of the performance. This is why the present study aims at analyzing literature that is related to the data types of the motorcycle rider models and systematically search associated research. Table 5lists the differences between this work and the previous ones. The action point-based motorcycle driving behavior, and deterministic, data-driven models have been covered based on the availability in the articles that have been gathered. Traffic regulation and road safety have been surveyed, which specify requirements for the enhancement of developments in those fields of research. Using an AI model for motorcycle recognition has been illustrated and examined. The process of the labeling of the gathered data has been researched as well as the algorithms of the classification. The problems of recognition and classification have been addressed based on the availability of those subjects in the collected articles. Finally, a section of recommendation will be presented for the future researches.

7- FUTURE RESEARCH DIRECTION

One of the potential research directions could be given on the basis of our understanding regarding literature that is related to behavior of motorcycle driving. Several points have been considered for the future developments in this research area.

Table 5. Comparison of our work vs. other review articles.

Ref#	Years	Types	Areas	Factor Types	Taxonomy	AI Model Analysis	Sensors & DAS
[123]	2016	Review	Safety	Cooperative driving	NA	No	No
[139]	2018	Critical review	Traffic and safety	Behaviour	NA	No	Yes
[144]	2018	Review	Safety of PTWs	PTW driving behaviour and attitudes	NA	No	Yes
[197]	2018	SLR	Traffic and safety	Human factors	NA	No	No
[198]	2019	SLR	Traffic and safety	Behaviour	NA	No	No

SLR: systematic review; PTW: powered two-wheelers; AI: Artificial Intelligence; NA: Not Available.

7.1 Accurate Methodologies

The data collection based on the GPS or the technological sensors was too expensive to eliminate bias in the data sets [59]. A lot of current datasets and novel models/approaches to produce datasets were needed to examine the safety measures, traffic accidents, and determining the driving behavior [41]. In addition, numerical and hypothetical methods should be improved to enable the classification models related to driving behavior to identify elements affecting the model's performance [87]. Also, embedded sensors, including the smartphone's sensors app, must be utilized in present approaches for producing suitable driving behavior features [113]. Different datasets should be used mainly, and extra aggressive driving must be utilized [193]. Another factor that must be explained is the AI models' capability for solving problems of the rule-based models [52].

7.2 The role of AI in motorcycle driving behavior analysis and classification

The majority of researchers used rule-based, one-to-one, and deterministic approaches to showing driving behavior in various situations[113]. Shifting to intelligent models, especially AI models, is an excellent step for accelerating driving behavior analysis and classification modeling [111]. heterogeneous traffic mostly exists in a developing country that consists of different types of the vehicles besides the motorcycle, therefore need to type of analysis that disposal the limitations in the classic methods by adopting logic as a method for The driving behavior analysis and classification must be modeled with the use of real-time data that has been obtained from real-time driving behavior throughout long periods and within various driving conditions for obtaining more reasonable results with not much level of uncertainty [80]

7.3 The role of deep learning in motorcycle driving behavior analysis and classification

ML techniques are required for considering the best approach to describe the heterogeneous driving behavior. ML approaches require human interpretations regarding data labeling that cannot identify the driving actual behavior [72]. Frequently, the feature extraction might be manually implemented via practitioners since it is based on human perception[199]. In addition, ML-based models might fail in the extraction of efficient features that are hidden in the data sets and could be requiring a certain automation degree for accomplishing such tasks. Deep learning techniques are eliminating such feature extraction burden since they were automatic and might be select efficient features that increase the accuracy of the model [200]. Yet, deep learning models require various datasets for suppressing ordinary ML classifiers, requiring time-consuming and costly procedures[49]. Thus, deep learning methods, which are conducted with driving behavior modeling to increase the accuracy of the representation, are going to be a remarkable leap forward in this field of study [197].

7.4 Driving Behavior Classification model

This section discusses a process that may be carried out to meet the requirements of developing a model of analysis and classification of driving behavior of motorcycles with a high accuracy rate to eliminate motorcycle accidents and improve the motorcyclist's safety. The procedure includes four main phases, which are: (1) investigation phase (2) data collection, (3) data cleansing and analysis, (4) ML classifier development, such as sensors installed on the smartphone with android system, computers, and required programs for data analyses, are prepared for classifying and describing driving behavior of motorcycle validation of the model.

7.4.1 Investigation Phase

Investigate the techniques, methods, and approaches based on driving behavior with the motorcycle and highlight their weaknesses. Where able to survey the current literature and choose articles based on the criteria described in the following sub-phases (Figure 6), All information related to the major problems has been indicated. The selection of the study included a search regarding sources of literature, and after that, 3 iterations that are related to filtering and screening were utilized as the same eligibility criteria. Also, the main aim has been identified for mapping research space on behavior of the motorcycle driving, a general taxonomy that included 4 categories. The 1st group was derived from a pre-survey related to the literature review. The 2nd group, regarding the investigation phase, provides the related research on motorcycle driving behavior. This group aims at highlighting the trends of the research in such an area by concentrating on three literature content aspects: the drives to develop applications based on the driving behavior, obstacles to effective use of such technologies, and the suggestions to alleviate such obstacles. Finally, the 3rd group of investigation phase presents the substantial analysis, reviewing the majority of methods utilized in previous articles for getting a

clear idea regarding the suggested system structure that must be applied.

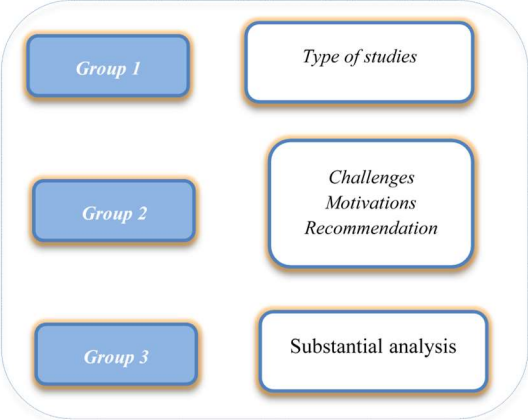

Figure 6. Investigation phase related to the driving behavior of the motorcycle

7.4.2 Data collection phase

Upon completing the previous phase, collecting data by experimental means where participants experiment with driving a motorcycle in real-time and recording data such as acceleration, deceleration, and deviation angle, through two applications installed on the android device (Speedometer GPS version:3.7.76, AndroSensor v1.9.6.3). Then used data mining software Microsoft Excel and RapidMiner to store collected data and then process data to extract all related features. Finally, the results have been compared to the literature to determine if the sample size and related features are suitable for studying driving behavior and within the limits used in previous studies.

✓ ***Experimental field*:** Experimental approaches show that most research is carried out on highways. In addition, the proposed route has been approximately 10-15 km for each of the participants on highways, and in-city ways. The drive time of the motorcycle is approximately 20 minutes. All participants were also requested to drive a motorcycle on a given route; the smartphone APP gathers raw data.

✓ ***Participant selection*:** Participants are selected driving of all genders and races. All participants should have a valid driving license as well as driving experience of a minimum of three years. Based on critical analyses, the size of the sample in the majority of the previous research was not more than twenty participants; therefore, the desired number was between 15 and 20 driving.

✓ ***Sensor and factor selection*:** Activities have to be specified in experimental research to analyze the driving behavior. Such activities were also vital in choosing the needed sensors and collecting precise data in the empirical study, along with the motorcycle's speed, deceleration, and acceleration. Furthermore, the smartphone sensors were used in experimental work to study the chosen factors. Table6 provides sensor names in addition to sources regarding all of the sensors and the justifications for using each one of the sensors.

7.4.3 Pre-processing data and Statistical Features Extraction Phase

This process should be done as part of data collection that will be conducted to analyze collected data that is related to motorcycle driving behavior, following preprocessing of raw data (reformat and remove unwanted values). The statistical analysis has been carried out on leading as well as following parameters (speed, deceleration, acceleration). Descriptive analysis has also been utilized in the data's final form (following the preprocessing) for providing deep insight into chosen parameters. Every one of the parameters specified in the statistical form (variance, median, mean, maximum, minimum, standard deviation, and mode) will be analyzed. These features were evaluated for later processing and ML and compared and descriptive analysis.

7.4.4 Driving behavior Classification Phase

The data that had been collected from the phase of the experimental study were categorized throughout the phase. Before classification, feature extraction was conducted for deducing the needed features from deceleration and acceleration. Following the feature extraction, features were labeled for determining the style of driving. Also, labeling was conducted using either parameter thresholds from expert opinions or literature. Following the labeling of data, a classification model in terms of the dataset might be utilized for identifying non-aggressive and aggressive motorcycle driving behavior. At least one ML classification approach was utilized in the collected dataset to identify driving behavior throughout the drive. Many ML techniques were tested and compared (fuzzy logic, Bayesian network, and SVM) for selecting the primary precise

classification method. A five-fold cross-validation approach was utilized for comparing the adopted classifiers).

7.4.5 Evaluation Phase

The last phase explains the performance evaluations of the classification in research. Accordingly, a series of experiments on data in real-time, such as evaluations, include qualitative and quantitative assessments, where the former will be conducted through experts, whereas the latter will be conducted through standard measurement methods such as evaluation matrices. The subsections below discuss how it will be performed and also how it shall be done Qualitative and Quantitative.

Process 1: Detection of the systematic exploration of aggressive behavior's features. will do two assessment

Qualitative: - This will be conducted through experts. After getting the feature from the literature, then experts will be asked. It is feature enough to develop and classify models or not if agree and assessment, develop Feature Selection and Classification Model of Aggressive Behaviour Styles among motorcyclists using Convolutional Neural Network (CNN).

Quantitative: - Here, we compare with recent studies and techniques in the literature to assess if the sample size and related features are suitable to study driving behavior and within limits used in previous studies, more / less.

Process 2: Feature Selection and Classification Model of Aggressive Behaviour Styles among motorcyclists using Convolutional Neural Network (CNN). It shall be done through two assessments.

Q***ualitative***: after the development of the Feature Selection and Classification Model of Aggressive Behaviour Styles among motorcyclists using Convolutional Neural Network (CNN), data collection will be done by the experimental method in real-time then extract feature and determine feature significance, after that ask the expert t to assessment the model and features.

Quantitative: - quantitative assessments can be through a case study, where this procedure shall be done in a developed country, and the examination shall be implemented using real-time data from a specific location

8- LIMITATION

Although this study's data-base sources have covered several groups and have been reliable, the identification remains complex. Moreover, a disadvantage on the timeliness of the review has been a result of the increase in the progression of the present area. The studies at certain periods on such a fundamental area are not actually indicating actual usage or impact. Nonetheless, the information had shown the response of the research community to this area.

9- CONCLUSION

There is an increase in published articles on driving' behavior. Yet, there remain unresolved research issues. Motorcycle driving behavior is one of the emerging areas warranting attention. This article's main contribution is the comprehensive survey and the classification of studies associated with the motorcycle's driving behavior. Unique patterns have been found in the literature. In addition, the selected articles have been categorized into four categories: social science studies, experimental, development Apps and systems, and Review. We comprehensively analyzed most of the articles by highlighting their recommendations, motivations, and challenges associated with motorcycle behavior. Data types and data analysis were identified. Many recommendations have been offered towards tackling such issues. Such instructions must also be followed via social workers, researchers, and other persons who are involved in the driving behavior. Furthermore, such recommendations provide the future researchers with many research gaps to various challenges numerous stakeholders encounter in motorcycle driving behavior studies. The majority of such challenges were associated with motorcyclists' data. They involve sampling nature, findings, collection, and lack of research in such areas. The present review summarizes the relevant literature ideas that provide vital references for researchers.

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