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ORIGINAL RESEARCH

# Development of an AI-Integrated Smart Helmet for Motorcycle Accident Prevention: A Feasibility Study

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**Introduction:** The purpose of this research was to develop a smart helmet, including emphasizing the AI integration and the device's role in enhancing road safety with a mechanism that stimulates the driver to recognize which vehicle is approaching and the speed levels of the vehicle while it is moving, and to assess the satisfaction and feasibility of drivers while using the smart helmet.

**Methods:** This study included 139 participants who were general people in Thailand. The research model consists of four research and development steps: research, design and development, implementation, and evaluation. The questionnaires included general information, satisfaction, and feasibility of using a smart helmet.

**Results:** The study showed that males had a greater number of participants (63.31%), aged between 21 and 40 years (64.03%), higher education (73.38%), and most of the participants were university students (90.64%). Overall, satisfaction with using smart helmets was high (mean = 4.20, SD = 0.83), and the overall possibility of using smart helmets was very high (mean = 4.33, SD = 0.75).

**Conclusion:** The participants' reflections indicated that smart helmets can be a possibility for further development and are highly feasible practical application devices. Moreover, the smart helmet is beneficial to riders in terms of warning functions to prevent and monitor accidents. Nurses and health care providers may use these results to develop programs or devices that can encourage people to be aware of harm on the road while riding motorcycles.

**Keywords:** smart helmet, artificial intelligence, prevent driving accidents

## Introduction

According to Thailand's road accident statistics, it has the highest road accident fatality rate among ASEAN countries and the 9th highest in the world.[1] Each day, Thailand experiences approximately 60 deaths, 2,500 injuries, 500 serious injuries, and 20 disabilities from road accidents.[2] Road accidents affect economic costs, which are approximately 500 billion baht or 12.5 million USD.[3]

Road traffic injuries caused by motorcycle accidents are a major public health burden that leads to high rates of disability and mortality.[4] Helmets are considered important protective devices for motorcyclists, significantly reducing the risk of brain injury by approximately 69% and decreasing death rates from motorcycle accidents by approximately 42%.[5,6] Moreover, helmets can provide effective protection against moderate to severe traumatic brain injuries by reducing the impact or crash on the head because the soft material that is part of the helmet can absorb forces on the head to stop or move more slowly.[7] Therefore, helmets are protective devices enforced globally for riders.

Nurses and health care providers play an important role in terms of involvement in promoting and preventing preventative care.[8] Providing risk factors and encouraging people to be aware of health burdens are strategies used by

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nurses and healthcare providers to prevent diseases and traumatic accidents.[9,10] Some road accidents are caused by a lack of awareness. In particular, motorcycle accidents were unaware of wearing a helmet while riding, and a lack of awareness of riding at controlled speeds can cause accidents. Moreover, riding a motorcycle has vision limitations. This is because riders must focus their eyes on a subject or object while riding. Tunnel vision can occur in which riders focus less on circumstances, which impacts their ability to avoid dangers.

## Literature Review

According to the Road Accident Data Statistics Injury Surveillance of Thailand, over 100,000 people have been injured or died from road accidents in the last two years.[11] Khon Kaen Province has the third highest rate of injury and death from road accidents in Thailand between 2020 −2024.[11] The main cause of accidents is motorcyclists not wearing helmets.[1]

Behavioral factors revealed that the most unsafe riding behavior was not wearing a helmet while riding, with a prevalence of over 80% in both accident and non-accident groups. The study identified significant factors associated with motorcycle accidents in rural communities, including a history of alcohol consumption, changing lanes without using turn signals, and a strong disagreement with the notion that listening to music while riding is dangerous.[12]

Thailand, a middle-income nation in Southeast Asia, exemplifies this alarming trend. Motorcycle accidents are the leading cause of fatal traffic incidents in the country, which has experienced a sharp increase in private vehicle ownership. This surge has led to significant economic impacts and loss of life.[13] In the Thai context, a literature review identified several social determinants of helmet use. These include being female, younger in age, and living outside Bangkok, particularly in the Northeast region, which are associated with non-helmet use. Additionally, behavioral factors such as riding motorcycles as a passenger and driving at night after consuming alcohol are strongly linked to non-helmet use.[14]

Cultural and regulatory factors from a study on motorcyclists and passengers not wearing helmets in Thailand revealed several reasons for this behavior. Many believe that riding a motorcycle for a short distance does not require wearing a helmet. Some cite being in a hurry as the reason for not having time to put on a helmet, while others believe that the area they are riding in is not monitored by the police. These perceptions contribute to the ineffectiveness of helmet enforcement. Motorcyclists still have significant misconceptions about the purpose of wearing helmets. They often see it as a legal requirement rather than a safety measure to prevent or reduce the severity of injuries in accidents. The ineffectiveness of helmet enforcement can be attributed to three main factors: 1) Social Environment: The fast-paced lifestyle and time constraints of modern society. 2) Attitudes: The expectations of people in society, the relevant perspectives that are considered social risks, are 2 main issues: perspectives on helmet wearing and perspectives on police officers' performance. and 3) Public Communication and Awareness: The frequency of public communication and awareness campaigns is insufficient to drive behavioral change or create awareness that leads to self-initiated changes in behavior.[15]

A literature review revealed the development of an artificial intelligence (AI) and internet of things enabled smart safety helmet for real-time environmental and health monitoring.[16] The smart helmet's technology is essential for sensing, actuation, and distress alarms. It offers critical features and applications for health and safety. While smart helmets appear to be in high demand, only a limited number of commercial products are currently in the pilot stage.[17] Additionally, a study highlights that the smart helmet system is an advanced gadget utilizing modern technology to reduce the risk of two-wheeled accidents. It can alert users to the presence of alcohol, overspeeding, nearby vehicles, and other potential hazards in an efficient manner.[18]

Currently, people are aware of the effectiveness of helmets in protecting against head injuries.[5] Additionally, intelligent technology influences daily life, including health dimensions such as technology, which has been used to reduce traffic injuries.[19] AI has been developed worldwide to solve security problems and improve the efficiency of transportation systems worldwide.[20] Therefore, the researcher and team realized the importance of AI. This inspired us to combine AI with a standard helmet that can be used for the notification of approaching objects and surveillance to prevent head injuries.

The smart helmet developed by our team was designed to record data on an SD card by using a camera. We visually accessed all the data from the camera on the helmet. We also used AI as a program that notified the rider by sending a message to their cell phone by interpreting the results as the vehicle was approaching and the speed levels of the vehicle while it was moving through. Moreover, a notification voice was sent to the rider by connecting the headphone to the cellphone.

Therefore, we expect that the development of a smart helmet will be an effective device that can protect riders from head injuries. In addition, the development of alert systems may cause riders to notice harm on the road. This study aims to develop a smart helmet to promote and prevent riding accidents by reporting feasibility and satisfaction.

## Data and Methods

### Study Context

This device was developed using the 4 steps of research and development. The helmet. In the first step, we created a prototype of a smart helmet that had 7 parts; including 1) a helmet, 2) four small video cameras, 3) four sensors, 4) two batteries, 5) an AI analysis system, 6) a cell phone, and 7) a headphone. We used a standard helmet from P. Narong and P. N.I. Co., Ltd., Thai Industrial Standard (TIS) 369–2557 which is a standard approved in Thailand. We used an original helmet and applied a smart helmet device on top. The details of the views are as follows: Figures 1–4. In this study, the engineering details for the smart helmet are as follows:

1. The ESP32-CAM board is a microcontroller board with an integrated camera that can connect to Wi-Fi. This board supports microSD cards and can be connected to a computer via cable for control. It requires a 5-volt power supply to operate. The ESP32-CAM boards will be installed on all four sides of the helmet.

2. The speed sensors are built using SR04P ultrasonic sensors. These sensors can operate with power supplies of either 3.3 volts or 5.5 volts, can detect objects within a range of up to 5 meters, and are compatible with Arduino or Raspberry Pi. The speed sensors measure the distance to objects and send the data to the ESP32-CAM boards. Each speed sensor is paired with an ESP32-CAM and installed on all four sides of the helmet.

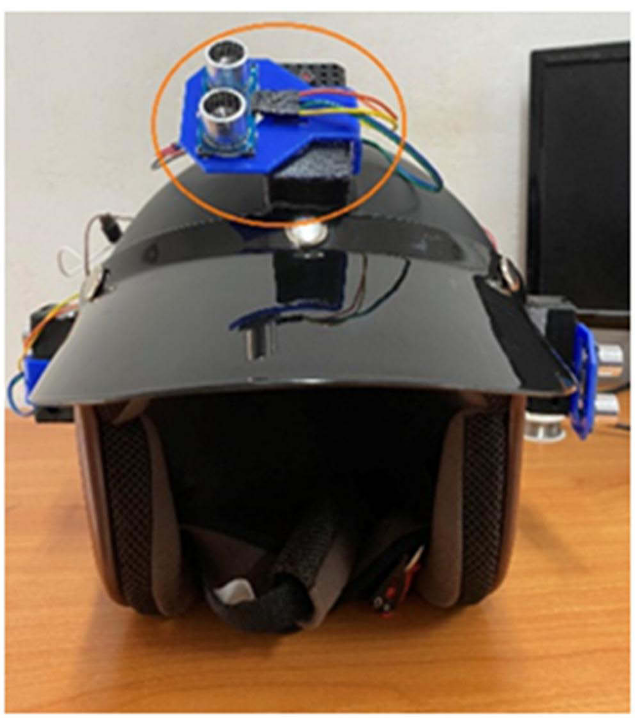

**Figure 1** Smart Helmet - Front view.

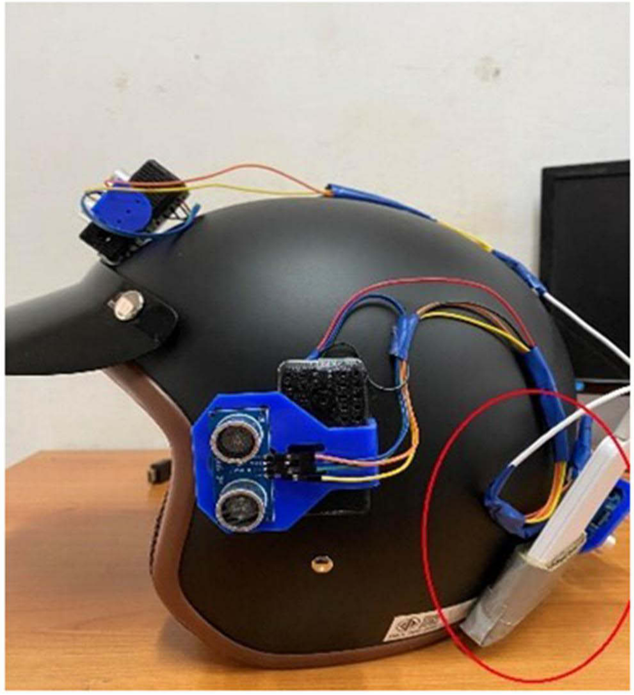

**Figure 2** Smart Helmet - Left side view.

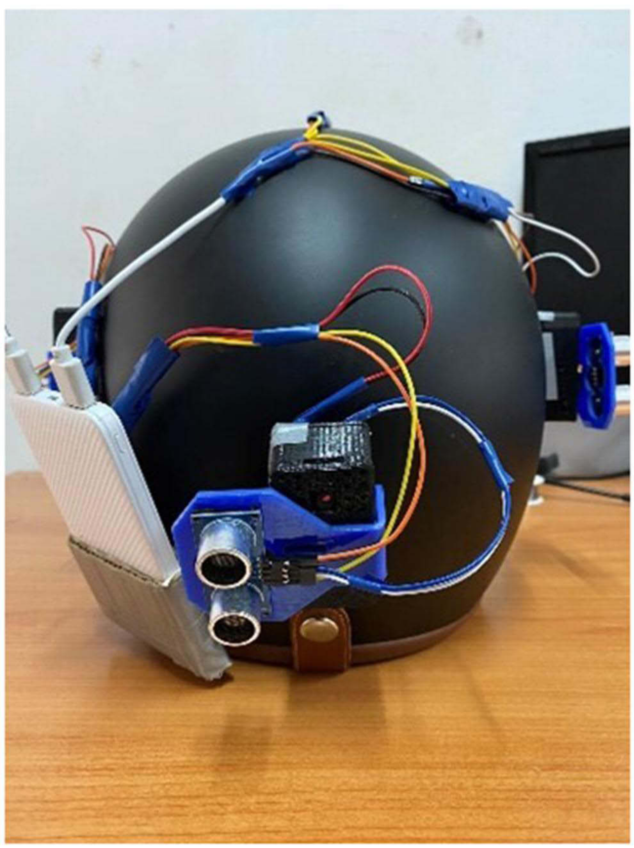

**Figure 3** Smart Helmet - Back view.

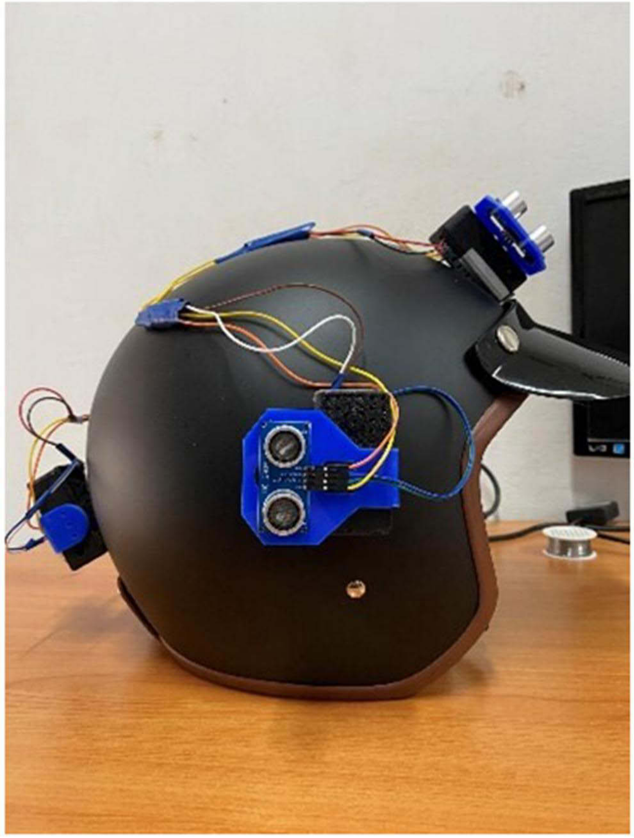

**Figure 4** Smart Helmet - Right side view.

3. A mobile phone will act as an intermediary to create a hotspot for Wi-Fi signals, allowing the ESP32-CAM boards to connect to the AI processing unit, the Raspberry Pi 4 Model B. The developers must prepare a pre-configured mobile phone to act as the data transmission hub. This phone does not need to be installed on the helmet and can be placed anywhere as long as it can transmit signals to the ESP32-CAM boards and the AI processing unit. The mobile phone does not require a SIM card and will be used solely for enabling the Wi-Fi hotspot.

4. The Raspberry Pi 4 Model B is a single-board computer that integrates all components into one circuit board. It is used as the AI processing unit. AI algorithms trained to classify different types of vehicles on the road will be deployed on this board. The alert system will also be developed on this board. This board does not need to be installed on the helmet and can be placed anywhere within the Wi-Fi range of the mobile.

5. The connection and data transmission between the components of the helmet rely on the mobile phone as an intermediary. It uses a 2.4GHz Wi-Fi signal from the phone's hotspot. The helmet does not store any data during the development and performance analysis phases. Instead, the required data will be sent to a personal computer for display and analysis before being implemented in actual use.

In addition, the in-depth details of the working principles of the smart helmet prototype can be explained in 5 steps as follows:

**Step 1**: The smart helmet functions by receiving data from small cameras installed on all four sides of the helmet, along with data from distance sensors. The data collected by the cameras and sensors is processed by the processing unit. The processed information is then used to alert the rider about the speed of approaching vehicles, the direction from which they are coming, and their type.

**Step 2**: The processing unit responsible for data analysis and rider alerts is the Raspberry Pi 4, a single-board computer. This processing unit handles multiple aspects of the data, as outlined below.

**Step 3**: For object detection and classification of approaching vehicles, the processing unit utilizes an artificial intelligence system called YOLOv8. This AI system can identify six types of objects: person, bicycle, car, motorcycle, bus, and truck.

**Step 4**: For speed detection, the processing unit calculates the speed of approaching vehicles using data from distance sensors. The speed is initially measured in meters per second and is then converted to kilometers per hour. Speeds are categorized into three levels: 1) Slow: 0–10 km/h 2) Medium: 11–22 km/h, and 3) Fast: 23–36 km/h.

**Step 5**: For rider alerts, the processing unit uses Python's text-to-speech library to generate voice alerts in English. The system announces the type of vehicle detected, the direction from which the vehicle is approaching, and the speed of the vehicle.

We tested the reliability of the smart helmet in two steps. First, the rider wore the helmet and rode a motorbike at a consistent speed of 30 km/h to examine the device's ability to accurately detect and interpret nearby moving objects, as presented in Table 1. Second, the rider wore the helmet and rode a motorbike at three different speed ranges: 0–10 km/h, 11–22 km/h, and 23–36 km/h. This step was designed to examine the device's capacity to interpret objects moving at different speed levels. It was observed that slower speeds resulted in higher detection accuracy and more accurate reporting. The results showed that at speeds of 0–10 km/h, the device achieved the highest accuracy of 79%, followed by 11–22 km/h with an accuracy of 65%, and 23–36 km/h with an accuracy of 51%, indicating reduced accuracy at higher speeds, as shown in Table 2.

After experimenting with vehicle classification in each speed range, we found that motorcycles had very different classification performance in different speed ranges. However, other vehicles, such as cars and trucks, did not exhibit different classification performances when the speed was increased. As shown in Figure 5, motorcycles in the speeds of 23–36 km/h achieve the highest accuracy, followed by the speeds of 0–10 km/h and 11–22 km/h, respectively.

## Study Framework

Research and development consisted of 4 steps of research, design and development, implementation, and evaluation was used as a framework for this research as follows.

**Step 1**: We studied various situations and analyzed problems from previous studies to use these databases to develop a smart helmet.

**Step 2**: We designed and developed a smart helmet.

**Step 3**: We implemented a smart helmet with participants. In this step, we examined the process of using a smart helmet in a closed system. We set up an arena to be a place that was suitable for a closed testing system. We created five spots, A, B, C, D, and E, to test each process (see Figure 6). Spot A: The participants received introductions and information regarding the smart helmet from the researcher and team. Spot B: The participants wore smart helmets. Spot C: Participants rode motorcycles from Spots C to D. In this process, the participants were required to ride through objects such as a person, bicycle, motorcycle, or car. Finally, spot E: Participants completed a self-report on their satisfaction with the smart helmet and its feasibility.

**Table 1** The Accuracy of a Smart Helmet Tested in a Real Traffic

| | Number of Objects can Detect and Correct Interprets | Number of Objects can Detect During Testing | Accuracy (%) |
|---|---|---|---|
| **Test 1** | 235 | 276 | 85.15% |
| **Test 2** | 635 | 756 | 83.99% |

**Table 2** The Capacity of a Smart Helmet Tested in Different Speed Levels

| Mode | Speed Levels | Accuracy (%) |
|---|---|---|
| SLOW | 0–10 km/h | 79% |
| MEDIUM | 11–22 km/h | 65% |
| FAST | 23–36 km/h | 51% |

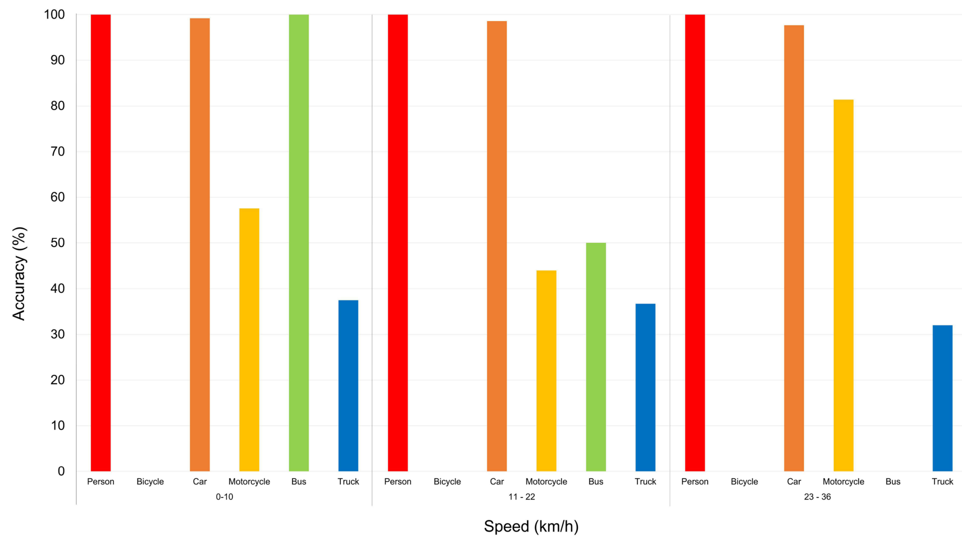


**Figure 5** The accuracy results of vehicle classification.

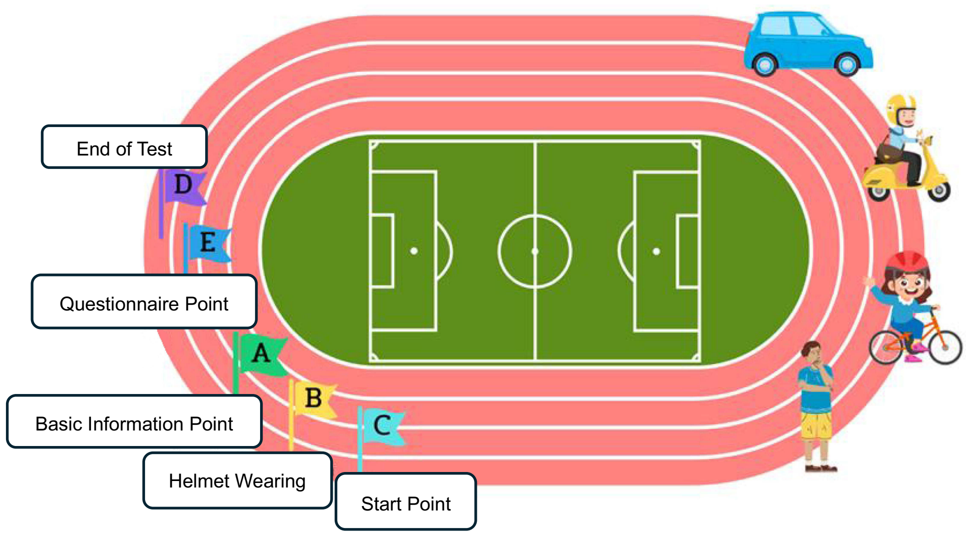


**Figure 6** The model of testing process of using a smart helmet in a closed system.

The smart helmet test during riding was divided into 2 points.

1. We examined a vehicle-type alert test during the ride from spot C to spot D. Participants drove past the persons and objects mentioned above. The helmet notifies the object type through headphones built into it. The notification was considered complete if the participants heard the alert and it was the correct type of object alert.

2. The speed range alert test of the approaching vehicles was conducted by measuring the speed of an object using an ultrasonic distance sensor. The purpose was to test the radial range of the sensors that could measure the speed of approaching objects from point C to point D. After the notification was tested, we rode and drove vehicles close to the participants. In this test, we wanted to determine the range of speed levels that the helmet alert system could interpret. Speed level was defined as slow, normal, or fast.

**Step 4**: After finishing step 3, we evaluated the satisfaction and feasibility of using a smart helmet.

## Study Participants

The target population was adults in Nai Mueang Subdistrict, Mueang Khon Kaen District, Khon Kaen Province, Thailand. The inclusion criteria were as follows: 1) aged 18 years or older, 2) healthy, 3) having their own motorcycle, and 4) willingness to participate. The sample size was determined using biostatistics as described by Daniel.[21] This was because the exact population in Nai Mueang Subdistrict, Mueang Khon Kaen District, Khon Kaen Province, Thailand, in 2023, was 104,037. The level of statistical significance was alpha equal to 0.05, and a power of 0.95, indicating a sample of 126 participants. A total of 139 participants were required to have an attrition rate.[21]

## Instruments and Analysis

The questionnaire included three parts: demographics, satisfaction with using a smart helmet, and the feasibility of using a smart helmet. The satisfaction of using a smart helmet and the feasibility of using a smart helmet were a rating scale with high scores indicated a high likelihood of satisfaction and feasibility. Cronbach's alpha of the scores from this study were 0.81 and 0.83, respectively.

Data analysis was conducted using the IBM SPSS version 26. First, demographic characteristics were computed as frequencies and percentages. Second, the satisfaction and feasibility of using a smart helmet were computed as the means and standard deviations.

# Finding

A majority of the sample was male (63.31%), aged between 21 and 40 years (64.03%), had a bachelor's degree or equivalent (66.19%), were students (90.64%), and had been riding motorcycles for more than 5 years (59.71%). See Table 3. Satisfaction and feasibility of using a smart helmet were high. See Tables 4 and 5.

**Table 3** Frequency and Percentage of Participants (N= 139)

| Demographic Characteristics | Frequency | Percent (%) |
|---|---|---|
| **Gender** | | |
| Male | 88 | 63.31 |
| Female | 51 | 36.69 |
| **Age** | | |
| Less than or equal 20 years old | 44 | 31.65 |
| 21–40 years old | 89 | 64.03 |
| 41–60 years old | 3 | 2.16 |
| 60 years old and older | 3 | 2.16 |
| **Education** | | |
| Lower than bachelor's degree | 37 | 26.62 |
| Bachelor's degree or relevant levels | 92 | 66.19 |
| Master's degree | 7 | 5.03 |
| Doctoral Degree | 3 | 2.16 |

(*Continued*)

**Table 3** (Continued).

| Demographic Characteristics | Frequency | Percent (%) |
|---|---|---|
| **Occupation** | | |
| Student | 126 | 90.64 |
| Engineer | 3 | 2.16 |
| Faculty member | 2 | 1.44 |
| Others: Nurse or health care provider, wife house, driver, businessman, village headman, agriculture educator etc. | 8 | 5.76 |
| **Experienced in riding motorcycles** | | |
| Less than 1 year | 2 | 1.44 |
| 1–2 years | 15 | 10.79 |
| 3–5 years | 39 | 28.06 |
| More than 5 years | 83 | 59.71 |

**Table 4** Means and Standard Deviation of Satisfaction of Using a Smart Helmet (N= 139)

| Satisfaction Topics | *Mean* | *SD* | Result |
|---|---|---|---|
| **Satisfaction of receiving instructions before using the smart helmet** | 4.50 | 0.39 | High |
| Important information for using | 4.37 | 0.65 | High |
| The difference between a smart helmet and a regular helmet | 4.24 | 0.83 | High |
| Steps to use the smart helmet | 4.48 | 0.72 | High |
| Instructors | 4.81 | 0.48 | Highest |
| Timing for receiving instructions | 4.61 | 0.68 | Highest |
| **Satisfaction of the driving alert function due to the artificial intelligence system on the smart helmet** | 4.00 | 0.70 | High |
| Notification volume level | 3.99 | 0.88 | High |
| Sensitivity of alert to vehicle types | 3.93 | 0.96 | High |
| Vehicle speed detection performance | 3.73 | 1.04 | High |
| Detectable vehicle direction alert performance | 4.08 | 0.87 | High |
| No distracting during riding and feeling like wearing a regular helmet | 4.22 | 0.86 | High |
| Increased sense of safety while riding and wearing a smart helmet | 4.07 | 0.93 | High |
| **Overall of satisfaction** | 4.20 | 0.83 | High |

## Discussions and Conclusions

Overall satisfaction of participants with the use of smart helmets was high ($M$ = 4.20, $SD$ = 0.83), especially on the topics of "Detectable vehicle direction alert performance" and "No distracting during riding and feeling like wearing a regular helmet." This indicated that after wearing the smart helmet, the participants had an increased sense of safety. Rahman

**Table 5** Means and Standard Deviation of Feasibility of Using a Smart Helmet (N= 139)

| **Feasibility Topics** | ***Mean*** | ***SD*** | **Result** |
|---|---|---|---|
| Appropriate to use for early warning on high speed and noticing for accidents | 4.32 | 0.75 | High |
| Useable to warn against speeding and notice for accidents | 4.33 | 0.72 | High |
| Practical use should continue to develop | 4.59 | 0.64 | Highest |
| Useful in terms of use as a device to warn against speeding and notice for accidents | 4.39 | 0.74 | High |
| Appropriate as it provides a device against speeding and accident monitoring | 4.45 | 0.74 | High |
| Suitability for practical use | 4.12 | 0.82 | High |
| **Overall of Feasibility** | 4.33 | 0.75 | High |

et al[22] studied AI helmets and found that a smart helmet saves lives and makes two-wheelers safer. First, the vehicle direction alert performance was good because having alert signals in both voice and vibration can alert riders to be aware of their speeds and harms. Riders may pay more attention to riding and focus more on subjects and objects on the road. The topic of not distracting during riding and feeling like wearing a regular helmet can be explained by Rusli et al[23] reported that one of the high risks of riding accidents was wearing inappropriate gear. This was because riders could have uncomfortable feelings or limitations of movements while riding with inappropriate gear, including helmets. Therefore, the development of smart helmets without increasing barriers was another satisfaction factor for riders in this study.

The overall feasibility scores of participants who used smart helmets were high ($M$ = 4.33, $SD$ = 0.75). In the topics of "Practical use should continue to develop" and "Appropriate as it provides a device against speeding and accident monitoring." This is because participants may have increased their safety perceptions and awareness by wearing a smart helmet. This aligns with the study by Tabary et al[24] who reported that a new smart helmet, which is a high technology that addresses sensors in a helmet, can increase safety and decrease the risk of accidents or death from two-wheel accidents. Moreover, Ledesma et al[25] indicated that a lack of attention could be associated with accident errors and also claimed that manually checking mobile phones while riding was a significant error among riders in their study. They recommended that decreasing distractions by using cellphones and addressing more utilities or applications could decrease the causes of motorcycle accidents.

Promoting and preventing health is a key role of nurses and healthcare providers because gaining more knowledge to take care of themselves is an excellent strategy that can increase well-being for each individual regarding health, economics, and nurses and healthcare providers' workload.[26,27] Moreover trauma cases in hospitals are mostly from transportation, which includes personal vehicles such as cars and motorcycles.[27] Riding motorcycles showed higher injury and death rates because this vehicle required more protective gear that could save vital organs, especially helmets.[28] Thus, encouraging people to wear helmets and providing safety devices, such as technology or AI, may help riders to get a warning of harm while riding a motorcycle.

Technology and AI tend to be programs that people integrate into their daily lives in several ways. One of these is the development of a smart system that evaluates and interprets results.[29] Additionally, smart cellphones have a system that can connect to other devices via wireless technologies such as Wi-Fi, Bluetooth, or applications.[30] Wi-Fi and Bluetooth are generally compatible with iOS and Android platforms. Other platforms may need to create applications for pairing with AI or other systems.[30] Undeniably, technology and AI will be programs that are used to support life, consisting of healthcare to develop programs or strategies that suit modern societies currently.[20]

However, the reduced performance of the smart helmet at higher speeds may limit its effectiveness in certain situations. Additionally, the study's demographic skew toward younger participants may not provide a complete representation of the diverse population of riders, leaving gaps in understanding its usability across different age groups. Economic barriers also warrant attention, as the cost of the smart helmet could pose a challenge for widespread adoption.

Furthermore, the long-term impact of integrating such technology into daily use, including maintenance and user behavior over time, remains unclear and requires further investigation.

This study demonstrates that using technology to promote health is valuable for saving lives and reducing costs. While the findings align with the objectives, addressing practical limitations is essential. The study does not evaluate long-term outcomes, and the results indicate that most participants are university students, which may limit generalizability. Furthermore, the reduced detection accuracy for fast-moving vehicles raises safety concerns. Future studies should include more diverse participants, improve detection accuracy, and assess long-term impacts to strengthen the research. Conducting follow-up studies would also provide further evidence to substantiate the device's long-term effectiveness and public health impact.

## Ethics Approval and Informed Consent

This study was approved by the Khon Kaen University Ethics Committee for Human Research (HE662208) in accordance with the Declaration of Helsinki and ICH Good Clinical Practice Guidelines. All participants provided informed consent.

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## Disclosure

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this study.

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