IBIMA Publishing
Communications of International Proceedings
https://ibimapublishing.com/p-articles/44AI/2024/4448624/
Vol. 2024 (22), Article ID 4448624

The Principle of a System for Training Motorcyclists Using Automatic Analysis of Telemetry Data*

Marian LAMR, Pavel TYL, Premysl SVOBODA and Petr BILEK

Technical University of Liberec, Czech Republic

Correspondence should be addressed to: Marian LAMR, marian.lamr@tul.cz

* Presented at the 44th IBIMA International Conference, 27-28 November 2024 Granada, Spain

Abstract

This article describes the principle of a system designed to improve the quality of teaching and training of motorcyclists. From the user's point of view, the system consists of telemetry data acquisition hardware, a mobile application and a web application. The system should help driving school instructors to better and faster recognize the mistakes of the motorcycle driver in connection with his control. The data from the drive mainly consists of the values of the accelerometer and gyroscope in three axes and the exact geographical position (coordinates from the navigation system). These data are important for evaluating the behavior of the motorcycle driver in certain model situations, such as correct cornering, correct behavior before and after the curve, intersection, etc. The system also includes a neural network model, which, with a sufficient amount of data from driving on the polygon, can evaluate the quality of the student's driving by itself.

Keywords: telemetry data measurement, data analysis, motorcycle training, machine learning

Introduction

Motorcycle accidents pose significant risks to drivers, and understanding the factors contributing to these incidents is crucial for developing effective prevention strategies. One of the key aspects influencing motorcycle accidents is the driving style of the drivers, which can be quantitatively assessed through analyzing motorcycle telemetry data such as motorcycle inclination, GPS (Global Positioning System) tracking, speed, and acceleration. This data provides insights into how driving behaviors correlate with accident rates and severity. Approaches to safety on motorcycles may vary depending on the concrete country, traffic regulations, population, traffic density, quality of roadways, and so on.

Some studies deal with the possibility of reducing the accident rate by predicting the locations of frequent traffic accidents using accident rate data and adequate driver warnings (Lamr, 2019). Driving style is a critical determinant of motorcycle accident risk. Research indicates that certain driving behaviors, such as aggressive acceleration and improper cornering techniques, significantly increase the likelihood of accidents. For instance, studies have shown that drivers who engage in risky behaviors, such as speeding and overtaking inappropriately, are more prone to accidents(Zehra *et al.*, 2019; Yousaf and Wu, 2023). The analysis of driving telemetry data can help identify these risky behaviors, allowing for targeted interventions. Furthermore, the use of pass-through *late apex* point techniques in cornering has been associated with improved safety outcomes, as it allows drivers to maintain better control during turns (Dewar *et al.*, 2013). Telemetry measurements have emerged as a valuable tool for assessing driving behavior and enhancing safety. Additionally, the use of driving simulators in training programs has been shown to enhance the perceptibility of motorcycles among other road users, as demonstrated by Eichberger et al. (Eichberger, Kraut and Koglbauer, 2022). Such simulator-based training can help mitigate the risks associated with poor hazard detection, which is often exacerbated by the complex visual environments in urban settings (Shaheed, Marshall and Gkritza, 2015). Research indicates that inexperienced drivers are more

Cite this Article as: Marian LAMR, Pavel TYL, Premysl SVOBODA and Petr BILEK, Vol. 2024 (22) "The Principle of a System for Training Motorcyclists Using Automatic Analysis of Telemetry Data " Communications of International Proceedings, Vol. 2024 (22), Article ID 4448624, https://doi.org/10.5171/2024.4448624

likely to engage in risky behaviors, underscoring the need for comprehensive training that addresses these issues (Wigum *et al.*, 2023).

The design of road infrastructure is another significant factor influencing motorcycle safety. Research has demonstrated that motorcycle-only lanes can reduce accidents by as much as 39% by separating motorcyclists from heavier traffic (Hasan *et al.*, 2019). Additionally, identifying high-risk road sections using accident probability models can help in implementing preventive measures (Kraft *et al.*, 2023). The presence of adequate signage and road markings, along with the design of safe road curves, can also mitigate risks associated with motorcycle riding (Akalin, 2022). The implementation of vehicle-to-infrastructure (V2I) systems, as explored by Hsu et al., can provide critical warnings to motorcyclists about potential hazards, thereby improving situational awareness and also reducing accidents (Hsu, Wen and Liu, 2022).

Moreover, the importance of protective gear, particularly helmets, cannot be overstated. Studies have shown that wearing helmets significantly reduces the severity of head injuries and fatalities in motorcycle accidents (Fong *et al.*, 2015; Barzegar *et al.*, 2020). Educational campaigns aimed at promoting helmet use and safe riding practices are essential for enhancing driver safety.

Alcohol consumption remains a pervasive issue in motorcycle safety. Studies indicate that alcohol-related accidents are disproportionately high among motorcyclists, with impaired judgment leading to increased crash severity (Liu *et al.*, 2015; Santoyo-Castillo *et al.*, 2018). The prevalence of alcohol and substance abuse among drivers, as reported by Heydari et al., further complicates efforts to enhance safety (Heydari *et al.*, 2016). Addressing this issue through targeted interventions, such as sobriety checkpoints and educational programs about the dangers of riding under the influence, is essential for reducing accident rates. Psychosocial risk factors are also associated with alcohol consumption and play a critical role in motorcycle accidents. Stress and mood disorders can impair a driver's ability to react appropriately to road conditions, increasing the risk of accidents(Rana *et al.*, 2022). A study highlighted that drivers experiencing social-related stress are more likely to engage in reckless driving behaviors, which can lead to accidents (Rana *et al.*, 2022). This suggests that addressing mental health and stress management could be an essential component of motorcycle safety programs.

In conclusion, motorcycle accident prevention requires a multifaceted approach that considers driving style, training, road infrastructure, protective gear, alcohol consumption and further factors. By leveraging telemetry data and implementing targeted interventions and lessons learned, motorcyclists, traffic policy makers, and safety advocates can significantly reduce motorcycle crashes and increase traffic safety.

Assessment of proper motorcycle riding

The evaluation of correct riding on a motorcycle can be assessed according to many aspects (Novotný *et al.*, 2021). The basis of driving theory is the use of controls, which include the position of the hands on the handlebars, the way the front brake lever is operated, the release of the arms when gripping the handlebars, the way the clutch lever is operated when starting and driving slowly and when shifting higher gears, the position of the foot on the footrest and gear lever control and foot position on the footrest and rear brake control. Furthermore, speed, stability and their interrelationship (gyroscope principle), correct starting and braking (front vs. rear brake and their effects, correct dosing, behavior of the motorcycle when braking at different speeds, effects of electronic systems on braking) are also important. An equally important, but difficult to measure, aspect of driving is the driver's gaze (direction of gaze and fixation on a certain point).
However, from the point of view of the possibility of assessing the quality of driving within our project, the following aspects are the most important and measurable or evaluable by us:

- smooth driving,
- correct passage through the bend a
- keeping the right track.

Methodology and principle of the system

The system is primarily intended to help instructors in driving schools or motorcycle schools. From the point of view of safety, passing through curves is the most important. There are several scenarios of how our system can be used by driving and motorcycle school instructors. Primarily, the system should enable instructors and their students to view the student's driving style in detail and possibly compare it with the instructor's driving style.

Example of a system operation scenario from the user's point of view:

1) Attaching and starting the TetryBox telemetry device on the motorcycle
2) Starting the measurement using the TetryApp mobile application
3) Completing the measurement and sending the data to the server using the TetryApp mobile application
4) Evaluation of the student's driving style in the web application with the help of the instructor

The principle of the system

The entire system consists of a chain (Fig. 1), at the beginning of which is a measuring device. The measuring device collects telemetric data from the motorcycle drive and, depending on the type of measuring device, stores the data in its memory or sends the data directly during the measurement to the next link in the system chain. The second link in the chain is a mobile phone, which serves as a control element of the measuring device (if the device supports such a feature). The mobile phone can serve directly as a measuring device and also has the function of temporary data storage. The data stored in the mobile phone is further sent to the server. The server receives data in raw form as binary files and pre-processes them and stores them in the database so that they can be displayed in a suitable form on the client and further processed.

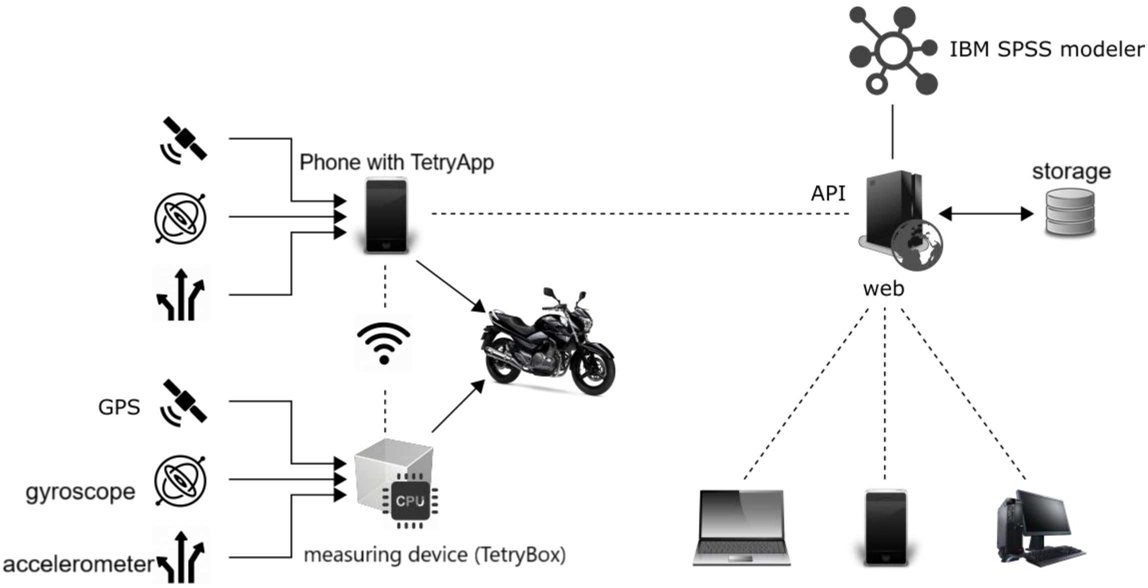

Fig. 1. The principle of the system.

The system is composed of three main parts/modules:

- Module for capturing driving data
- Data collection and transmission module
- Module for data storage, data management, data post processing and data presentation

Data capture module while driving

This part of the system primarily consists of the TetryBox telemetry device developed as part of the project. Originally, the possible use of sensors available in a mobile phone or the use of suitable sensing hardware that would be commercially available was also assumed. The following 3 variants can be used to measure telemetry data.

The first device tested was a mobile phone, or mobile phone sensors. Specifically, the phones Xiaomi Poco X3 NFC, Motorola Moto G30, Samsung SM-G990B, Xiaomi MI 9 were used for testing. If a mobile phone is used as a data collection device, an application that can collect telemetry data must be available. After analyzing the available applications for the Android platform, the Sensor Record and Yamaha MyRide applications were tested. During testing, however, it became clear that exporting data from these applications is possible, but it is not possible to effectively process and store this data. Exporting from the Sensor Record application is possible via

CSV files, but the overhead for managing the data obtained in this way and their subsequent export to your own database would be inefficient. Due to the human factor, sooner or later data inconsistency would occur in the database. For the project, additional metadata about all the drives and drivers, which the applications do not provide, needs to be stored. For that reason, we decided to devote ourselves to the development of our own mobile application, which would collect telemetric data directly from the accelerometer, gyroscope and GPS located in the mobile phone. However, the accuracy and frequency of data in current mobile phones is insufficient for the needs of our project.

The second type of device for collecting the necessary telemetry data was intended to be commercial HW available on the market, which is used by professional drivers to improve their sports performance. There are several telemetry data collection devices on the market. However, most devices are proprietary and data from these devices can be difficult to export to your own database. Data tends to be available to users within a closed system. With some products, the data can also be visualized, but primarily these devices are mostly intended for measuring telemetry in order to achieve the fastest possible drive on a predefined circuit. This approach also goes against the idea of our project, which aims to teach drivers to drive safely. After research and discussion with experts who use similar devices, we backed away from the idea of testing the professional RaceCapture device, which necessarily requires power via the OBD (On-Board Diagnostics) connector and does not support data access for third-party applications. A prerequisite for using any device for development is its openness. This condition of use for third-party applications is fulfilled by the Racebox Mini device, which was developed as part of a startup project. Of the telemetry data, RaceBox mini mainly provides GPS data, acceleration, rotation and time, other data such as speed and direction, signal information, time measurement accuracy, etc. Then there is also specific information regarding the device itself, such as battery charge status.

The device has no data storage and only sends data via BLE (Bluetooth Low Energy) at regular intervals. A mobile phone with Bluetooth and a mobile app is required to save data. The "RaceBox" application can be used for normal use of the device. However, they cannot be used for the needs of our project. For the purposes of our project, we collect data from Racebox using the TetryApp mobile application developed by us. Accelerometer and gyroscope data are sufficient. In practice, however, the accuracy of GPS data is sometimes even more than 0.5 m.

The third and at the same time ideal variant is the measurement of telemetry data with the TetryBox (Telemetry Box) device developed by us, which meets the requirements for the type of data captured and their transfer to a smartphone. Control of TetryBox is handled by the TetryApp application.

HW and SW requirements for TetryBox:

- Powered by a small rechargeable battery, 12 hours of battery life
- Charging via USB interface.
- Small dimensions max. 15 x 10 x 5 cm
- Device status indication
- Communication via Bluetooth
- Partial data preprocessing
- Reception of RTK (Real Time Kinematic) data to refine the GPS position

Data Requirements:

- Data Gyroscope 3 axes (x, y, z) data reading frequency 1 kHz
- Data Accelerometer 3 axes (x, y, z) data reading frequency 1 kHz
- GNSS (Global Navigation Satellite System) data (X, Y, altitude, speed, time and date) frequency 25 Hz
- GNSS data with accuracy in the order of centimeters
- Additional diagnostic and calibration data
- All data is sent via Bluetooth 25 times per second to the mobile application.
- (Accelerometer and gyro data are averaged)

The core of the device is a microcontroller of the STM32 series, specifically the STM32L476RGT6 type with a sufficient number of inputs (64). A RESET button, a 10-pin programming connector for SWD and a MEMS (Micro-Electro-Mechanical Systems) circuit as a 24 MHz clock signal source are connected to the microcontroller for its basic operation. The microcontroller is powered by 3.3V as are the rest of the electronics in the device. The device is powered by a LiPol battery. The battery has dimensions of 80 x 50 x 6 mm (the length of the battery is in accordance with the length of the PCB (Printed Circuit Board)) and a capacity of 3 Ah, which should be sufficient for the planned operation of min. 12 hours. The battery is charged with 5 V from the USB connector from the PC. The printed circuit board was designed double-sided with spilled copper, where the spilled copper on the top side is connected to the 3.3V supply voltage and on the bottom side to GND. In the device, the gyroscope and accelerometer are solved by one combined automotive circuit IAM-20680HP. The GNSS module can receive signals from the GPS, GLONASS, Galileo and BeiDou constellations with an accuracy of up to 0.01 meters. However, such accuracy can only be achieved with RTK data. RTK data is sent to the TetryBox using a mobile application. TetryBox is equipped with an external active antenna. The device case is custom made using 3D printing. The PCB model is in Fig. 2.

Fig. 2. Printed circuit board model.

Data collection and transmission module

Commonly available applications measuring telemetric data from mobile phone sensors are not applicable to our system due to accuracy and limited data export options. For all measurement variants, the TetryApp mobile application developed within the project is a common element. The developed mobile application has several important functions within the system chain. The application is developed in the Visual Studio environment on the Xamarin/.NET MAUI platform and is currently available for the Android OS. The application is still under development and is not yet publicly available. The application is currently used only by professional test drivers from the team of our application guarantee. The main function of the application is driving record management, communication with an external measuring device, but it can also work directly with a mobile phone as a measuring device. One of the essential functions is also saving data in the mobile phone storage and sending driving data to the server. The TetryApp application, in addition to possibly controlling the measurement, can also receive RTK data and send it to the TetryBox. TetryApp is important for both collecting telemetry data and collecting user attributes related to the drive like road surface, weather conditions, lighting conditions, road condition, riding with a passenger. These attributes are filled by the user before the drive.

The main view of the application allows you to start recording data from the selected measuring device. The selected device is shown in the header of the view, below it is a button to start the recording and below the button elements for filling in metadata for the drive. Before starting the recording, you need to select the measuring device in the list of available devices that were found near the phone. After starting the recording, the application checks the sensor values and the captured GPS position.

After the device is ready to read values, the application goes into a state where it monitors the idle position of the device (Fig. 3). The application evaluates whether the device is at rest based on the values from the gyroscopes. The evaluation is performed on the average value of the last 50 measurements of all axes of the gyroscope so that if a significantly different value of the currently measured tilt change in one of the axes appears from the average value, the position of the device is declared unstable.

After reaching the rest position, the application goes into the state of the start of driving countdown, which lasts for 5 seconds. During this deduction, values are already being recorded and it is assumed that the device is at rest. The values measured in this way then serve as calibration values for the given drive.

After the countdown, it is possible to start driving. The application returns to the initial view, where it is possible to end the drive using the button. The application informs about the status of recording the drive in the header of the view. Until the countdown expires, it is possible to interrupt the process of starting a drive and return to the main view of the application.

After finishing the recording from the main view, the user is prompted to add a note and save the trip to the server. Sending is not mandatory, it is possible to skip it and send the drive later.
To use the application, it is necessary to fill in the username registered on the server and the authorization data for receiving RTK data. In the application, it is possible to view the history of completed trips, the user has the option

to resend the trip to the server if the upload fails. On the "Devices" tab, it is possible to search for available devices and diagnostic data for each device.

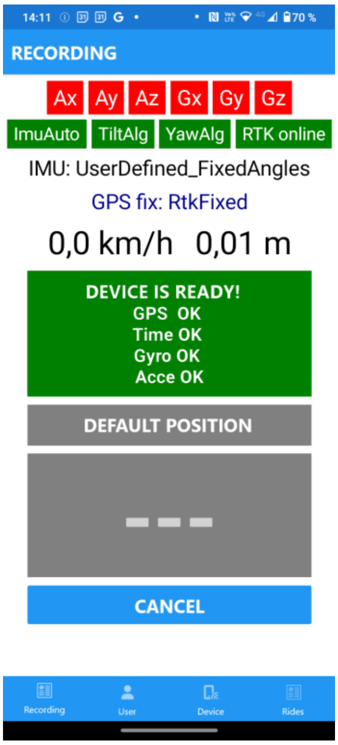

Fig. 3. The main view of the application – calibration at start.

Module for data storage, data management, data post processing and data presentation

Data processing is performed on the server. For this purpose, a service with an executable drive evaluation process is implemented on the server. The driving evaluation algorithm is determined based on experience with correct and optimal driving from the point of view of safety. The process performs data preprocessing for and data conversion into a result suitable for further processing and presentation. The evaluation is subsequently archived in the repository and can be further presented or processed.

A web application is implemented on the server for data management and presentation. The application uses storage in the form of a DB (a part of the server is a database server), where data from drives, the results of their processing and identities for accessing the application are stored. The application includes an API (Application Programming Interface) for communication with a smartphone (used by TetryApp). Professional drivers from the "Association of Driving Schools" and "Association of Polygons of the Czech Auto Club" participate in the collection, analysis of data and the resulting validation. The frontend allows the user to create an account in the application (a local identity within the application stored in the database), log in, and after logging in view the list of drives and, in the case of a higher user role, view the details of the drive and edit it.

In the view of the list of completed drives, it is possible to select by filtering the e-mail address of the trip of a certain user, or to filter according to the required metadata values associated with the trip. Time data, metadata in the form of labels or labels (notes, name of the device that captures data, etc.) are given in the trip list for individual items.

The driving detail view displays data from sensors (accelerometer, gyroscope) in the form of graphs. It is possible to zoom in on the data in the graph, move it or select an area, which will then also be displayed in the section of the route on the map. The map component is connected to aerial images of Google Maps. Thanks to accurate location data, it is possible to display the exact carriageway on the map. In the map background, it is possible to visualize detailed information about the passage through the bend. In the map, signs are visualized showing the right or wrong way to go through a turn. These symptoms include leaning, braking before a turn, unauthorized braking in a turn, non-smoothly passed turn, approaching a late apex, braking in a lean, "brake-throttle" driving style and others. It provides several analytical functions to the reviewer of the drive (see Fig. 4).

Fig. 4. Preview of the web application with analytical functions

A part of the drive evaluation is also an estimate made by a neural network, which is trained using telemetry data from professional drivers. The measurement of telemetry data takes place on selected circuits using our system. We try to collect as much data as possible about the so-called "OK drive" and "not OK drive". An OK drive is a drive performed by a professional driver who must complete all the turns correctly. Several professional drivers of different ages are engaged in data collection. Professional drivers include both men and women. The goal of all professional drivers who collect data is to collect data on safe defensive driving under all circumstances during the so-called "OK drive".

Conclusion

The goal of the project is to create and empirically verify software used for training, teaching and at the same time educating motorcycle drivers. The outputs of the project will lead to the development of abilities to better and faster recognize the mistakes of the motorcycle driver in connection with his control. At the same time, motorcycle drivers can adopt better self-reflection and objectively assess their riding style explicitly expressed over the defined result values, combined with the verbal interpretation of the instructors.

Acknowledgment

This article was created with the support of the IMETAS project, which is co-financed with state support from the Technology Agency of the Czech Republic within the Transport 2020+ program.

References

- Akalin, K.B. (2022) 'The effects of the hazard on road and road type on the motorcycle accident', *Academic Perspective Procedia*, 5(2), 124–128. Available at: https://doi.org/10.33793/acperpro.05.02.3701.
- Barzegar, A. *et al.* (2020) 'Epidemiologic study of traffic crash mortality among motorcycle users in Iran (2011–2017)', *Chinese Journal of Traumatology*, 23(4), 219–223. Available at: https://doi.org/10.1016/j.cjtee.2020.05.008.
- Dewar, A.R. *et al.* (2013) 'Improving Motorcycle Training Programs: Suggestions and Recommendations', *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 57(1), 1485–1489. Available at: https://doi.org/10.1177/1541931213571331.
- Eichberger, A., Kraut, M. and Koglbauer, I.V. (2022) 'Improved Perception of Motorcycles by Simulator-Based Driving Education', *Sustainability*, 14(9), p. 5283. Available at: https://doi.org/10.3390/su14095283.

- Fong, M.C. *et al.* (2015) 'Rates of motorcycle helmet use and reasons for non-use among adults and children in Luang Prabang, Lao People's Democratic Republic', *BMC Public Health*, 15(1), p. 970. Available at: https://doi.org/10.1186/s12889-015-2304-2.
- Hasan, O. *et al.* (2019) 'Motor-vehicle Crash Patient Injury Patterns from a Level One Trauma Center in a Metropolitan City: A Cross-Sectional Study', *Cureus* [Preprint]. Available at: https://doi.org/10.7759/cureus.4073.
- Heydari, S.T. *et al.* (2016) 'Prevalence and risk factors of alcohol and substance abuse among motorcycle drivers in Fars province, Iran', *Chinese Journal of Traumatology*, 19(2), 79–84. Available at: https://doi.org/10.1016/j.cjtee.2015.12.006.
- Hsu, T., Wen, K. and Liu, C. (2022) 'Safety effect analysis of motorcycle V2I collision warning system', *IET Intelligent Transport Systems*, 16(1), 13–23. Available at: https://doi.org/10.1049/itr2.12124.
- Kraft, S. *et al.* (2023) 'Modelling the road network riskiness for motorcycle transport: The use of accident probability and accessibility to emergency medical service', *Moravian Geographical Reports*, 31(2), 64–72. Available at: https://doi.org/10.2478/mgr-2023-0006.
- Lamr, M. (2019) 'Big Data and Its Usage in Systems of Early Warning of Traffic Accident Risks', in *2018 Sixth International Conference on Enterprise Systems (ES)*. IEEE, 154–157.
- Liu, H.-T. *et al.* (2015) 'Alcohol-related hospitalizations of adult motorcycle riders', *World Journal of Emergency Surgery*, 10(1), p. 2. Available at: https://doi.org/10.1186/1749-7922-10-2.
- Novotný, Jiří *et al.* (2021) 'Metodika provádění kurzů pro motocyklisty'. Česká kancelář pojistitelů. Available at: https://ebook.ucmeseprezit.cz/public/files/ucme_se_prezit_metodika_provadeni_kurzu_screen_dvoustrany.pdf.
- Rana, A. *et al.* (2022) 'Motorcycle Accidents in Punjab: A Critical Analysis', *Pakistan Armed Forces Medical Journal*, 72(2), 632–36. Available at: https://doi.org/10.51253/pafmj.v72i2.5797.
- Santoyo-Castillo, D. *et al.* (2018) 'Estimating the drink driving attributable fraction of road traffic deaths in Mexico', *Addiction*, 113(5), 828–835. Available at: https://doi.org/10.1111/add.14153.
- Shaheed, M.S., Marshall, D. and Gkritza, K. (2015) 'Factors Affecting Drivers' Ability to Detect Motorcycles during Daylight in a Simulated Environment', *Transportation Research Record: Journal of the Transportation Research Board*, 2520(1), 143–150. Available at: https://doi.org/10.3141/2520-16.
- Wigum, J.P. *et al.* (2023) 'Analysis of Risk Factors in Motorcycle Riding and Distribution of Attention Using Eye Tracking, Interview, and Video — Preliminary Study', in *Proceeding of the 33rd European Safety and Reliability Conference*. *33rd European Safety and Reliability Conference*, Research Publishing Services, 675–682. Available at: https://doi.org/10.3850/978-981-18-8071-1_P085-cd.
- Yousaf, A. and Wu, J. (2023) 'Motorcycle-Riding Experience: Friend or Foe? Understanding Its Effects on Driving Behavior and Accident Risk', *Sustainability*, 15(13), p. 10709. Available at: https://doi.org/10.3390/su151310709.
- Zehra, S.B. *et al.* (2019) 'Prevalence of Psychosocial and Behavioral Aspects in Victims of Motorcycle Accidents in Civil Hospital, Karachi', *Cureus* [Preprint]. Available at: https://doi.org/10.7759/cureus.4473.