McGill University

MECH 292
Project: Conceptual design report

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Executive Summary

This report presents the conceptual design process and results for the development of a solution that aims to address motorcyclists' vulnerability on the road. The project explores innovative solutions and design methodologies to answer the clear problem statement of: “Motorcyclists are a lot more vulnerable than other road users, in particular to road defects and spatial awareness challenges”.

Key design considerations include technological feasibility, ability to be easily implemented and ability to protect motorcyclists from potential threats, amongst others that will be further explored in the report.

This report will present a house of qualities that will assess the important engineering specifications and requirements, a morphological chart and a Pugh matrix to develop and decide between design concepts for the different functions in the design project. The report will explore three different potential solutions to the problem statement, before settling on one final design.

Statement of contributions

• Lora Izambard – Project Lead and Systems Architect: Oversaw the entire design process, coordinated team meetings, and integrated inputs from all members. Responsible for defining the project objectives and ensuring the design approach met the overarching safety and performance goals.

• Pierre Arbaji – Research and Development Specialist: Led the market and technology research, developed the house of qualities, and contributed significantly to developing the morphological chart and Pugh’s Matrix.

• Issa Abood – Technical Design Engineer: Focused on translating design concepts into practical engineering solutions, developed the preliminary sketches for each concept, and ensured the technical specifications aligned with the identified hazards.

• Rashid Abusafia – Prototype and Testing Coordinator: Managed sensor integration and the bill of materials and oversaw the initial prototyping and testing phases to verify the design’s performance under real-world conditions.

• Victoria Loumaye – Documentation and Analysis Manager: Compiled the design report, ensured proper formatting and citation according to IEEE standards, and performed a detailed analysis of the final design’s ability to meet engineering requirements.

Introduction

Motorcyclists are significantly more prone to fatal accidents [1][2]. Physical road hazards they face include potholes, cracks, debris or wet spots [3], that can reduce their traction or destabilize their vehicles particularly easily due to their two-wheeled nature. Another primary challenge they face is spatial awareness. Indeed, they are often less seen in blind spots [4] which leaves them vulnerable to sudden lane changes by other drivers, leading to catastrophic collisions [5]. Without a protective frame, seatbelts or airbags, motorcyclists are more easily injured and face mortality rates more than 4 times higher than car drivers [6].

Many attempts have been made to improve road conditions for drivers, from reducing road defects to campaigns [7]. Road maintenance programs, consisting of pothole-filling and resurfacing initiatives have been implemented in many cities. However, their challenge is their high costs and the never-ending ongoing wear of the roads. Motorcyclist safety campaigns have also been attempted [8], implementing defensive driving courses, educating on helmet laws and the benefits of wearing reflective gear. While these initiatives are worthwhile, they do not solve the core issue of unanticipated hazards.

Initiatives of pothole detection technologies include City Rover [9] and various research prototypes are in development stages [10]. These are sensor-based or AI detecting devices helping municipal road crews [11]. The limitations of these current technologies are their lack of real-time notification for riders and are still reliant on slow repair cycles. Finally, there are currently other motorcycle-specific concepts such as on-bike sensors, heads-up display and AR warnings [12] [13]. These are however mostly in prototype or research phases, not commercialized.

There is thus a clear need to find a holistic, multi-pronged approach that would allow for better driver awareness, real-time hazard detection and robust rider-assist systems reducing distractions to reduce motorcyclists' vulnerability on the road. The following problem statement is considered in this report: motorcyclists are particularly more vulnerable than other road users, especially to road hazards and spatial awareness challenges.

The stakeholders of this problem are motorcyclists that will use the product, car/truck drivers that share the road with them, emergency responders that must tend to injured motorcyclists in case of a crash, municipalities in charge of the state of the road and traffic flow, engineers that will design the product and retailers that will sell it.

Engineering Requirements

As mentioned above, there is a clear need to develop a product that will accurately detect road hazards in real-time to help reduce motorcyclists' vulnerability on the road. The primary requirement would be the detection of road hazards, which must be accurate and reliable, and distinguish between the types of hazards [14]. The product will also be required to communicate these hazards in real-time with the user while creating the smallest distraction possible such that the user can stay focused on the road. Additionally, the product should be easy to integrate with existing gear or bikes and comply with road safety regulations. Affordability, low maintenance and durability also are customer requirements. These requirements, their interdependences and their associated quality characteristics are summarized in the house of quality below, figure 1.

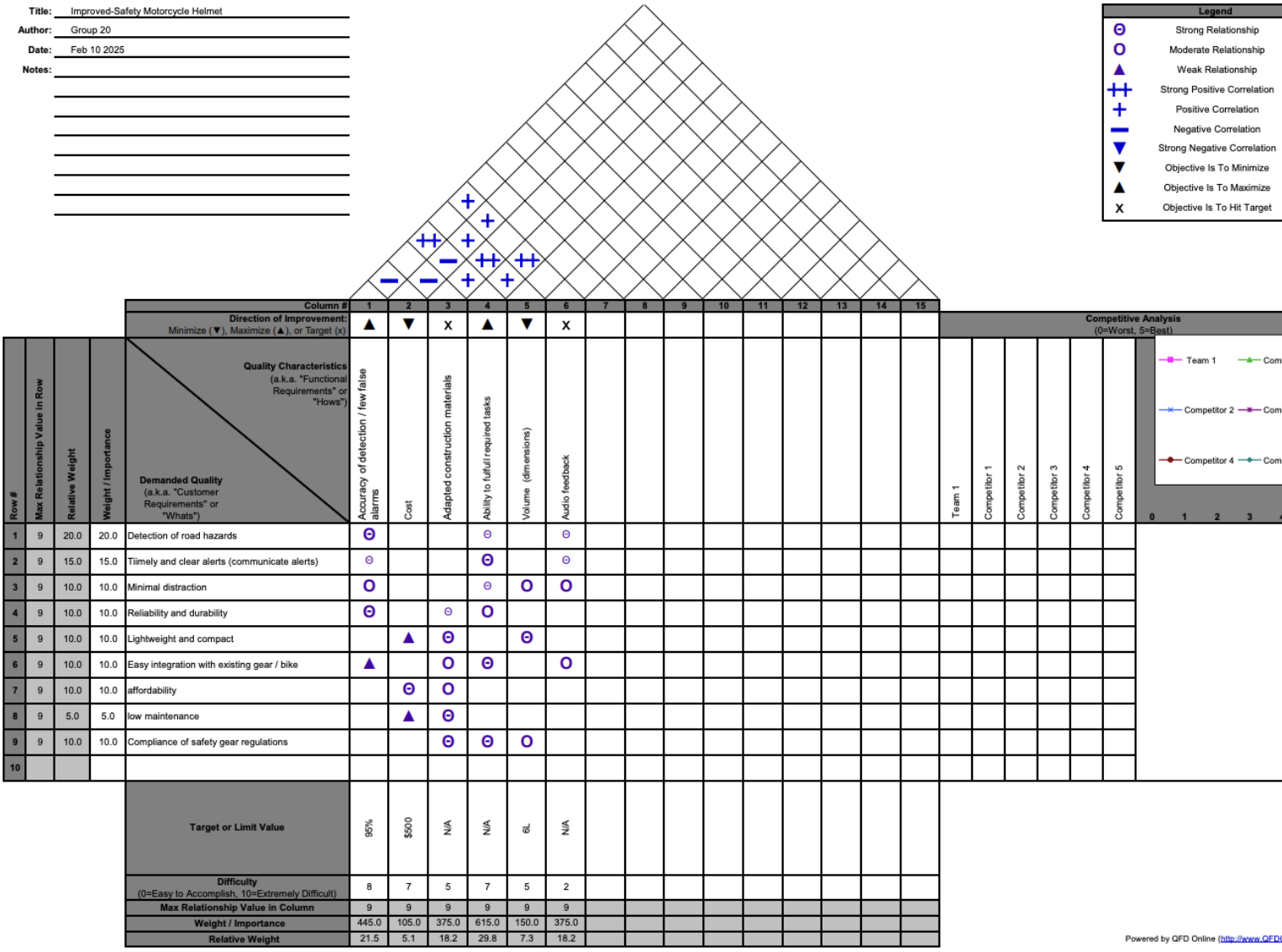

Figure 1: House of Quality

Different concepts for each of the product's desired functions were generated using a morphological chart, which can be found in Table 1 below.

Table 1: Morphological Chart

Functions	**Concepts**	

Communicate presence of hazard with driver	Visual-Augmented reality	Visual - Screen	Visual - LED lights	Audio cues
Characterize hazards	Ultra-detailed warnings with type of hazard, distance, avoidance strategy	Differentiated warning with type of hazard and position	Differentiated warning with type of hazard and side (left or right)	Undifferentiated warning between type of hazard, but side indicated
Warn driver in a timely manner	Predictive warnings, use of AI to analyze other vehicle's behaviors	Real-time detection and warning, as the vehicle moves on the road	For habitual routes, remember placement of permanent damage on road and warn driver ahead of those	
Integrate on existing gear / bike	Universal mounting brackets	Fully separate system in special gear item	Modulable mounting system / bike-based mounts	

Concepts and Evaluation

Three concepts to tackle the problem statement are outlined below. It is to be noted that all these concepts require the installation of some sensors on the bike, which would be identical for all three products, which is thus not considered when evaluating the concepts.

Concept 1: Augmented reality helmet

This first concept is a headset where the road hazards are displayed in augmented reality inside the helmet, superposed with real-life. The noteworthy features are visual warnings of the dangers present, the integrated screen in the visor and detailed warning about potholes, drivers in blind spots, etc. in real-time [12]. Figure 2 below shows a sketch of what the concept would look like.

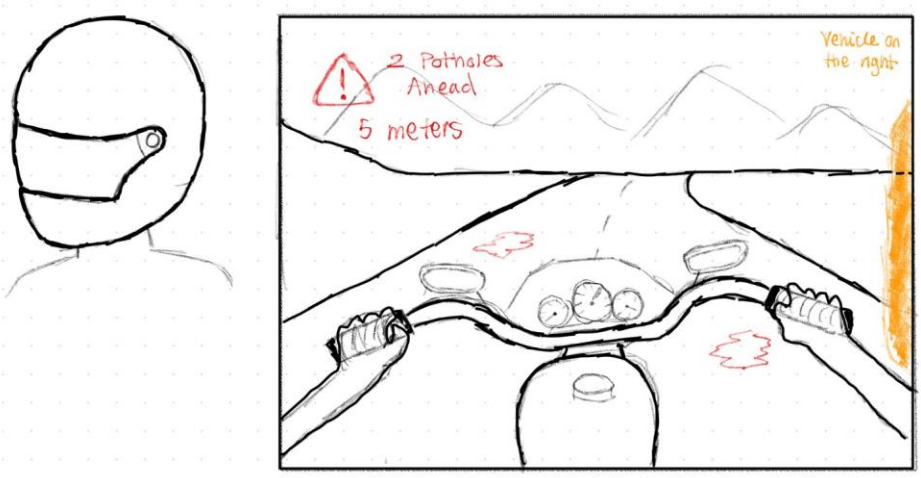

Figure 2: Augmented reality helmet concept sketch

Pros of this concept include a low level of distraction as the user doesn't need to change their gaze to see the warnings, and it would work with any bike. Cons would include the high cost for such an advanced design, and if the helmet went through a crash the entire system would have to be replaced, which would be costly. It would also be a substantially more complicated design to develop technically.

Concept 2: Dashboard screen

The second concept studied is a dashboard screen that would display the warnings. It features a screen mounted on the motorcycle dashboard, with visual cues that would communicate all hazards separately [15]. Figure 3 below shows an example of the cues for potholes.

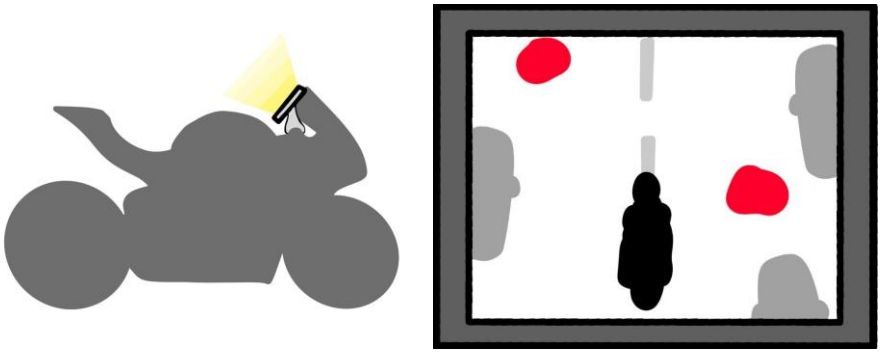

Figure 3: Dashboard screen concept

Pros for this concept are that iot clearly communicates the warning and is able to differentiate between types (ie. potholes versus lane change), and it would be cheaper and easier to develop than the AR helmet. Cons would be that it causes a high distraction, as the user needs to look down, and it would be harder to integrate on an existing bike.

Concept 3: Warning lights

The third and last concept is a couple of LED lights mounted on the bike to indicate the hazards. It features lights to indicate road hazards, one next to each mirror to indicate which side the hazard is on. There would be two colors, red for lane changes and blue to indicate road defects for example. In addition, there would be an audible beeping sound when the system lights up to make sure the user notices. Figure 4 below shows an example of the right light lightning up when a car gets closer.

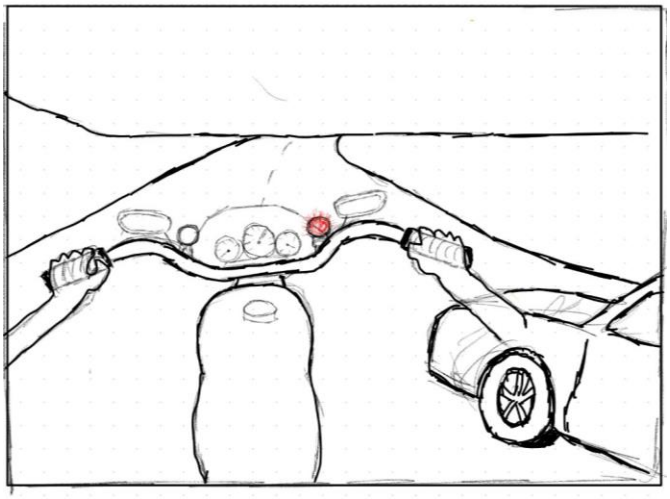

Figure 4: Warning light concept

Pros for this concept are its simplicity and affordability, as well as the low distraction since the lights are next to the mirrors, where the user already should be looking. Cons include it being unclear about the type of hazard (the user needs to learn and remember the meaning of the colors) and not differentiating between the type of road defect (eg. pothole, debris, wet spot).

Pugh Decision Matrix

The table below is a decision, or Pugh, matrix used to choose which concept to elect as the final design.

Table 2: Pugh Matrix for the three concepts mentioned above

	AR Helmet	Screen	Lights	Weight
Real-time detection	1	1	1	5
Clear communication	2	1	0	4
Specific detection of challenges	2	2	-1	3
Low distraction caused	1	0	2	3
Affordability	-2	1	2	2
Ease of integration	0	1	2	2

Technical simplicity and feasibility	-2	1	2	1
Total	16	20	18	-

The selected final concept is the second one, as it fulfills the primary requirement of clearly communicating road hazards in real-time, while offering a good balance of technical feasibility and ease of integration.

Final design

Final design presentation

After evaluating multiple concepts for an advanced motorcycle safety system, the dashboard screen has been selected as the optimal solution. This concept offers a clear and effective way for motorcyclists to receive critical safety warnings while maintaining control of their ride.

Its features include:

- Mounted display: a screen that is securely mounted on the motorcycle dashboard, providing a stable and easy-to-read interface.
- Visual hazard warnings: the system detects and categorizes road hazards, alerting riders with distinct visual cues.
- Comprehensive hazard detection: the screen identifies and differentiates between multiple threats, such as potholes, vehicles in blind spots and any other sudden obstacles, and informs the user of their position.

The advantages of this system include:

- Clear communication: the dashboard screen offers a structured display of warnings, making it easier for riders to interpret and respond quickly to threats.
- Cost-effective: compared to the helmet-integrated solutions, this concept is more affordable and does not require costly replacement when the helmet is changed.
- Durability: since the system is mounted on the motorcycle, it is more robust and less prone to wear-and-tear compared to helmet-based solutions.

While the rider must glance at the screen for alerts, the structured and well-placed design minimizes distractions. Additionally, integrating the system into various motorcycle models may require some modifications, but the advantages in safety and affordability make it a compelling option. This concept is significantly less complicated to develop, which makes it more likely that the product development could see the end, compared to more advanced concepts like the AR

helmet, of which some versions have been prototyped and given up by other companies like mentioned in the introduction.

The dashboard screen is thus the best solution for improving motorcycle safety. By offering clear visual warnings, affordability, and long-term durability, it ensures riders remain aware of their surroundings while maintaining an optimal balance between cost and effectiveness [12].

Detail description and design requirements fulfillment

The following section details the different features of the product and how they fulfil the design requirements outlined at the beginning of this report.

1) **Mounted Display:** The high-brightness, waterproof, and anti-glare LCD ensures optimal visibility in various lighting conditions, meeting the engineering requirement for clear communication, even under adverse weather. Such a screen offers versatility on what can be displayed, allowing for differentiating between the road hazards.
2) **Sensor Integration:** Including ultrasonic sensors, an IMU sensor, and a GPS module provides comprehensive real-time hazard detection. These components work simultaneously to monitor road conditions, detect nearby obstacles, and accurately map hazards, thus addressing the need for immediate and reliable alerts [16].
3) **User-Centric Interface:** The dashboard screen is designed to minimize distractions by offering a structured layout of visual cues. The warnings are presented clearly and concisely, enabling motorcyclists to quickly interpret and react to potential hazards without diverting excessive attention from the road.
4) **Robust Construction:** All electronic components are housed within a waterproof enclosure and secured by a custom mounting bracket, ensuring durability and resistance to the vibrations and environmental conditions typical of motorcycle operation.
5) **Cost-Effectiveness and Integration:** Compared to alternative solutions, such as helmet-integrated systems, this dashboard design reduces long-term costs by eliminating the need for frequent replacements and extensive modifications (a typical motorcycle helmet should be replaced every 5 years [17]). The product development would also be significantly easier, reducing the product's cost. The design easily adapts to different motorcycle models, fulfilling the integration requirements while maintaining affordability.

The final dashboard screen design offers a balanced solution that improves rider safety while meeting practical constraints and budget considerations by addressing each of the specified engineering criteria, real-time hazard detection, clarity of communication, durability, and ease of integration.

Bill of Materials

Table 3 below presents a Bill of Materials for the dashboard screen concept.

Table 3: Bill of Materials

Item	Quantity	Description

LCD display	1	High-brightness, waterproof, antiglare screen
Single board computer (SBC)	1	Computer to do the required tasks
Ultrasonic sensor	2-4	Detects nearby obstacles and hazards
IMU sensor (gyroscope/accelerometer)	1	Detects sudden movements or accidents
GPS module	1	Provides real-time location for mapping hazards
Microcontroller	1	Manages sensor data and display output
Power supply (12V to 5V converter)	1	Converts motorcycle battery voltage to power for electronics
Waterproof enclosure	1	Protects electronics from weather conditions
Mounting bracket	1 per component	Securely attaches the screen the motorcycle dashboard
Wiring and connectors	As many as needed	Cables, terminals and connectors for installation

Conclusion

In conclusion, after a thorough evaluation of multiple advanced safety concepts, the dashboard screen emerged as the most effective solution for addressing the high frequency of motorcycle incidents. This design was selected due to its clear and structured approach to communicating critical safety warnings. Unlike the more complex and cost-intensive alternatives, such as the AR helmet, the dashboard screen offers a practical balance between innovation and feasibility.

The dashboard screen is characterized by its secure, mounted display that provides motorcyclists with an easy-to-read interface. It offers real-time visual hazard warnings by detecting and categorizing various threats—from potholes and blind spots to sudden obstacles—ensuring that riders are promptly and effectively informed of potential dangers. It's clear communication strategy minimizes distractions, which is crucial for maintaining control and safety during a ride. Additionally, the system's cost-effectiveness and durability make it a robust choice that can be integrated across a wide range of motorcycle models.

Ultimately, the dashboard screen concept represents a significant advancement in motorcycle safety technology. By delivering reliable, immediate hazard detection and communication, it not only enhances rider awareness but also contributes to the overall reduction of motorcycle incidents. Moving forward, further refinements and rigorous real-world testing will be essential to optimize the system's performance, ensuring that motorcyclists benefit from improved safety and confidence on the road.

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