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## Enhancing Biker Safety through Ergonomic Design: An Integrated Smart Helmet Solution for Lahore Market

**Muhammad Qamar**

MS Art and Design, Superior University, Lahore

[muhammadqamar609@gmail.com](mailto:muhammadqamar609@gmail.com)

**Saba Hisham**

HOD MS Art and Design and Director School of Art and Design Superior University Lahore

**Humaira Kanwal**

Assistant Professor, Superior University Lahore

### ABSTRACT

*The aim of the study is to examine the trends of usage and challenges of wearing helmet among motorcyclists in Lahore, study the ergonomic constraints of the current helmets in the local market, and design an ergonomically optimized smart helmet design that improves the safety and usability of the riders. The study is based on the fact that although people are aware of helmet safety, the rate of wearing a helmet remains low because people experience practical discomforts and functional limitations. Thus, the research is concerned with recognizing actual user issues and converting them to effective designed solutions using a user-centered methodology.*

*The approach to the study was a mixed-method research to meet the study objectives. The quantitative part was carried out with the help of a descriptive cross sectional survey of 100 motorcyclists including delivery riders to examine their behavior in terms of helmet use and the challenges associated with it. The qualitative aspect comprised of case study analysis of five of the different helmets available including branded, institutional and locally available helmets to assess the ergonomics features, the use of materials and the integration of technology to the different helmets. The results of the two approaches were integrated to formulate the design requirements, which informed the concept development and digital 3D modelling of the proposed smart helmet.*

*According to the results, the key obstacles to the use of helmets include thermal discomfort, communication challenges, and limited visibility as opposed to lack of awareness. The current helmets were observed to be ineffective in ventilation, ergonomic comfort and incorporation of user-relevant technologies. In reaction to this, the study suggests a smart helmet design that will include multi-point ventilation system, hands-free calling using Bluetooth connectivity and rear-view camera with a front-mounted display to enhance situational awareness. The study concludes that a user-based and ergonomically informed design approach can greatly increase the usability of the helmets, as well as stimulate their constant use, thus, contributing to better road safety results.*

**Keywords:** smart helmet, ergonomics, user-centered design, helmet design, ventilation system, Bluetooth communication, rear-view camera

**INTRODUCTION**

One of the most common forms of transport in urban Pakistan and especially in Lahore is the use of motorcycles as a means of transport, which provides a cheaper and efficient way of transportation to the issues of commuting to work. Nevertheless, the growing popularity of motorcycles has caused the number of road safety issues to increase as well, and motorcyclists present one of the most vulnerable segments in traffic accidents. Since there is little physical protection, even the slightest collisions may lead to severe injuries, and safety gear (helmets in particular) is a critical part of the rider protection. Although the law enforces the use of helmets, a high proportion of the motorcyclists in Lahore do not wear the helmets at all or do not wear them appropriately. A large number of riders find the use of helmets uncomfortable, especially during hot and humid weather in Lahore due to poor ventilation that causes too much heat to build up and causes sweating. This means that the consumers usually take off the helmets when riding or do not wear it altogether, which jeopardizes their safety.

Along with the issues of comfort, the behavioral tendency of the riders also adds to the un-safety of the riding. The most apparent one is the necessity to answer phone calls during a ride and, in such a case, the rider may be compelled to either take off their helmet or to use handheld devices, thus losing control and exposing themselves to a higher risk of accidents. Likewise, the lack of rear visibility in heavy traffic situations can pose even more difficulties because riders have to often turn their heads or use poor exterior mirrors, which may interfere with the balance and situational awareness. The challenges indicate the existence of a serious gap in designing the current helmets on the local market. Majority of the commercially offered helmets focus on entry-level protection and forget the ergonomics of the helmet including fit, airflow, usability and incorporation of the helmet with the daily needs of the user. This translates to lack of connection between safety requirements and user acceptance to result in poor compliance and poor use of protective gears.

Ergonomics is crucial in improving the safety and usability of the product, in terms of product design. An efficient helmet should be not only safe but comfortable, easy to use and fit the local conditions. Including the concept of user-centered design enables designers to solve real-life issues because they can learn about user behavior, physical needs, and circumstances. Moreover, the introduction of the right smart functionalities, i.e. better ventilation, hands-free communication via Bluetooth and greater rear visibility, can facilitate safer riding habits without interfering with comfort and usability. This paper seeks to unravel the connection between user behavior, ergonomic constraints as well as the helmets design in Lahore context. The research aims to create a combination of smart helmet solutions that address the local needs by researching the issues of motorcyclists and the failures of current designs of helmet designs. The design methodology aimed at enhancing comfort by making the building climate-responsive ventilation, minimizing unsafe behaviors by promoting handless communication, and improving situational awareness by increasing the rear visibility systems. With this study, this study will aim at making a contribution to the product design field based on how the application of ergonomics and user-centered innovation can be used to create more effective safety products. Finally, the aim is to promote regular helmet wearing and enhance the overall safety of the riders by aligning product functions with its user needs and environmental conditions unique to Lahore.

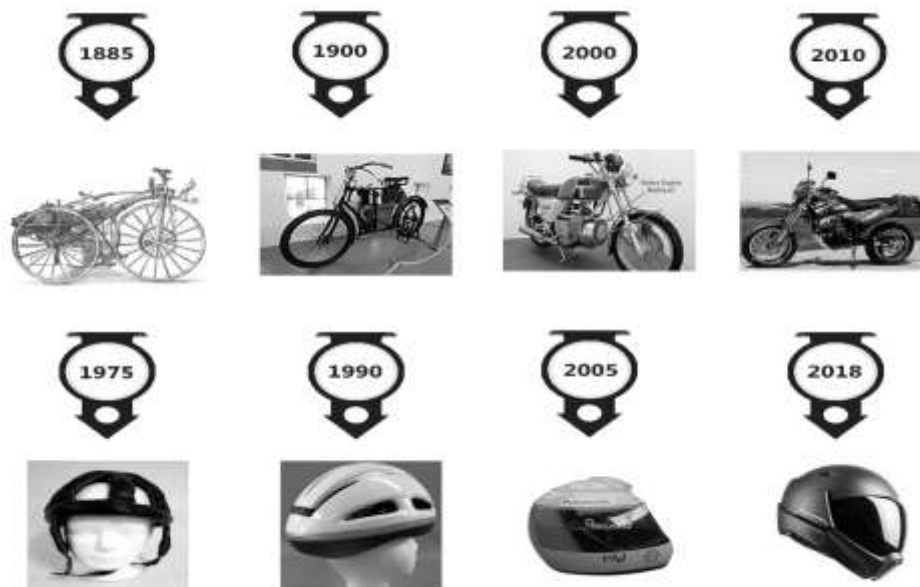
## Historical Background

As author was going through the history of helmets for a wider approach, one thing that was in front of designer that the development in design of helmet & bike took place parallel, as helmets are used by the bikers (cycle, bicycle, motorcycle ) so with change in bike designs, the helmet design also took place. The brief history of bicycle & helmet is given below:

## Research Objectives

The following are objectives of the research of this study:

1. To examine the trends in helmet usage, and the issues related to helmet usage among



motorcyclists in Lahore.

2. To examine ergonomic constraints of available helmets in the local market.
3. To come up with an ergonomically efficient smart helmet that increases the safety and usability among bikers in Lahore.

## Research Questions

To discover the following questions need to be answered I am working primarily on the question that: How can ergonomic design help to make the use of helmets more convenient and safer to the bikers in Lahore?

1. What are the patterns of helmet use and what are the challenges that the motorcyclists in Lahore have in wearing helmet?
2. What are the main ergonomic constraints with helmets in the market present in the area?
3. What is the most ergonomically efficient way of creating a smart helmet which suits the needs of users and enhances safety and usability to riders in Lahore?

## LITERATURE REVIEW

Motorcycle helmets are generally accepted as one of the most efficient types of personal protective gears to minimize the severity of head injuries and deaths in road traffic accidents. The main role of the helmet is to absorb and dissipate the impact energy when there is a collision and hence reducing the trauma caused on the skull and brain. The studies have continuously indicated that the use of the helmet reduces the chances of head injuries and death among motorcycles riders to a great extent (Liu et al., 2008; World Health Organization [WHO], 2015).

Norman (2013) says that good design must be usable and human based such that products are easy to use and match the expectation of the user. The design of helmets is usually in several layers, each layer having a particular protective purpose. The outer cover, usually made of polycarbonate, fiberglass or composite fibers, is designed to disperse the shock forces evenly, and to prevent penetration. Under the shell is an energy absorbing liner, usually of expanded polystyrene (EPS) which is significant to eliminate the force to the head by compressing on impact (Mills and Gilchrist, 2008). Ergonomics is another factor of user-centered helmet design, it is concerned with the optimization of the interaction between the product and the user. The appropriate fit, weight distribution, ventilation, and convenient usage are important aspects that determine user satisfaction. Improperly made helmets may cause pressure points, lack of airflow and handling difficulties, which may result in frustration and non-compliance with the use of the helmets (Sanders & McCormick, 1993). Helmet ventilation usually works with the help of intake and exhaust vents that help to maintain the flowing of air. The vents are usually situated at the front or at the top of the helmet where they allow the cooler air to pass in and the warm air to go out, and exhaust vents are situated at the back of the head where they suck the warm air out of the helmet. This airflow system serves to keep the inside environment balanced and to avoid heat and moisture build-up within the helmet. The system is efficient because the vent locations, size, internal channel design and the overall design of the helmet (Bogerd, Walker, & Bruehwiler, 2011).

Recent research has started to shift emphasis to motorcyclist safety and helmet-to-helmet communication devices. An attention problem with hands-free mobile phone use has been identified as a serious safety concern. Talking on the phone distracts the rider from the road and away from his or her hands on the bars, making crashes more likely. Previous research has demonstrated that manipulation of a phone decreases vehicle control and increases reaction time, increasing the risk of accidents (Strayer & Johnston, 2001; Caird et al., 2008). Bluetooth in helmet may be distracted since they have part of their attention on the conversation or audio instructions. There is evidence that mental distraction is still a problem with hands-free systems (McCartt, Hellinga, & Bratiman, 2006). However, these systems are believed to be safer than using a hand-held phone, especially in high traffic volumes (Hosking, Young, & Regner, 2010). Some studies have investigated the impact of in-helmet communication system on a rider's situation awareness. In this way, decision making can be supported by auditory navigation, for example. However, the system may if not well-designed then deliver too many instructions and thus distract the rider, or fail to increase the rider's situational awareness (Lee, Caven, Haake, & Brown, 2001). This is a good example of the positive effect of good design, including aspects like quality audio, little distraction and simple controls to keep the rider focused. The location and design of the controls is also important. If riders have to make complicated adjustments whilst riding, then it may undermine the safety gain. Studies have found that controls need to be easy to find, easy to operate, and not require much effort to use so that the controls can be operated while maintaining attention on the task of riding (Burns, Parkes, Burton, Smith, & Burch 2002). The aim is to have communication options that help the rider, without adding to the distraction. Visibility and situational awareness are important aspects of motorcycle safety, as riders primarily use visual cues to perceive and navigate the traffic environment. Motorcyclists are more exposed to environmental factors than drivers of other vehicles and need to keep track of traffic from all directions. Situational awareness involves the rider's recognition, understanding, and projection of features of the environment, such as other vehicles, road conditions and hazards (Endsley, 1995). Deficits in peripheral vision have been seen to have a negative effect on hazard awareness and reaction, particularly in more complex traffic situations (Wood &

Troutbeck, 1994). Therefore, it is important for a wide and unobstructed view while riding.. Motorcyclists need to perceive and integrate multiple visual and contextual factors, and any increased cognitive load due to reduced visibility or limited mobility can impair their performance. Studies indicate that better visual clarity and less restriction of movement can aid in identifying hazards and improve overall riding performance (Horswill & McKenna, 2004)

Most of the literature on motorcycle helmets has concentrated on helmet impact and safety standards, with less attention given to ergonomic aspects such as ventilation, comfort and ease-of-use, especially in a hot climate. Although research has focused on user behavior and helmet use, there is a gap in the research that directly relates these behavioral issues with design approaches in developing nations such as Pakistan. Moreover, while studies have addressed smart helmets with technologies such as Bluetooth communication and visibility features, there is a lack of research examining the integrated use of these technologies in a single, ergonomically-optimized helmet. Current designs fail to address user acceptance, usability and riding environments. Thus, there is a need for a user-focused, ergonomically improved smart helmet incorporating ventilation, communication and visibility features that considers environmental factors and user behavior of motorcyclists in Lahore.

### **Theoretical Framework**

This research is based on the principles of User-Centered Design (UCD) and Ergonomic Design (Human Factors), which offer a holistic theoretical framework for understanding and enhancing helmet design with respect to user needs, usage and safety. These perspectives help pinpoint user problems and develop suitable designs. User-Centered Design is a design philosophy that focuses on the user's needs, preferences and capabilities during the design process, to ensure the product is based on user requirements. Norman (2013) suggests that good design should focus on usability and user experience, rather than technical or aesthetic considerations. When it comes to helmet design, UCD focuses on understanding motorcyclists' interactions with helmets in their everyday activities, as well as the problems they face in helmet use.

In this study, UCD is applied through the exploration of user behavior and helmet use patterns of motorcyclists in Lahore. Issues such as irregular use of helmets, discomfort, inability to communicate and lack of visibility are investigated to understand why users behave in a certain way. Through user surveys and observations, the study allows the design process to be driven by user feedback, rather than presumptions. If a helmet is uncomfortable or inconvenient to wear, it may not be worn as frequently as it should be, regardless of its effectiveness. So, by emphasizing ease of use, comfort, and convenience, UCD plays a role in improving user compliance and safety.

Ergonomic Design (Human Factors Engineering) aims to enhance product interactions with humans in terms of comfort, efficiency and safety. This entails creating products that fit human physical and cognitive abilities. Pheasant and Haslegrave (2006) note that ergonomic design seeks to minimize discomfort, fatigue and injury risk by taking into account human size, abilities and limitations. Ergonomics is essential in designing helmets to combat comfort and convenience issues. Fit, weight, ventilation, visibility and ease of use are important ergonomic considerations. Ergonomic shortcomings of many helmets can cause discomfort, leading to problems with heat, sweating, lack of mobility, and pressure points, which leads to helmet noncompliance by users. These ergonomic problems were identified through surveys and case studies and are of great interest to this research. In the hotter climates like Lahore, ventilation is of paramount importance due to ergonomics because of the high temperatures and humidity. Weight and balance impact the posture of the neck and the rider's fatigue during more lengthy riding sessions, especially for commercial riders. Mobility and visibility are also important for being

aware of the situation and riding safely. Ergonomic considerations help enhance comfort and safety through these factors. Moreover, the placement of features on the helmet is also related to ergonomics. For example, communication devices must be placed carefully, so as not to obstruct movements and/or distract from the task. In this way, the advantages of technology integration will be achieved without any user hindrances.

## **RESEARCH METHODOLOGY**

### **Research Design**

The study will be designed in a mixed-method way; quantitative data collection and qualitative analysis of the product will be used for informing the design. The study is structured to get interested in the behavior of the users and the difficulties encountered by the use of the helmets and then an analysis has been done to the available designs of the helmet in the local market. These stages are later used to guide the development of an ergonomic smart helmet solution. The design approach is a user centered approach where the end product would be defined by actual and specific user needs, environmental and usage specificities of Lahore.

The quantitative part of the research was based on descriptive type of cross-sectional survey design that was used to collect data regarding Lahore's road users, motor cyclists at one particular time. The methodology enabled the researcher to look at the trends of helmet use, the problems that might arise and what the users are likely to do in the existing conditions. The qualitative part involved case study analysis of present helmets in the local market, which assisted in recognizing the design constraints and the possibilities to improve the design.

### **Research Approach**

The research is divided into three major stages: user survey, product case study, and design development. All the phases are linked and help in attaining the research aims. The survey stage concentrates on finding information about the user on the behavior of using the helmet and the problems and the case study stage is going through the designs of the current helmets to identify the ergonomic constraints and the design stage converts the findings into an offer.

### **User Survey**

The aim of the survey is to explore the patterns of helmet use, users behavior, and the issues related to helmet use among the motorcyclists in Lahore.

### **Sampling**

Participants that are sampled are regular motorcycles riders using purposive sampling technique. The sample is made up of about 250 respondents, namely In Drive riders, and the Food panda riders. Such users are chosen due to the fact that they ride longer hours and have higher chances of having problems regarding the comfort of the helmet, its usability, and safety.

### **Data Collection Method**

The data is gathered by means of structured questionnaire containing close-ended questions and rating scales. The questionnaire constructed to obtain data about the frequency of helmet use, the lack of helmet use, comfort and ergonomic factors, riding habits like answering phone calls, visibility problem on the road and user desiring better features in their helmets.

### **Data Analysis**

The data obtained is analyzed with the help of the descriptive statistical techniques. The responses are analyzed on percentage basis and frequency distribution basis to find out the patterns and trends. The results are presented graphically to make it easier to understand the users' requirements and problems.

### **Helmets Case Study**

The aim of carrying out the case study is to examine the currently existing designs of helmets to determine their strengths and weaknesses with regard to their ergonomic and usage design. This

analysis helps in the examination of how existing helmets needs of the users and where these helmets need to be enhanced.

### Sample Selection

The sample for the case study includes, Helli helmets, helmets worn by the In Drive riders, Food panda helmets, Dolphin Force helmets and regular helmets which can be found in the general market, all of which are subject of the case study. The helmets come in a range of types and levels of use are of varying quality, providing a complete picture of the status of the design.

### Method of Analysis

The chosen helmets are discussed using the observation and comparison. The details of each helmet are judged on the comfort, fit, weight, ventilation, visibility and usability. The results are recorded and compared to point out typical ergonomic problems and design flaws. This discussion helps establish critical areas that need to be improved in the proposed design.

### Design Development

#### Design Approach

The design phase is user-centered and iterative where the findings of the survey and case study are converted into design solutions. It is concerned with solving the user issues that are identified by ergonomics and proper feature combination.

#### Concept Development

Preliminary ideas are developed by sketching and exploring ideas that aim at improving ventilation, incorporating Bluetooth communication, and enhancing rear visibility. Various design options are discussed and final concept is chosen according to usability, feasibility and usefulness to the needs of the user.

### 3D Model Development

The chosen design is worked out to a detailed 3D digital model. The 3D model is the shape, design and combination of features in the helmet. This step is aimed at visualizing the final design and how the ergonomic and functional elements will be integrated.

## DATA ANALYSIS AND FINDINGS

The survey data is analyzed using descriptive statistical techniques such as frequency count and percentages to determine the trends and patterns.

### Frequency Distribution of Challenges Associated with Helmet Use

| Sr. NO. | Questions   | Agree (f) | No Opinion(f) | Disagree (f) |
|---------|---|-----------|---------------|--------------|
| 1.      | The helmet is heavy and I don't use it for this reason                          | 140       | 53            | 57           |
| 2.      | I feel heat on my head when wearing the helmet                                  | 230       | 3             | 17           |
| 3.      | In summer, I cannot use a helmet due to excessive warmth                        | 203       | 5             | 42           |
| 4.      | Helmet cause sweating and I feel suffocation in helmet                          | 238       | 0             | 12           |
| 5.      | I have to attend calls while riding , that why I don't wear helmet              | 178       | 13            | 59           |
| 6.      | Helmet leads to restriction of rear view vision                                 | 170       | 5             | 75           |
| 7.      | I have to look back while turning and I can't turn my head when wearing helmet. | 183       | 8             | 59           |

Table shows the frequency distribution of respondents' perceptions of the problems with helmet use. The findings show that thermal discomfort is a major factor affecting helmet use. The majority of respondents (92%) agreed that they feel hot on their head when wearing a helmet; and 81% agreed that they find it hard to use helmets in summer because they get too hot.

Likewise, 95% of respondents agreed that they sweat and feel suffocated when wearing helmets, indicating ventilation problems. Along with heat discomfort, physical discomfort was also reported: 56% of respondents felt helmets are bulky and this discourages their use. Other factors that play a role in helmet noncompliance include behavioral, with 71% of respondents agreeing that they do not wear helmets because they need to answer phone calls. Impacts of helmets on visibility and mobility was also reported. Most participants (68%) concurred helmets limit their ability to see behind them, and 73% reported they have difficulty turning their head with a helmet on, especially when turning their head backwards to check for traffic. These results indicate helmet design may restrict visibility and mobility. In nutshell, the results indicate that thermal discomfort, sweating, and helmet usability, combined with behavioral factors, such as the ability to communicate and visibility, make significant contributions to helmet use.

**Ergonomic Issues in Existing Helmet**

**Frequency Distribution of Computed Challenges Associated with Helmet Use**

| Variable            | Agree (f) | No Opinion(f) | Disagree (f) |
|---------------------|-----------|---------------|--------------|
| Heat issue          | 223       | 3             | 24           |
| Call handling issue | 178       | 13            | 59           |
| Visibility issue    | 175       | 5             | 70           |

To determine the key problems with existing helmet usage, the responses in Table 4.2 were computed and recoded into major categories such as heat-related issues, communication-related issues and visibility-related issues. This was done to reduce the complexity of the analysis and to identify the major issues contributing to helmet use by motorcyclists. The table shows the distribution of percentage responses of the major issues associated with the use of helmets, grouped into categories. The findings show that heat is the most prominent problem, as 89.3% of the responses showed agreement with heat-related issues. Issues related to communication are also significant, with 71% of respondents agreeing that communication problems were an issue. Likewise, 70.5% of respondents expressed issues with visibility, which relates to vision and head movement. In summary, these results demonstrate that heat, communication and visibility are important factors in helmet use.

**Challenges Associated with Helmet Use**

The results presented in Table 4.3 clearly demonstrate some of the major issues faced while using helmets, which are important factors to consider in the design of the proposed helmet. The major issue here is thermal discomfort, as the majority of respondents felt hot, sweaty and suffocated while using helmets. This suggests a need for effective ventilation to provide adequate airflow and prevent heat build-up within the helmet. Thus, the design should include weather-adaptive ventilation to enhance thermal comfort, especially in hot climates.

Weight of the helmet, which was reported by many participants, suggests the need to find the materials that are light, but strong enough, as well as optimize the weight distribution on the helmet. The weight of the helmet can be decreased so as to minimize the fatigue of the neck and make it more comfortable for long periods of time, especially for commercial motorcycle users. Considering the problems associated with riding, including using a mobile phone to communicate, it seems there is a need for a hands-free communication device. The use of Bluetooth technology in the helmet can help overcome this problem by enabling the rider to receive calls without having to take off the helmet or use a handheld phone, thus eliminating unsafe riding behavior. Also, limited rear vision and lack of flexibility in head movement suggests the need for better situational awareness through design. This issue can be overcome by

implementing a rear camera and display design that offers improved visibility of traffic without the need for excessive head movement. This can enhance safety in heavy traffic.

In general, the study highlights that the new helmet design should prioritize comfort, usability and safety, by addressing the critical issues of **ventilation**, weight, **communication** and **visibility**. These findings provide a basis for designing an ergonomic smart helmet that meets the needs of Lahore's motorcyclists.

### **Case Study of Helmet**

This section provides a case study of a few motorcycle helmets available locally to assess their ergonomic features, design aspects and usability. This evaluation aims to assess how current helmet designs cater to user requirements related to comfort, ventilation, visibility and usability. Through analysis of widely adopted helmets under real-world usage scenarios, this section highlights common design flaws and performance issues that impact user performance and safety.

Five selected helmets (Helli helmet, Dolphin helmet, In Drive rider helmet, Food panda helmet, local market helmet) are analyzed and a significant variation in terms of design philosophy, features and user requirements is found. Each of the helmets represent different use scenarios; however, none of the current options seem to consider the triad of safety, comfort and functionality.

The Helli helmet is a very technologically advanced and innovative solution with features such as Bluetooth, monitoring heart rate and an integrated front camera. It seems to be more theoretical and may not sufficiently address issues of price, air flow and user-friendliness in local conditions. The Dolphin helmet, worn by government-run teams, provides more of a practical design with an emphasis on communication. The Bluetooth function is useful for emergency response as it enables squad members to communicate. Good for communications but not as sophisticated as has an ergonomic feature like ventilation and comfort. On the other hand, the In Drive rider helmet and Food panda helmet are based on practical experiences of commercial riders. The designs of these helmets are primarily traditional with little to no smart integration. While they provide basic protective functions, they do not support the demands of long hours of use by riders, in terms of communication, comfort, and usability.

The helmet sourced from the local market is the most widely used type of helmet, as it is cheaper and easier to access. However, it is the most deficient in design, safety and ergonomic considerations. Common problems include insufficient ventilation, bad fit, and the lack of smart features. From this comparative study, it is evident that there is a need for a transition from technologically driven ideas to real solutions for helmets. Helmet designs sometimes feature smart technologies but lack design refinement and the most popular helmets lack smart technology and ergonomic refinement. This suggests a compromise between safety, comfort, air ventilation, communication and visibility features in a single, ergonomic helmet design that meets the demands of motorcyclists in Lahore.

### **COMPETITIVE AUDIT**

This project aims to assess the design of a number of motorcycle helmets from the local and conceptual market and to propose improvements in terms of safety, comfort, usability and integration of technology components.

|                                   |   |
|-----------------------------------|---|
| <p><b>Competitor Strength</b></p> | <ul style="list-style-type: none"> <li>• Offer basic protection against blows (hard shell)</li> <li>• Comfortable, lightweight helmets for everyday wear</li> <li>• Full-face and open-face designs</li> <li>• Visor protection against dust and other elements</li> <li>• Communication systems (Bluetooth) are available (Helli, Dolphin)</li> <li>• Smart helmets offer supplementary protection devices (cameras, sensors)</li> <li>• Readily available and inexpensive in local market</li> <li>• Customized helmets (Food panda, Dolphin) aid in identifying users</li> <li>• Easy-to-use buckles and straps</li> <li>• Shells made from materials like polycarbonate and ABS are used</li> <li>• Visor can be removed for versatility</li> <li>• Helmets can be easily put on and taken off</li> </ul>   |
| <p><b>Competitor Weakness</b></p> | <ul style="list-style-type: none"> <li>• No ventilation system to avoid suffocation and heat stress</li> <li>• Overheating and suffocation after prolonged use</li> <li>• Lack of communication system in widely used helmets</li> <li>• Riders use mobile phones, which could be dangerous</li> <li>• Poor rear vision and awareness</li> <li>• Limited head mobility when wearing helmet</li> <li>• Uncomfortable for prolonged wear</li> <li>• Unequal weight distribution leading to neck strain</li> <li>• Poor quality inner lining and moisture management</li> <li>• No use of antibacterial/ moisture-wicking textiles</li> <li>• Lack of integration of several smart features in one helmet</li> <li>• Sizing and fit issues in readily available helmets</li> <li>• No quality checks and standards in cheap helmets</li> <li>• Helmets are not designed according to hot climatic conditions</li> <li>• Removal of helmet decreases compliance</li> <li>• Poor appearance in low-cost helmets</li> <li>• Ergonomic integration of electronic devices (if available)</li> <li>• User-centered design principles are not considered in most helmets</li> </ul> |
| <p><b>Market gap</b></p>          | <ul style="list-style-type: none"> <li>• Lack of helmets combining ventilation, communication and visibility solutions</li> <li>• No helmets tailored to hot weather conditions such as Lahore</li> <li>• No helmets with built-in hands-free communication devices</li> <li>• Absence of rear-view assistance system in helmets</li> <li>• Lack of attention to comfort for long rides</li> <li>• No sweat-absorbent and antibacterial liners</li> <li>• No consideration for rider's behavior (phone calls, discomfort, low visibility)</li> <li>• Inability to provide smart helmets at low prices for local users</li> <li>• Lack of balance between technology and user-friendliness</li> </ul>  |

|                                       |  |
|---------------------------------------|--|
| <p><b>Improvement Opportunity</b></p> | <ul style="list-style-type: none"> <li>• Use an improved ventilation system with air passageways for inhalation and exhalation</li> <li>• Hybrid (Coolmax + Bamboo fiber) inner lining for comfort and hygiene</li> <li>• Design Bluetooth phone system for convenience</li> <li>• Build-in rear-view camera with screen for better visibility</li> <li>• Employ lightweight and strong outer shell (polycarbonate)</li> <li>• Ensure better fit and adaptability to different head shapes</li> <li>• Increase safety via design and technological integration</li> <li>• Adopt rider-centered design process based on feedback</li> <li>• Create cost-effective smart helmet designs for market uptake</li> <li>• Include reflective materials for night-time visibility</li> <li>• Include accessible controls (external buttons)</li> <li>• Priorities user-friendliness with smart features</li> <li>• Enhance user experience with contemporary and practical design</li> </ul> |
|---------------------------------------|--|

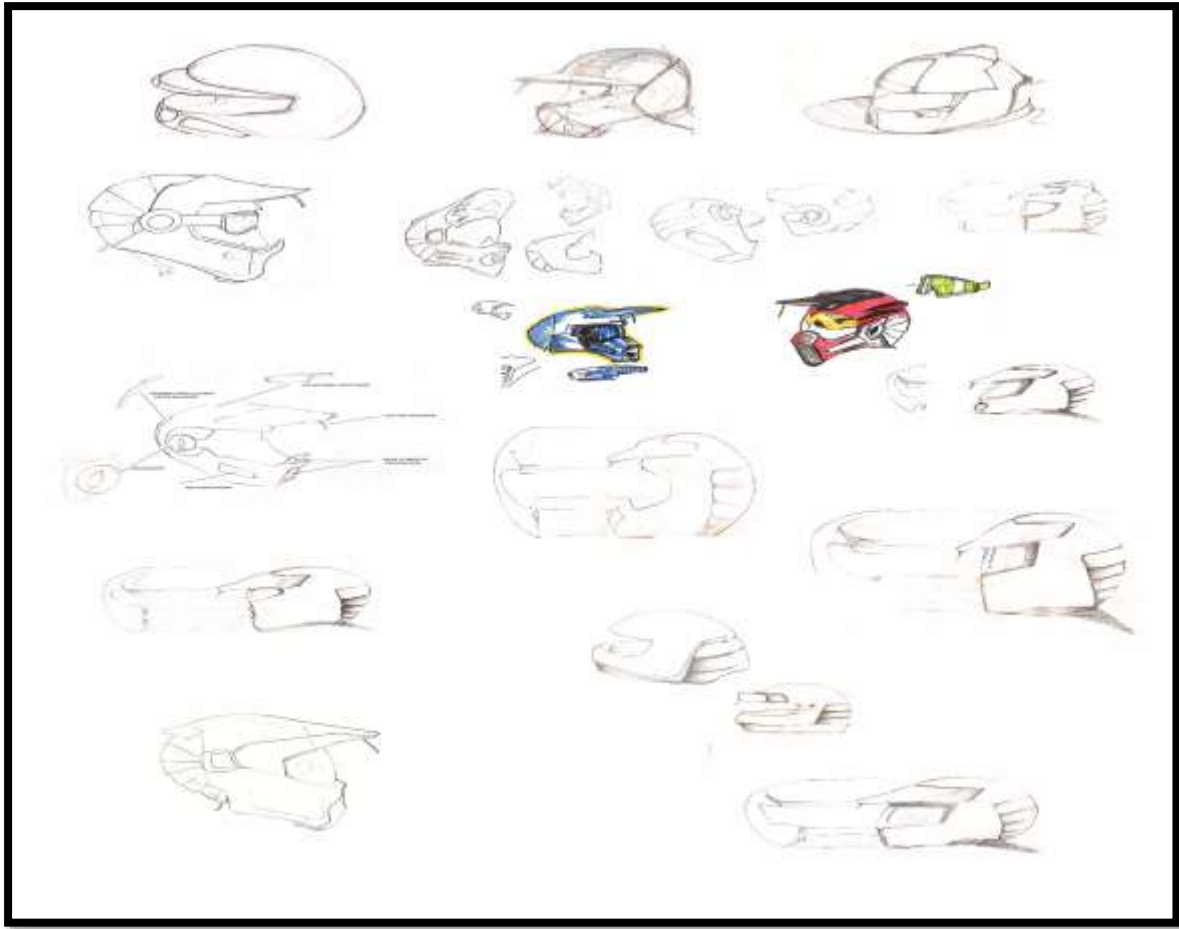
**Initial Sketches**

In the first stage of concept development, the most critical user problems based on the results of the survey and competitive audit were converted into design challenges. The main problems, mentioned by users were too much heat and uncomfortable feeling, when wearing helmets, when riding in the middle of the day; it was difficult to make and receive calls, and see behind, which posed a safety risk. These problems have been captured into targeted problem statements to steer the ideation process.

A series of ideation sessions was then adopted using the How Might We (HMW) ideation framework to identify possible solutions. Each problem area (how ventilation in the helmet could be improved to enhance thermal comfort, how communication could be enabled without compromising rider safety and how rear visibility could be increased without obstructing the forward view of the rider) had developed a series of exploratory questions.

On the basis of these questions, several conceptual ideas were created and visualized with the help of primary sketches. These drawings examined the various designs of ventilation placement, integration of Bluetooth communication system and placement of rear-view assistance features like camera and display units. These sketches were designed to explore form, functionality and feature integration whilst maintaining a user-oriented and ergonomically reactive design process.

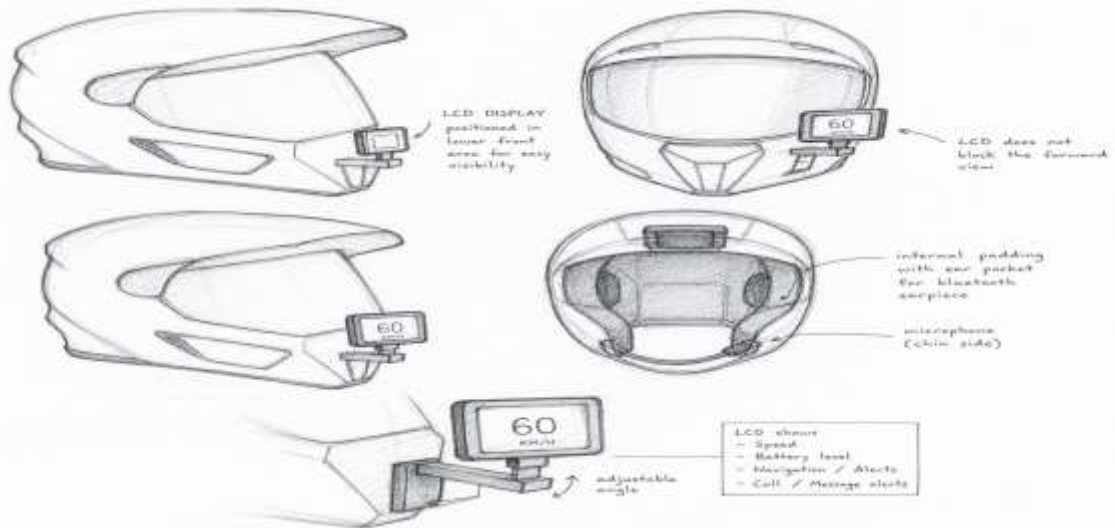
The preliminary sketching process enabled quick visualization of concepts, and assisted in assessing the different design direction options before progressing to an advanced and integrated smart helmet design concept.

**Figure : Initial Sketches****Layout and Reachability**

To guarantee user-friendly interaction and harmless usability throughout the ride, various layout arrangements of the helmet parts were tested during the concept development stage. These designs dealt with the arrangement of important features like ventilation ports, Bluetooth control buttons, rear camera, and LCD display. The goal was to create a setup in which every vital functionality can be easily accessed without making the rider distracted or not to achieve safety on the road.

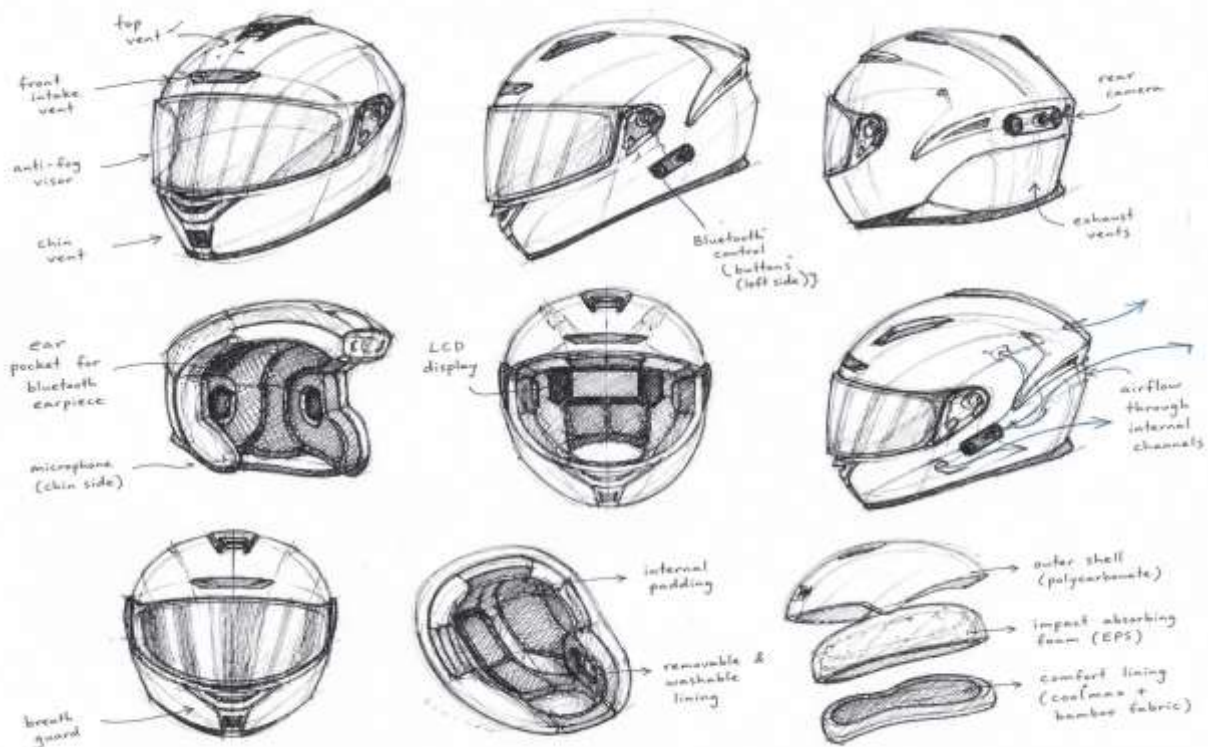
The accessibility to commonly utilized controls was also a special consideration. Several locations of the Bluetooth control interface were sketched and tested and the left side location of the control interface was selected so that the riders could conveniently operate the controls without causing any interference with the throttle handling. On the same note, the placement of the LCD display was experimented in various positions in order to make sure the display is visible enough to help a driver with a rear-view camera; and yet to avoid putting the forward part of the field of view at risk.

To optimize the rear camera positioning, it was mounted at the back of the helmet to provide wide field of view to ensure that there is improved situational awareness. Reading through the layout exploration, there was a focus on ease of interaction, minimum cognitive load and ergonomic efficiency so that, the final layout exploration concept entailed that, there was a well-integrated and user-friendliness of the final layout exploration concept.



### Internal Structure and Component Organization

Deviations were also created to understand how the internal structure of these parts of a helmet functions, and the development of safety, comfort and technological attributes. Special ear holes (recessed padding areas) have been designed to fit the Bluetooth earphone peppers without pressure and discomfort. The microphone, similarly, was located in the chin region, but with slight offset so as to allow clear recording of the voice without causing much interference in terms of wind and breathing. Channel internal design was planned to neatly wire the channels to avoid blockage and to allow the user comfort. This organized system of inside organization will need all the parts to be functional, without losing the main purpose of the helmet: protection and comfort.



### Technical Detail

Technologies which would be the additional feature of designed helmet are discussed in the given table along with their brief & specification.

#### Integrated Technologies in Proposed Smart Helmet

| S.NO | Technology                            | Description   | Specification   |
|------|---------------------------------------|---|---|
| 1.   | <b>Bluetooth Communication System</b> | Inbuilt Bluetooth device to make hands free communication with device where rider can attend to calls without holding the gadget either by using his / her hands or hands free devices thus increasing the riding safety and convenience. | Wireless connectivity, in-built speakers and microphone, low-power consumption.           |
| 2.   | <b>Rear-View Camera</b>               | It has a rear-mounted camera that is used to give visual feedback on the situation, and eliminate the necessity of physical head movement to view the back of the traffic.  | At least 2 MP image resolution, wide-angle image lens (angle 120 - 150), waterproof case. |
| 3.   | <b>LCD Display</b>                    | The display unit consists of an LCD display mounted on the front of the bike, and it is also called the live feed because the rear camera shows the rear traffic in real-time, thus forming the live feed.                                | Display screen size of about 3-inch; adjustable viewing angle; anti-glare screen.         |
| 4.   | <b>Battery System</b>                 | Battery System is a rechargeable battery unit that supports all integrated electronic components such as Bluetooth, camera and LCD display, to ensure continuous operation during use.  | Approximately 12V, lightweight lithium-ion battery, small and rechargeable.               |

### 3D Model Development

After the concept development stage, the final design was converted into a detailed digital three-dimensional (3D) model to visualize the form, structure and integration of features. The 3D model was created to show the proposed smart helmet in a realistic and accurate way, which would allow to learn more about the design, proportions, and functional parts of the proposed smart helmet.

### Conclusion

The objectives of this study were to explore the patterns of helmet wearing and challenges among motorcyclists in Lahore, analyses the ergonomic constraints of the current helmets, and develop a smart helmet design that is user-centric to improve safety and usability. The results show that though there is awareness on the subject of helmet safety, its constant use is heavily affected by practical factors of comfort, convenience and functionality as opposed to ignorance. The quantitative research revealed that one of the main reasons why riders do not wear helmets, especially in hot climatic conditions, is thermal discomfort that includes heat build-up, sweat and suffocation. Problems related to communication were also a big issue, with many riders saying that they needed to take calls whilst riding, which led to unsafe practices or the removal of helmet. Also, the rear visibility constraints and restricted head movement were found to

contribute to the decrease in the rider confidence and situation awareness. These findings indicate that the present helmets are not taking the consumers' real life needs and behaviors into account.

In order to solve these perceived problems, the study recommended a smart helmet design that is ergonomically optimized with important features like multi-point ventilation, Bluetooth communication and rear-view camera with a front display. Careful consideration of material selection, weight distribution and internal component organization has also been taken into consideration to ensure comfort and durability in the design. The breathable and moisture-wicking inner materials are also used to further enhance the user experience and moisture-wicking inner materials reduce fatigue whenever using the product. In conclusion, this paper indicates that the user-centered and ergonomically-informed method of improving helmet design could be a significant factor shaping the behavior of the riders and safety statistics.

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