Collision Avoidance Systems to Improve Motorcyclist Safety

Engineering 2225

Stephen Lonergan
u5349877

Abstract

This report details the design of a motorcycle collision avoidance system, aimed to reduce the number of motorcyclist fatalities and injuries from motorcycle-car collisions. A systems engineering approach is used to break down the problem and ensure that the full functionality is planned out in detail.

The final design relies on a camera with image recognition, paired with a radar. These go in a combined module, attached to the front of the motorcycle, facing forward. The system warns the user of a possible collision, and to perform a braking maneuver when the user does not have time to react. Further information is supplied to the system via user input to a dash mounted control and information panel, and through a weather sensor. Warnings are given to the user via a helmet mounted speaker, and a dash mounted LED.

Contents

List of Figures

List of Tables

1 Introduction

Motorcycles are a convenient and cost effective form of transportation. They are cheaper to run than a car, due to their lower fuel consumption and cheaper registration costs. Due to their small size, it is often easier to find parking, because numerous motorcycles take up the same space as a single car. There are often also designated parking areas. Additionally, motorcycles often reduce overall travel time, due to their ability to pass through congested areas thanks to their ability to lane-filter[1](Federal Chamber of Automotive Industries, 2013). Because of all these benefits, the number of motorcyclists on Australian roads is growing at a faster rate than other forms of transportation (Transport for NSW, 2012). This is beneficial to all road users, as swapping cars for motorcycles reduces congestion.

There is a large drawback from this though, stemming from the high fatality rate of motorcyclists compared to all other groups of road users. This is not only an issue due to the loss of human life, but also due to the burden placed on others, for example, police and medics that respond to collisions when the resources could be used elsewhere. This report looks at the potential implementation or adaption of existing technologies to try to reduce this rate.

2 Background Information

2.1 Australian Road Fatality Rates: 2003 - 2012

Motorcycles account for 4.5% of all registered passenger vehicles in Australia, but are only used for around 0.9% of the total distance travelled (Johnston, P. et al., 2008). It would be expected by most that motorcyclists are over-represented in crash statistics, but the extent is surprising. An Australian government statistical summary on all road related fatalities showed that motorcyclists accounted for 17% of all road related fatalities while occupants of cars have averaged around 70%. When adjusting for the large difference in total distance travelled, it can be seen that motorcyclists are 20-30 times more likely to be in a fatal collision than any other passenger vehicle (Bureau of Infrastructure, Transport and Regional Economics (BITRE), 2012).

This high fatality and injury rate has been around for a long time. It was so significant that in the seventies the U.S Department of Transportation commissioned a study into why so many fatal motorcycle collisions occurred. The study, headed by H.H. Hurt Jr., titled *Motorcycle Accident Cause Factors and Identification of Countermeasures - Volume I: Technical Report* sheds a lot of light on what types of accidents occur, and why. The study has become well known, commonly being referred to as *The Hurt Report*.

2.2 The Hurt Report

One of the most important findings of the report, was that the majority of all accidents resulting in an injury or fatality aren't single vehicle - almost 75% are multiple vehicle collisions. Of these, around a third are caused by a vehicle turning across the motorcyclists line of traffic (Hough, D. L., 1981). "The two

---

[1] Lane-filtering is the act of driving between slow-moving or stationary vehicles

most common errors motorcyclists make are believing the other driver sees them and not taking any evasive action. For example, 32% of accident victims rode into a collision without doing anything." - [Ibid., 23]

Although the report is now 35 years old, the findings still hold a lot of merit. *"The more time goes by, the less things look different. Riders today have the same sort of accidents as riders in the 1970s, except that today they crash much more expensive bikes."* [Hurt, 2000 - as cited in Hough, 2000, 21]. 16 years on, and motorcyclist fatality rates have not decreased, suggesting that the data is still representative.

If 32% of motorcyclists fail to react prior to a collision, and many more have a delayed reaction that is limited in effectiveness (H.H. Hurt, Jr, 1981), then there is a window for technology to step in to reduce the chance of a collision, or to minimise the injuries in the event of one. This is done through the design of a collision avoidance system.

3 Design Scope

To determine what aspects of the design can be controlled, what need to be accounted for, and what need to be ignored, a system boundary chart was crated, as shown in table 3.1.

Table 3.1: System Boundary Chart of Internal, External and Excluded Aspects of System

Internal	External	Excluded
Condition of Motorycle (eg. tyre pressure)	Other Road Users	Motorcycle Failure (eg. tyre blowout)
Motorcycle Control Systems	Road Condition/Hazards	Rider's Characteristics (eg. Sex, Age)
Rider's Reaction[1]	Rider's Reaction[2]	
Component Cost	Weather Conditions	
Design Aesthetics	Road Lighting	
	Rider's Height & Weight	
	Traffic Conditions	

The most important factors relate to how the motorcycle will perform. Things like the rider's weight must be accounted for, because this affects braking distance and traction. The rider's height will affect the centre of gravity, altering turning characteristics.

The road surface and conditions must also be taken into account, as vehicle stopping time on a wet or gravel road is significantly increased (Layton, R.D., 1997).

The actions of other road users must be accounted for, and for the purposes of this report it is assumed a motorcyclist has no control or influence over other road users. This matches the model that in a large number of collisions, car drivers fail to see, or fail to accurately determine the speed, distance, and path of a motorcycle (de Craen, S. et al., 2011).

---

[2] Motorcyclist's actions may be influenced, but not fully controllable

4 Ideation of Collision Prevention System

Several ideas for different systems were created, split down into sensor systems, information transfer system, and active response systems. These ideas are shown in concept classification trees, in figures 4.1, 4.2, and 4.3 respectively.

4.1 Sensor System

The first system is based around sensor systems - these will attain information about the surroundings of the motorcycle, like the relative speed of objects around it, and whether or not obstructions are present. The difference between the motorcycle mounted sensors comes down to the direction the sensor/s face - one fixed facing the same direction as the front wheel will not be able to detect an obstruction along the path of travel while the motorcycle is in a turn, due to the complex dynamics of turning motorcycles, however a sensor system that were to reorient itself could still attain accurate data.

The difference between the helmet systems comes down the the number of sensors, and the data that they attain.

Additionally, there is the possibility for weather sensors, which would determine the road conditions.

As the sensors are the backbone of this system, 3 sensor types will be considered - Radar, Lidar, and camera, as well as fusions of these. This is looked at in section 9

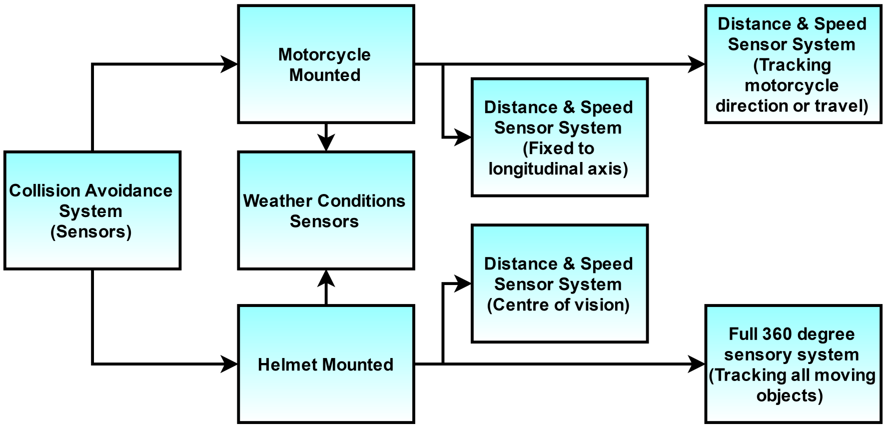


Figure 4.1: Concept Classification Tree - Sensors

4.2 Information Transfer System

The different methods of data transfer again are split between motorcycle mounted and helmet mounted. The motorcycle mounted include a dash-integrated information system, similar in design to a GPS navigator, would allow detailed information transfer, whereas light and audible transfer would be limited in the amount of data they can transfer.

Helmet mounted includes a HUD, which would be a more advanced, and potentially more extensive version of the integrated-dash system. The audible system would be more limited, however substantially easier and cheaper to implement.

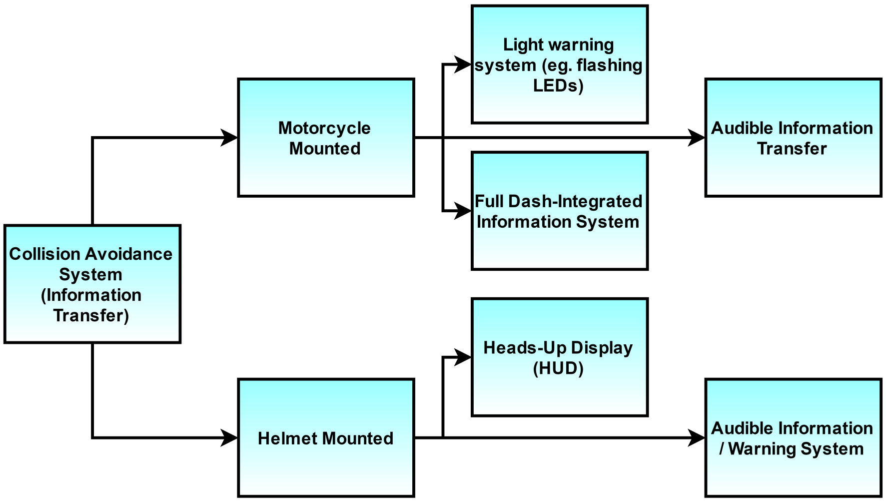


Figure 4.2: Concept Classification Tree - Information Transfer

4.3 Active Collision Prevention System

The last component of the system is intended to act as the last-possibility collision prevention, only to activate when the user no longer has time to react. It is broken down into two sections - braking and swerving. Swerving is further broken down into whether the motorcycle is turning or not. Braking is broken down slightly further, to determine the reaction while turning. The possibilities are a full braking action (which has additional risks and complexity)(Hough, D. L., 1981), or to brake a limited amount to reduce the force of the impact.

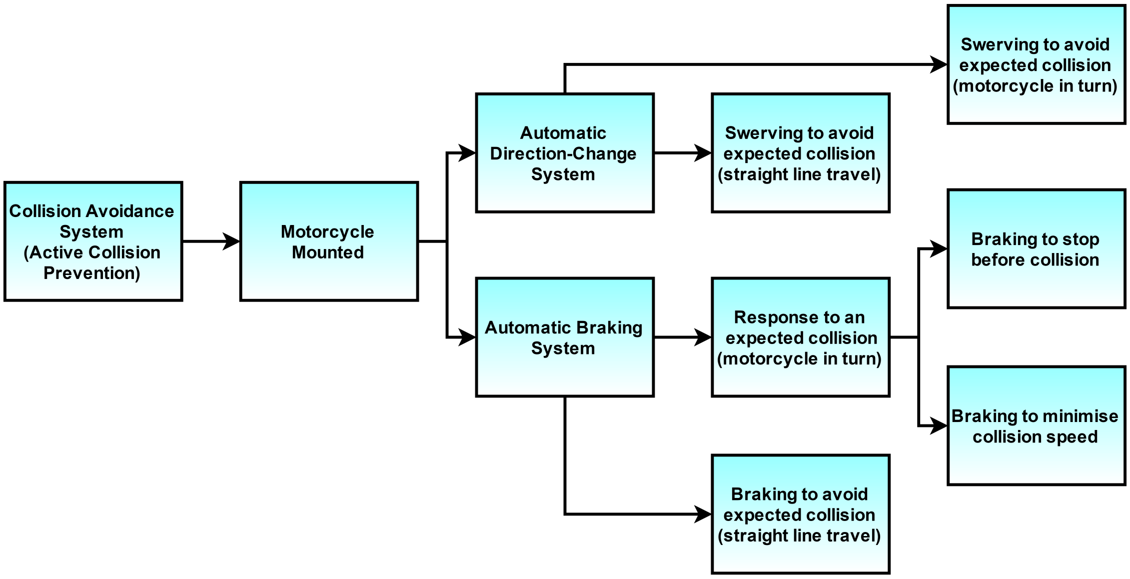


Figure 4.3: Concept Classification Tree - Active Collision Prevention

5 System Requirements from Client Input

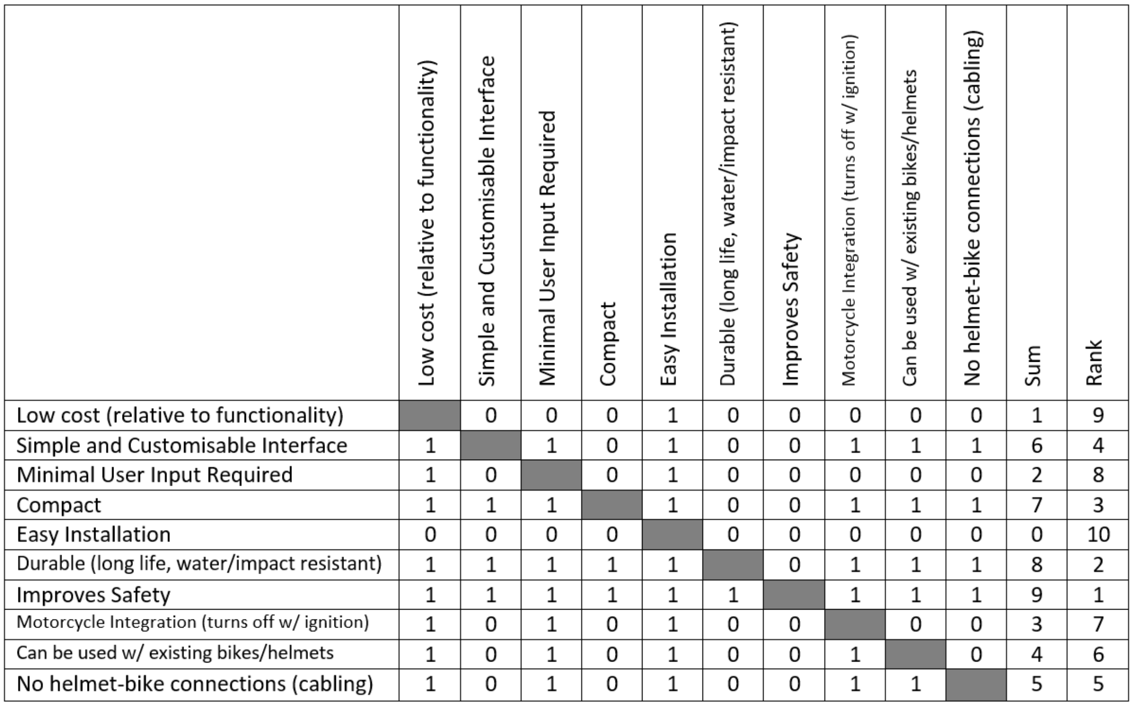
The client for this system is an average motorcycle rider, who often spends time driving in areas with many other road users. The client is willing to make an investment to improve their safety on the road.

5.1 Customer Requirements

To begin analysis of the different concepts, the client was asked what requirements they would have of the system
Their main requirements related to the functionality, shape, and installation of the system.

- Simple, easy to use interface that the can customise to their own preferences
- Doesn't require much user input, so that it is 'set & forget'.
- Easy to install, and the full system is compact, as to not largely alter the motorcycle appearance
- Will function in all weather conditions
- Can be used with existing motorcycles and helmets, so that purchase of a new one is not necessary
- Cost is low for what it is capable of, however total cost can't be too high
- No cables required to connect helmet and motorcycle, or if any, ones that won't put rider at risk

A pairwise analysis was performed on these customer requirements, to rank them in terms of importance. This may be seen in figure 5.1.



	Low cost (relative to functionality)	Simple and Customisable Interface	Minimal User Input Required	Compact	Easy Installation	Durable (long life, water/impact resistant)	Improves Safety	Motorcycle Integration (turns off w/ ignition)	Can be used w/ existing bikes/helmets	No helmet-bike connections (cabling)	Sum	Rank
Low cost (relative to functionality)		0	0	0	1	0	0	0	0	0	1	9
Simple and Customisable Interface	1		1	0	1	0	0	1	1	1	6	4
Minimal User Input Required	1	0		0	1	0	0	0	0	0	2	8
Compact	1	1	1		1	0	0	1	1	1	7	3
Easy Installation	0	0	0	0		0	0	0	0	0	0	10
Durable (long life, water/impact resistant)	1	1	1	1	1		0	1	1	1	8	2
Improves Safety	1	1	1	1	1	1		1	1	1	9	1
Motorcycle Integration (turns off w/ ignition)	1	0	1	0	1	0	0		0	0	3	7
Can be used w/ existing bikes/helmets	1	0	1	0	1	0	0	1		0	4	6
No helmet-bike connections (cabling)	1	0	1	0	1	0	0	1	1		5	5

Figure 5.1: Pairwise Analysis of Customer Requirements

The more important requirements tended towards functionality and durability, and not largely altering the aesthetics of their motorcycle. Things that take up time, like installation time, were less important as they are a one off thing.

It can be seen that the most important of these is improved safety - this is logical, as this is the main intended purpose. The next most important are the durability of the design, how compact the design is, and having a simple & customisable user interface.

Of note, is that although low cost did not rank very highly, numerous other requirements impact this indirectly. For example, an increased durability increases the lifetime, decreasing the possibility of needing to purchase a new system.

5.2 Design Requirements

From the above customer requirements, a set of design requirements were created and metrics for each of these were determined. These are shown in table 5.1. The customer requirements have been ordered by the rankings determined in the pairwise analysis.

These metrics allow a quantitative analysis of the designs to be completed at a later stage.

Table 5.1: Technical Performance Measures of System from Customer Requirements

Customer Requirement	**Design Requirement**	**Metric**	**Direction**
(1) Improves Safety	Reaction Time	s	↓
	Braking Distance	m	↓
	Collisions	#	↓
	Percent Potential Collisions Detected	#	↑
(2) Durable	Component Lifetime	Years	↑
	Water Resistance	IP Rating	↑
(3) Compact	Physical Size (Volume, Dimensions)	m^3, m	↓ , ↓
(4) Simple & Customisable Interface	Number of Configurable Settings	#	↑
	Time Taken to Understand Data	s	↓
(5) No helmet-bike connections (cabling)	Number of Connections Required	#	↓
	Wired Connections Count (non-wireless)	#	↓
(6) Can be used w/ existing bikes/helmets	Modifications Required to Install	#	↓
(7) Motorcycle Integration	Systems not Integrating w/ Motorcycle	#	↓
(8) Minimal User Input Required	Number of Steps to Make Function	#	↓
	Initial User Information Required	#	↓
(9) Low cost	Lifetime cost per year	$	↓
(10) Easy Installation	Installation Time	Hours	↓

6 Analysis of Intended System Operation

To better describe how the system as a whole will work, a logical flow diagram was created. This shows a standard motorcycle trip with the collision avoidance system installed. It is shown in figure 6.1.

Several of the customer requirements were taken into account when creating this diagram, setting specific design pathways. Requirement (7) is incorporated by ensuring that the collision avoidance systems turns on when the motorcycle does. To account for (5), the user does not need to connect cabling from the motorcycle to their helmet, as all connections are wireless.

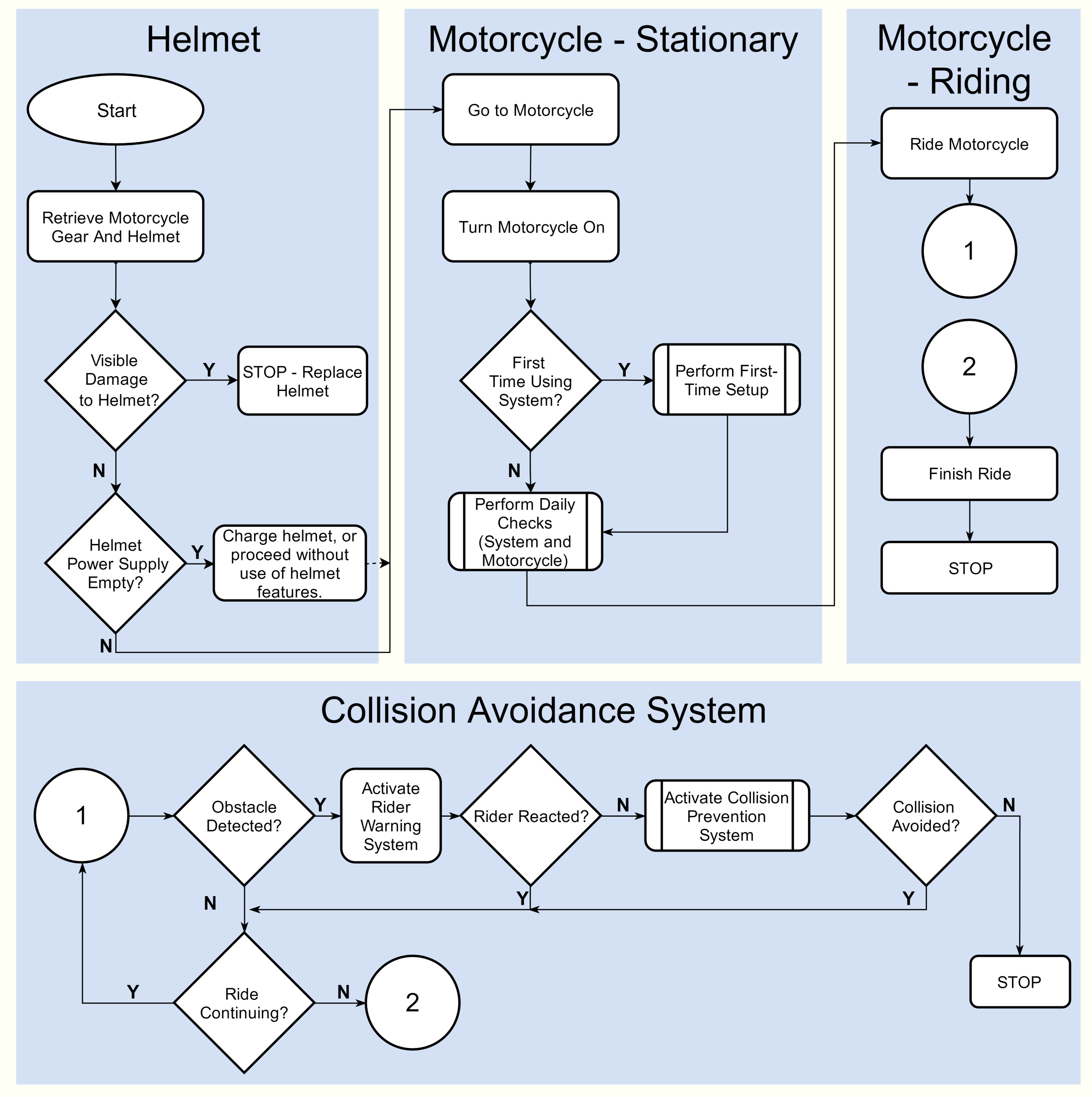


Figure 6.1: Logical Flow of General Daily Operation of Motorcycle with System

As can be seen, there are 3 complex functions in the diagram, relating to setup, checks, and the function of the collision prevention system. The specific functionality of the system is detailed later, in section 9. Details of daily checks is shown in section D. The first time set-up is simply data input of rider and motorcycle characteristics.

The collision avoidance system is running on an infinite loop while the motorcycle is running. The rate of this is determined by the pulse of the specific sensors chosen, ideally occurring many times per second.

7 Preliminary Analysis of Ideas Based on Customer Requirements

With the customer and design requirements established, the feasibility of ideas generated in section 4 was able to be determined. These are split into two sections - sensors & information transfer, and the active collision prevention systems.

7.1 Feasibility of Sensors and Information Transfer Ideas

The different designs were compared with the customer two main customer requirements - Improves safety (High Functionality), and Durability. This was done by placing these on two perpendicular axes, and determining where each idea sat along them. Figure 7.1 shows this. Blocks marked in green relate to information transfer ideas, and those in red are for sensors. Darker colours refer to systems placed on the motorcycle, while the lighter refer to those on the helmet. The idea position for the ideas to fall is in the upper right hand portion. It evidently be seen that several ideas fall outside this section.

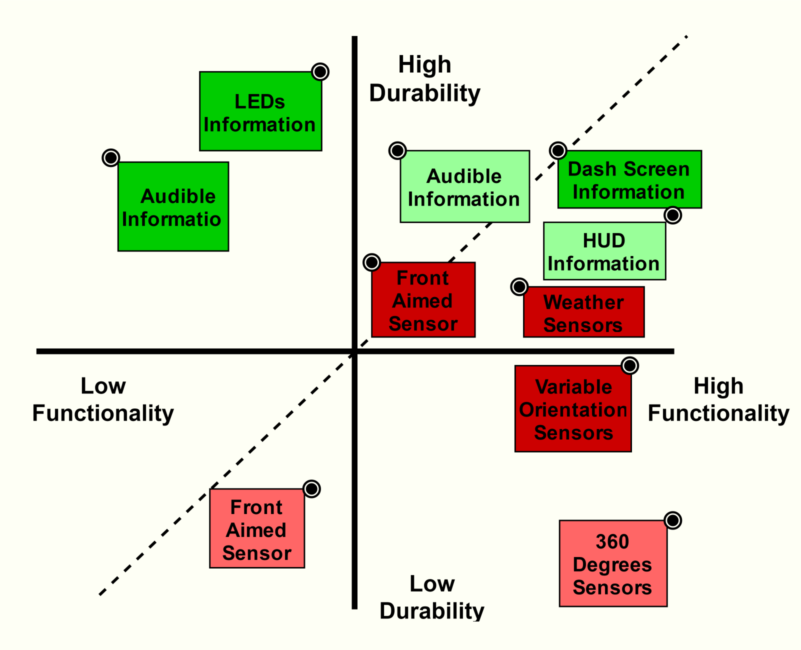


Figure 7.1: Durability vs. Functionality for Sensor & Information Transfer Ideas

The first two are the helmet based sensors. The durability is due to the high rate of replacement for helmets. Manufacturers often recommend that helmets be replaced every 2-4 years, or whenever a substantial impact occurs (Helmet Check, 2015). Additionally, having a very large number of sensors increases the chances of failure of one, and maintenance work on a helmet is not advisable. This removes these from consideration.

The audible information transfer is limited in its effectiveness, as it would need to be very loud for the rider to hear it at high speeds. The LED information lights are kept in consideration due to their very high durability, and the ease of integration and use - most motorcycles already use warning lights, so the inclusion of this would be simple and cost effective.

7.2 Feasibility of Active Collision Prevention Ideas

The above procedure was also completed for the active collision prevention ideas. These used a different set of axes, as this is what utilises the above sensors, and as such will not have a separate durability. The axes selected were Injury Reduction Potential (IRP), which is a measure of how likely it is to avoid a collision, taking into account the nature of such collisions (straight line generally suggests a higher speed), and the associated risk with performing these maneuvers.

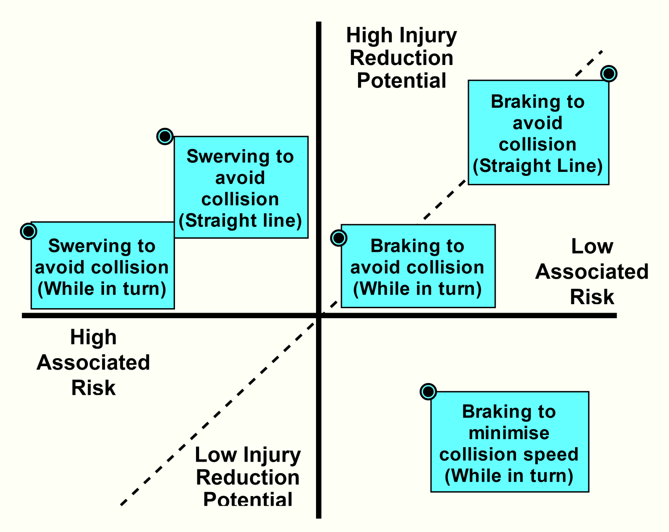


Figure 7.2: Injury Reduction Potential vs. Associated Risk for Active Prevention Ideas

Straight line braking performed better than all other methods, due to the simplicity of it, and its ability to completely prevent a high-speed collision. Braking while in a turn has a slightly lower IRP, due to the lower speeds. The associated risk is higher, as braking in a turn can cause the motorcycle to lose stability, and potentially slide off the road, or into oncoming traffic. Braking to minimise speed while in a turn does not have as large an associated risk, however, the chance of preventing a collision is much lower.

Swerving has larger associated risk as swerving to avoid a car would require the motorcycle to leave its lane, however, in certain circumstances it has been shown to be as effective as braking (Shuman, K.F. et al., 2012). This could be less hazardous on multi-lane highways while travelling straight forward, however a single lane while turning has very large associated risk. To successfully perform a swerving maneuver on a multi-lane road, the system would need a full map of position and speed of all objects around the motorcycle, and would need to very accurately account for the turning dynamics of the motorcycle.

This maneuver would significantly increase the complexity of the system, with little performance gain over braking. Due to this, swerving is removed from consideration.

7.3 Cost Of HUD

Helmets with working HUD's are only now beginning to enter the market, for example, the Skully AR-1 helmet released in 2015 (Gruber, B., 2015). The price of this helmet is 1500USD. Assuming that the additional complexity of the design would result in a price higher than this, it is likely that the benefit of added functionality over a dash-information system would not be enough to justify the substantially increased cost. Due to this, the helmet with an HUD will not be considered further.

8 Interactions Between Subsystems

To detail how the individual components of the system will interact with each other, a subsystem interface map was created. This is shown in figure 8.1.

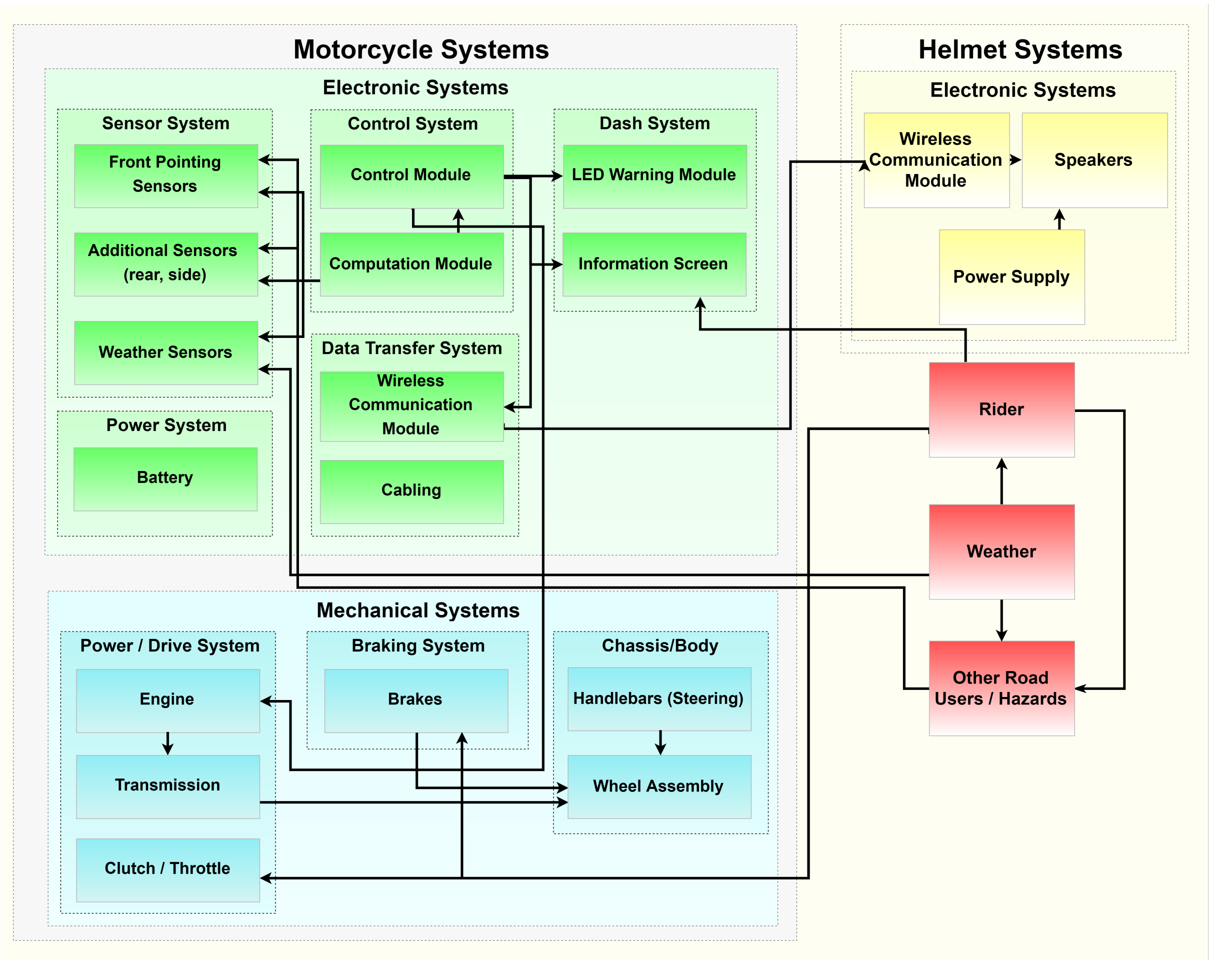


Figure 8.1: Subsystem Interface of Motorcycle and Collision Prevention Systems Combined

Only the electronic systems are included in the design boundary, however the mechanical systems of the motorcycle have been included due to the large number of connections and components. These are necessary to allow the system to fully function.

The connections shown in this diagram are important when determining the exact functionality of the system - information passing from the sensors to both the rider and other systems often passes through numerous other components and subsystems, and as such the processing time could be quite large. This may result in a large delay between sensing and object, and when the system can react to it. Given that a short delay could be the difference between stopping in time or not, it is very important to take these into account. This relates mainly to the type of testing required, and the types of sensors that may be used.

9 Design Refinement and Testing

9.1 Information Transfer System

As previously detailed, the remaining systems for information transfer are a speaker system in the helmet, and motorcycles mounted dash-screen and an LED warning module.

9.1.1 Helmet Speaker System

This is a simple system that may mostly be created with currently manufactured products. The system only requires a small wireless speaker with internal power supply.
As bluetooth speaker systems are often used in cars, and additionally for motorcyclists to communicate with each other while riding, this would be the most effective method.

Functionality of the system has two stages. The first is when the rider still has time to react to the obstruction, the speaker will emit a loud rapidly pulsing noise. Once the user has no more time to react, and the collision prevention system activates, the noise stops pulsing. The noise will stop once the motorcycle has come to a stop.

9.1.2 LED Warning Lights

This is the simplest component of the system - It follows the same pattern as the helmet speaker system - a bright rapidly pulsing light when the user still has time to react, which stops pulsing and stays switched on when the collision prevention system has activated.
The main purpose for this system is as a fail-safe for the audible system.

9.1.3 Dash Information Screen

The main purpose for the data screen is to allow configuration of the device. The user is able to input data to it, like the model of motorcycle, whether ABS is present, rider height, weight, etc.
Cost and dimensions of this module are minimal - small sized fully water and impact proof mobile phones are marketed for low prices, so producing one based off a currently available design is not complex, or expensive.
The information screen will also have a testing button, which will perform a test of the system to ensure all sensors and information transmission is working as expected. This reduces the required daily user input to a single step, which meets customer requirement (8).

9.1.4 Information Transfer System Testing

Testing of this system is requires human testing, to determine the speed at which a standard person can react to either an audible warning, or a warning light turning on that is directly in the centre of their view. The procedure for this is simple. The test subjects will be put in a computer simulated riding environment. The warning system will activate, and the screen will show a certain hazard. The time that it takes for a user to react by either braking or swerving is recorded.
After many repetitions, this is noted, and a standard reaction time value is taken (this time will be greater than around 99% of tested reaction times). This value is used for testing of the active collision prevention system, to determine when the rider should be alerted of a hazard.

9.2 Sensor Selection

As detailed previously, there are 3 main technologies that will be considered for object detection sensors - Radar(R), Lidar(L), and Camera(C). Information about their pros and cons may be found in appendix B. There are several key points from this section. Radar and lidar are both good sensors, however, they both exhibit a reasonable amount of noise in built-up areas. Lidar is still a reasonably new technology which is still decreasing in size and cost, however the functionality is equal or worse than radar. Camera image recognition on its own is not adequate to accurately determine speed and distance, and is subject to poor results in poor weather and lighting conditions. The data from this was compared with the relevant design requirements from table 5.1. The resulting evaluation matrix is seen in table 9.1.

Table 9.1: Weighted Evaluation Matrix of Different Sonar Technologies & Their Fusions

			R		**L**		**C**		**R+C**		**L+C**		**R+L+C**	
Design Requirement	Importance	Benchmark	S	I×R	S	I×R	S	I×R	S	I×R	S	I×R	S	I×R
Percent Potential Collisions Detected	5	3+	3	15	3	15	1	5	5	25	5	25	5	25
Component Lifetime	4	3+	4	16	4	16	5	20	4	16	4	16	3	12
Physical Size (Volume, Dimensions)	3	3+	5	15	5	15	5	15	4	12	3	9	2	6
Lifetime cost per year	2	3+	5	10	4	8	5	10	4	8	3	6	2	4
Installation Time	1	3+	4	4	3	3	5	5	4	4	3	3	3	3
Total			60		57		55		**65**		59		50	

It is evident that the radar and camera fusion performed best in this analysis, and as such, the Lidar-Camera Fusion is the sensor selection going forwards.

The outcome of this was due to Lidar being relatively new, so a module that meets the needs of this system is still large, expensive, and the reliability has not yet been shown. The camera technology is small and inexpensive, allowing it to be easily integrated, without much change to the other design requirements.

9.2.1 Sensor System Testing

The sensor system testing would be a staged process.

The first stage has the sensor unit on a fixed platform, repeated at different heights and angles to mimic different motorcycles and mounting positions.

The test will run to see if the sensor unit can pick up all objects that act as potential hazards, and record the time taken between noting that an object is a potential hazard, and when it becomes a likely collision. This will give information on whether the system can actually acquire data fast enough and accurately enough to enable the warning system and collision prevention system to activate.

If these are successful, the next stage would be attaching the sensor module to a test motorcycle, to determine if the speed that the unit is moving causes any additional complications. The motorcycle would be simply be a stock standard motorcycle, to minimise variables. Depending on how the results appear - if mounting position or angle cause any issues - the process may be repeated on different models of motorcycle.

The ideal sensing results, and the corresponding system states are shown in 9.1.

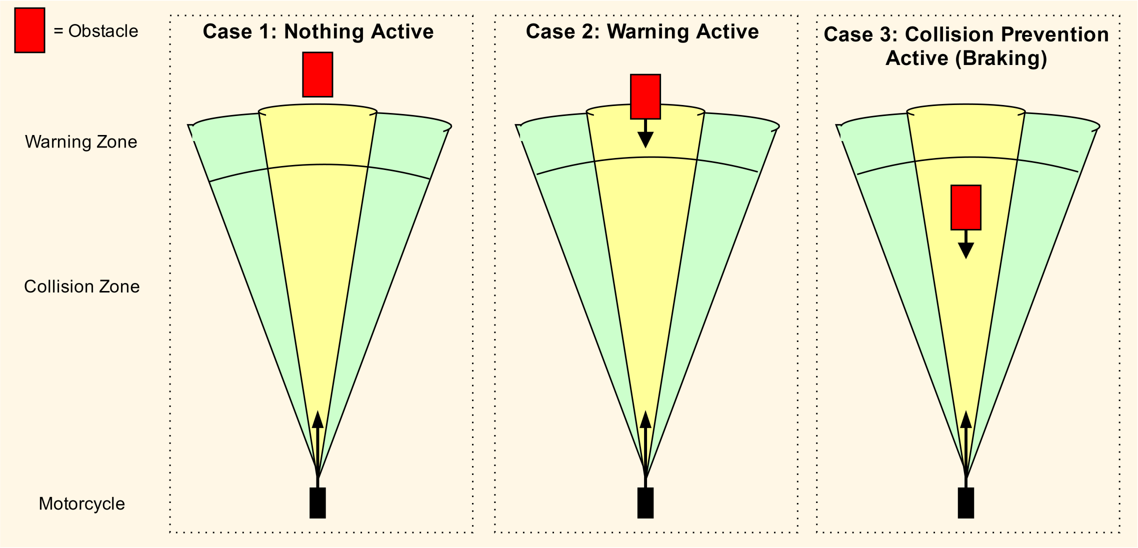


Figure 9.1: Function of System - Radar Field of View (FOV) in Yellow, Camera FOV in Green

9.3 Full System

The full system becomes a combination of the sensors, information transfer modules, and the control system.

The control system, will receive the inputs from the user, from the sensors, and if a collision is inevitable, it will activate the brakes to their full potential, in a controlled manner. An example of a possible collision is seen in figure C.1 on page 20. And additional function of this, is that if the user makes a conscious motion of swerving or increasing throttle, the system will deactivate, and give full control back to the rider. The testing for this is detailed in section 9.3.2.

The additional user inputs required are rider weight, height, motorcycle model, if ABS is present, and whether the system will activate the collision prevention system, or just the warning system. Additional options are possible, however, they are not fully required for the functionality of the system, so are not detailed. These would add to customer requirement (4). The weather sensor will give information about temperature and whether or not the road surface is wet / icy.

9.3.1 Full System Testing - Time Delay

The first stage of testing is very simple. A prototype of the control system, information and sensor systems would be put together, to determine the time taken for a warning to activate after the actual event occurred. This would be done by having the system stationary (with a manual input saying it is travelling at certain speeds, and braking distance will be a certain distance), and then moving an obstacle towards the system, so that the collision warning system will activate, followed by the collision prevention system. The time between the sensor readings that triggered the warning / prevention systems and the time they actually activated will be noted. This will be tested for numerous different input speeds and object distances, to establish a relationship between the system response time and the system input conditions. This will ultimately give a full understanding of how the system will be able to react.

9.3.2 Full System Testing - Braking System

The final section requires building up a database of information for how long different motorcycles take to stop under different conditions - wet road, turning, heavier rider, higher centre of mass, etc.). This would be done in a controlled environment, with riders testing motorcycles in the different conditions find a direct relationship between the parameters and stopping distances.

This data, paired with the data from section 9.3.1 will allow the control system to accurately calculate when it needs to activate the collision prevention system, and how it should activate it when the motorcycle is turning. A top down view of the functionality of the system is shown in figure 9.1.

10 Design Mock-Up

An example of the positioning and size of the module may be seen in figures 10.1 and 10.2.

The module (in green) may be seen on the front on the motorcycle, underneath the headlight section.

11 Reflection of Process

11.1 Benefits of Threshold Concept Process

The individual threshold concept tasks fully summarised the design process. This was beneficial, as although the topic was able to be changed, it ensured that a process was followed. The ability to change the topic allowed it to be gradually refined as further analysis was performed. For this portfolio, the topic was not fully changed, and the general concept of improved motorcyclist safety remained constant. Some of the content produced in the threshold concepts was able to be used, some was able to be adapted, and some was of no use. An example of this is seen in appendix D. This logical flow focuses mainly on improving maintenance procedures, however, it applies directly to the daily checks of collision avoidance

Figure 10.1: Design Mock-up - Front on View (Sensor Module Below Headlights)

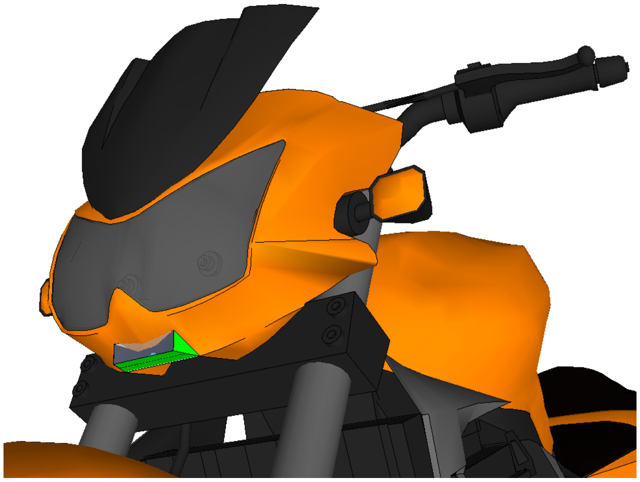


Figure 10.2: Design Mock-up - Bottom View - Motorcycle Model from SketchUp User 'Mandun'

system, which are unaltered with the inclusion of the system.

A slight fallback of the threshold concepts was not requiring substantial evidence or justification for each individual submission, but requiring a large list of citations at the end. This could have been better done by requiring citations in each relevant sections, for example, in the idea generation section.

Another slight fallback of these was that they were very 'figure-heavy', and producing a good quality figure is not a fast process. This greatly increased to time taken to finish each task, with it vastly exceeding the expected time. Due to this, the threshold concepts took time away from focussing on the stand-alone portfolio. A better connection between the two, a simplification of the requirements for each task, or a shift from figures to theory, would have greatly improved the process.

11.2 Peer Review Process

The value of the peer review process varied depending on the state of portfolio. For uncompleted ones, it was easier to give feedback towards new ideas and concepts to consider, but many sections lacked clarity or focus, so noting down these proved less valuable. For a nearly completed one, it was challenging to give new or different ideas of value, because the writers had often thought about it thoroughly, and incorporating new ideas at that stage would be very challenging.

This difference means that some writers would be lacking in their feedback in certain sections - having someone else read through to check the clarity is very beneficial, as the writer might deem it clear because of how familiar they are with the problem. If an uncompleted portfolio receives a peer review that can't focus on the clarity and flow, then they might not have another opportunity at a later stage to receive feedback on this.

A multi-stage peer review process would likely improve overall quality of portfolios - An initial one early on that focusses on the ideas that the writer has, and a later one that focuses on the clarity and flow.

The most useful feedback from the peer review for this portfolio was related to the clarity of different sections. For example, figure 6.1 had 3 complex functions, but only one had been detailed fully. This left the reviewer unsure of the exact details of the functions. This was then accounted for, which improves the clarity in that section.

Feedback from tutors was also beneficial, as they had experience with the process of creating a portfolio. This aided greatly in the formatting and structure of the portfolio.

12 Conclusion

This design for a collision avoidance system will potentially prevent a large number of motorcycle accidents, or reduce the impact force of them. This will minimise the over all motorcycle related fatalities and injuries.

To reach a final design, a systems engineering approach of analysis was used.

With a target functionality in mind, the problem was scoped out, by creating a system boundary chart of a motorcycle and other road related systems. This assisted in defining what could be changed, and also showed what the system needed to account for. This showed that the majority of things that a motorcyclist interacts with are out of its control, suggesting that the system needs to account for a large amount of variables.

Different potential ideas for systems and their functionality were then generated, and shown to the client to determine their requirements of such a system. These requirements largely focussed on increasing personal safety, but also showing desire for a simple system with good functionality. These requirements were then turned into specific design requirements, which allowed a comparison of each designs in the following sections.

The basic function of the system was then defined, to enable the refinement and removal of ideas. This determined that the system would only allow automatic braking to avoid a collision, and that information transmission would rely on simple technology, like bluetooth speakers.

With the system functionality defined, the interactions between different modules was described. This gave information for required testing, as it showed the large number of different systems that were connected, and that timing delays for the transmission of information between them could be hazardous.

The final design features an object sensing module, made up of a camera with image recognition technology, and a radar, that feed in to a control module. The control module also relies on user input about the physical characteristics of the motorcycle and themselves. Lastly, it relies on data from a weather sensor. The system sends a warning to the user via a flashing LED on the motorcycle dash, and via a wireless bluetooth earpiece in their helmet when a potential collision is detected that the user is able to react to. Once the user is no longer able to react, the autonomous braking system activates, bringing the motorcycle to a stop.

Further testing is required on the timing of different system components, rider reaction times, as well as data collection of different motorcycle systems, to ensure it will function on a large variety of motorcycles to its intended capabilities.

A Stakeholders for a System that Improves Motorcyclist Safety

Two Stakeholder Mud-Maps were generated to give insight into the problem space. These assisted in the selection of a relevant client, and additionally gave insight into the system boundary chart in section 3.

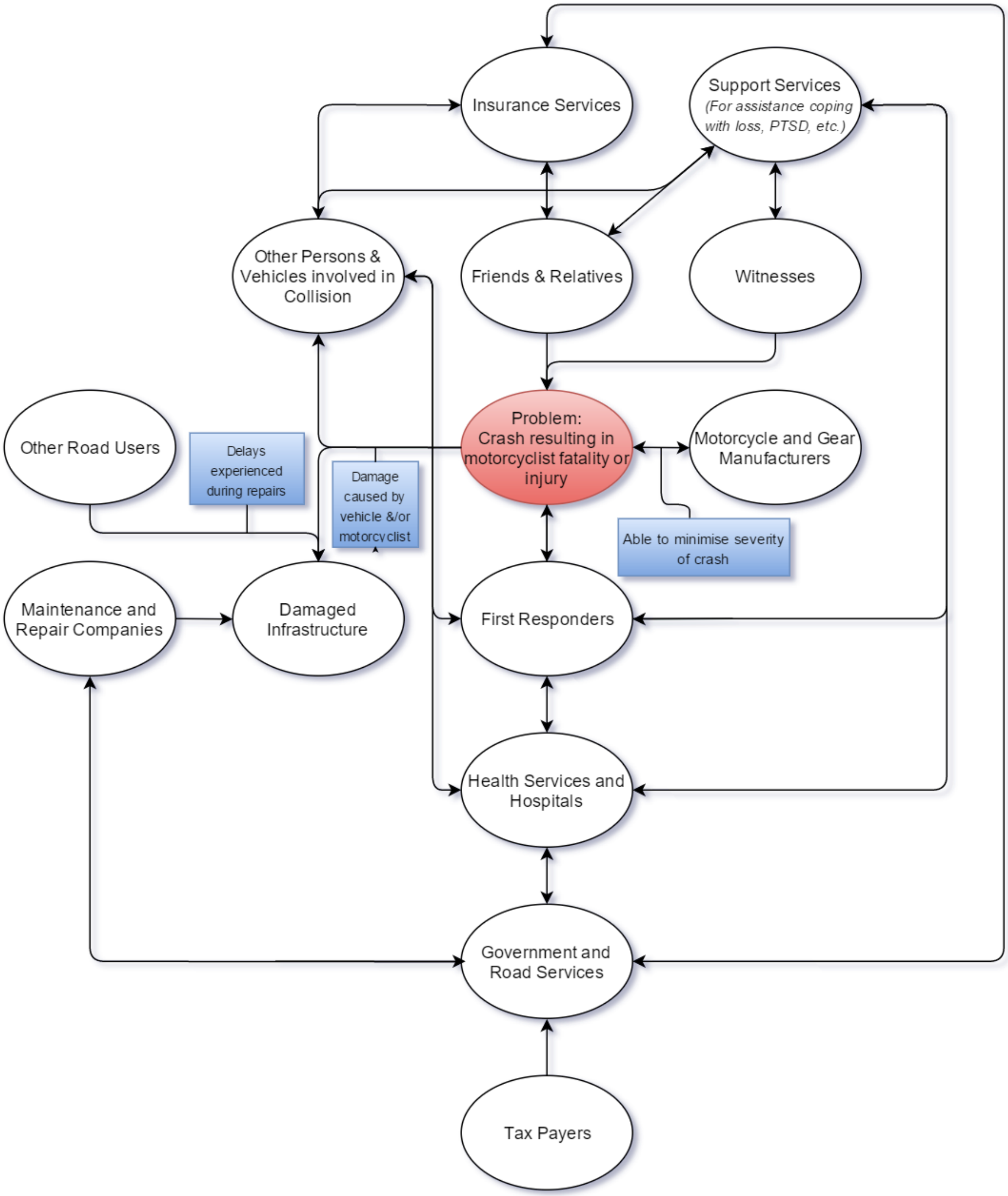


Figure A.1: Stakeholder Analysis Mud-Map around a Crash Involving a Motorcycle

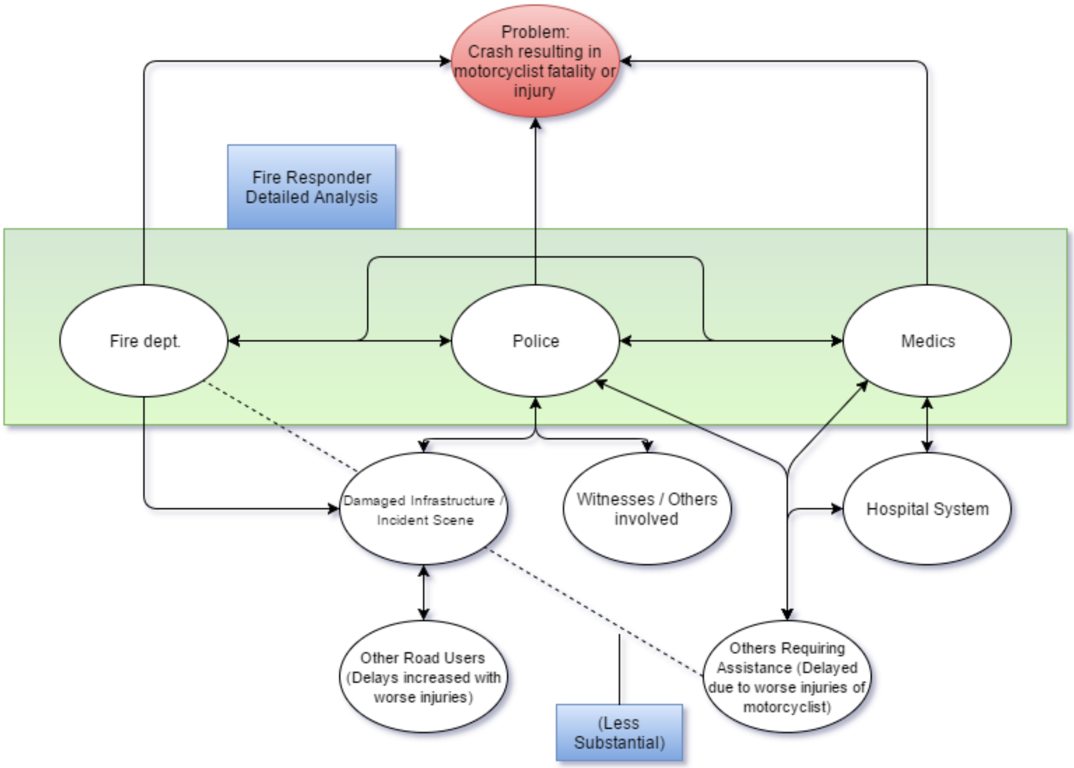


Figure A.2: In-Depth Mud-Map Around First Responders

B Details on the Different Sensor Technologies

B.1 Radar

Radar functions by sending a radio wave from a transmitter. If there is an object in the path of the radio waves, it will reflect a part of this radio wave, which will be picked up by a receiver. The receiver calculates the time taken for the wave to reach it after the pulse was sent to determine the distance. The receiver is also able to measure the angle the reflected wave is coming from, so the position may be detected. (Ridenour, L. N., 1947) Lastly, and possible the greatest benefit of radar is that they can take advantage of the Doppler effect.

The Doppler effect is observed when a wave is generated by, or reflected off a target that is moving relative to a point of measurement. If the object is moving towards the point of measurement, the frequency that they are received at will be greater than the frequency they were generated/reflected at. The opposite happens if the object is moving away from the point of measurement. This difference in frequency is measurable, and as such the relative speed of the object may be calculated (Ridenour, L. N., 1947).

This means radar would be very beneficial for a collision avoidance system, as it has very high accuracy, and only requires a single pulse to determine distance, position, and relative velocity.

The largest fallbacks of radar are the narrow field of view, and the potential for noise.

Unless there were numerous radar modules, or the modules were to perform a scanning motion, it would only be able to detect objects currently blocking the path motorcycle is travelling. This has potential to

improve motorcyclist safety, however, a better solution would be for the system to also predict if an object is about to cross the motorcycles path. Radar could may be capable of this, however further testing is required.
The second fallback is due to noisy signals - in built up areas, there will be many reflected signals, which could cause false readings, or to miss an object altogether. This is not so much of an issue just for a radar facing a single direction with a range of under around 200 metres (Fung, D., Lawson, T., 2015). But if scanning or angled radars were included, this potential for noise is significantly increased.

B.2 Lidar

Lidar operates similar to radar, with the main difference being it transmits light in the infrared spectrum, with a wavelength just longer than visible light. Current small-scale technology for lidars is very expensive, but is able to perform equally as well as radar in certain instances (Widmann, G. et al., 2000). For an affordable module small enough to fit on a motorcycle, the effective range is very short, less than 20 metres (Fung, D., Lawson, T., 2015). This substantially limits the effectiveness of the device for high speed collisions, as braking time would not be sufficient.

Lidar would still have a potential use by placing them directed to the sides of a motorcycle, to warn the rider if a vehicle following the same direction of travel is moving towards it. However, this is not a large cause of accidents, as detailed in section 2.

Lidar technology is predicted to improve substantially in the coming few years, with the price falling far enough to be used by many vehicle production companies (Berman, B., 2015). However, at this stage, it is safer to use a system that is known to work.

B.3 Camera

The camera technology would rely entirely on software to perform image recognition. This would enable classification of certain objects, to aid the processing of data from lidar or radar.
The benefit of being able to classify the types of objects that are observed comes mainly from being able to predict expected behaviour of the object. For example, radar will return a smaller readying from a pedestrian, because they are a smaller than a vehicle. Image recognition would be able to determine that it is a pedestrian, and weigh up the relative risk. Additionally, if it were able to recognise the side profile of a vehicle, it would be able to determine relative motion between different data samples, to determine if it will cross the motorcycles path of travel. The data from either the radar or lidar will determine the distance, and enable the control subsystem to determine the best course of action.

A potential issue with the image recognition is the time taken to process the data, and in heavy fog , rain, or dark conditions, images may be distorted or poor quality, decreasing the accuracy of the image recognition.

B.4 Fusion

Fusions of these systems have been tested and proved to work quite effectively in a built up environment to create a a full map of what is happening in front of a vehicle (Vu et al., 2014). The lidar is the least beneficial of the three, when they're all put together. Taking this into account, as well as the large cost of the module, and that the radar has similar or better performance, removes it from consideration.

This leaves a fusion of the camera and radar technologies. This is the selected system to use.
Radars and camera systems that are already on the market would be used to reduce cost. An example module is marketed by Delphi - an integrated radar and camera system. It has dimensions of 123mm × 68mm × 38mm. This is a small and compact size, allowing it to meet customer requirement (3) corresponding decreased physical dimensions design requirement. Although this specific module is not suitable for motorcycles, the important note is that the radar and camera system may be contained in a housing of this size.
By having a custom designed housing and mounting system, user requirements (2), (6), and (10) may be met.

C Example Situation Mock-up

Figure C.1 shows an example mock-up of a motorcycle detecting a car in it's path of travel.

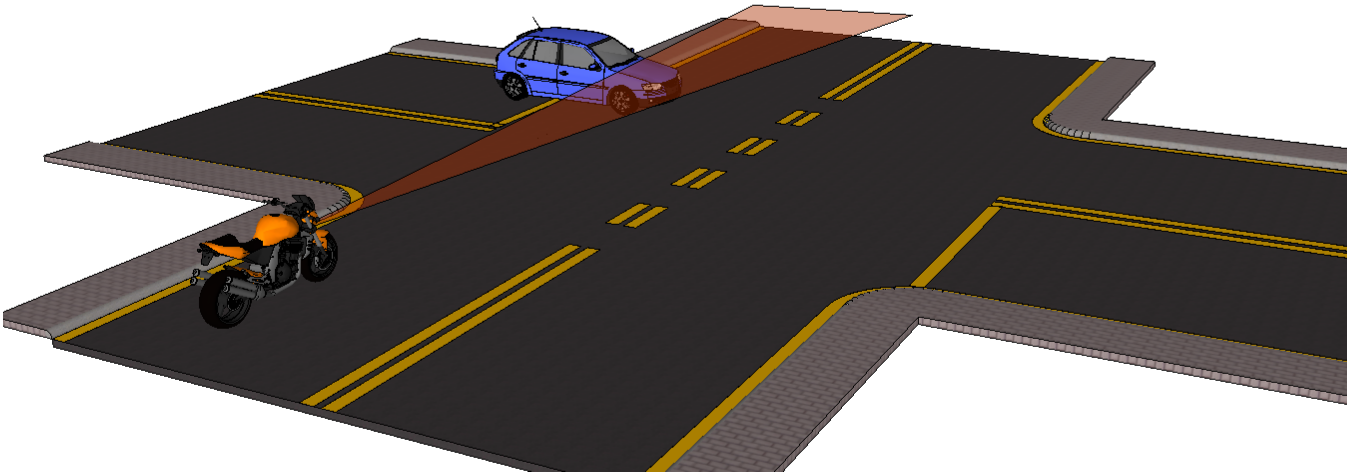


Figure C.1: Example of a Possible Collision Sensed by System - Models from SketchUp 3D Warehouse

D Example of Daily Motorcycle Checks for Motorcycle

Two Logical-Flow Diagrams were generated to show a typical daily road-worthiness check of a motorcycle Wilson, H. (1997), these are seen in figure D.1 on page 21 and D.2 on page 22.
The block in red in figure D.2 shows the section that will test the systems functionality.

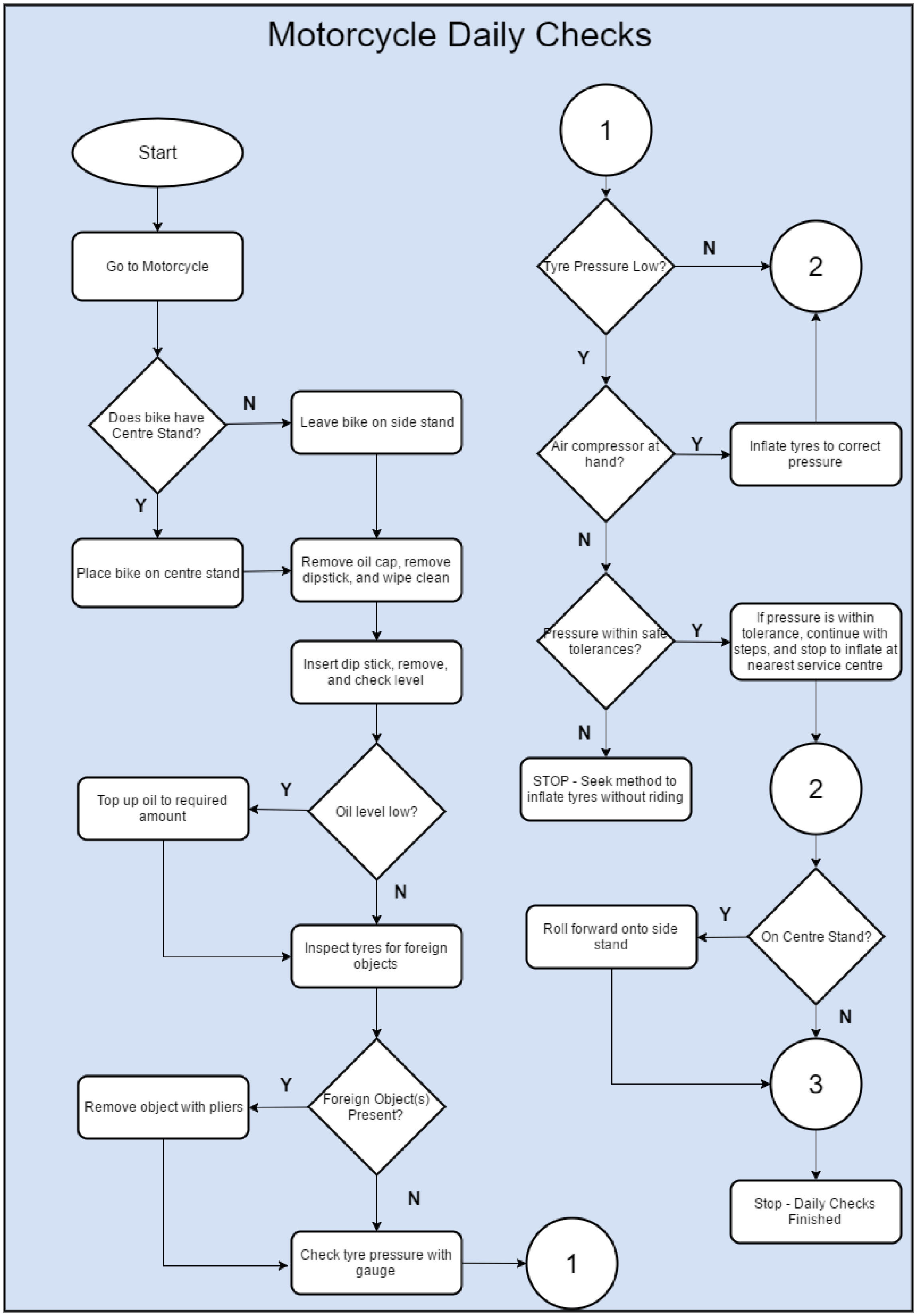


Figure D.1: Daily Motorcycle Pre-Ride Checks - Mechanical

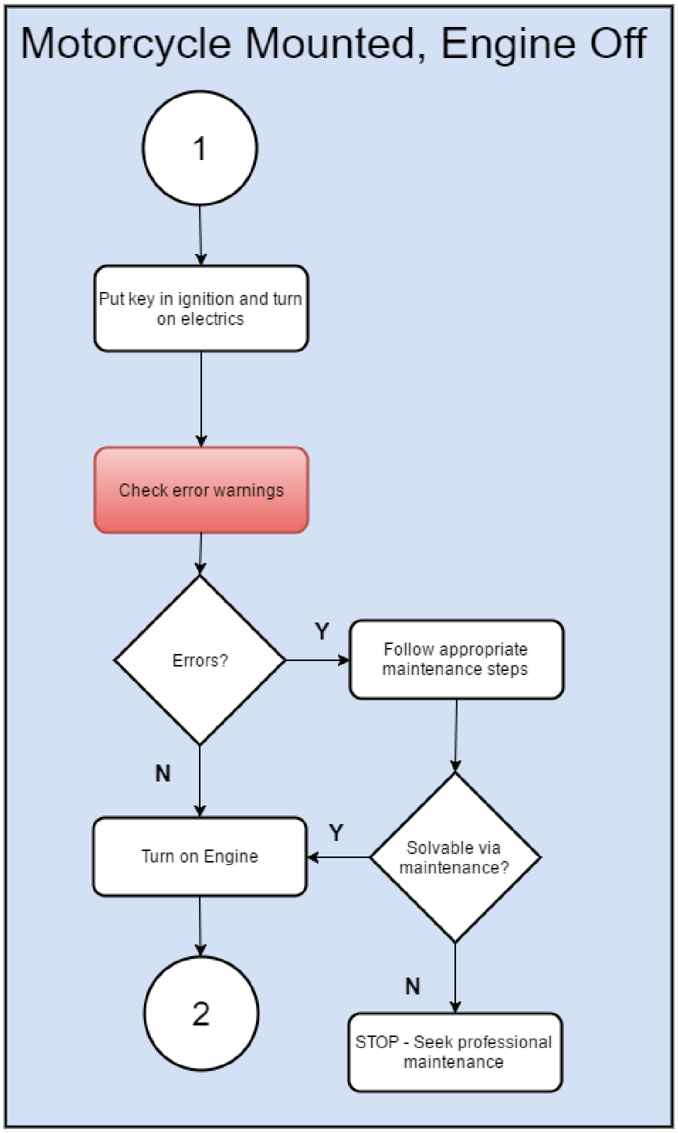


Figure D.2: Daily Motorcycle Pre-Ride Checks - Electrics

References

Wilson, H. Motorcycle Owner's Manual - A Practical Guide to Keeping Your Motorcycle in Top Condition. 1997.

Berman, B. "Lower-Cost Lidar is Key to Self-Driving Future", 2015. URL (`http://articles.sae.org/13899/`) `[Accessed APRIL2016]`.

Bureau of Infrastructure, Transport and Regional Economics (BITRE). Road deaths Australia, 2012 Statistical Summary. 2012.

Code, K. Motorcycle Accident Cause Factors and Identification of Countermeasures - Volume 1: Technical Report. 1993.

de Craen, S. et al. The roles of motorcyclists and car drivers in conspicuity-related motorcycle crashes. 2011.

Delphi. Delphi Integrated Radar and Camera System. 2013.

Doecke S.D. et al. The Potential of Autonomous Emergency Braking Systems to Mitigate Passenger Vehicle Crashes. 2012.

Federal Chamber of Automotive Industries. Directions for the Motorcycle Industry 2014 - 2016. 2013.

Fung, D., Lawson, T. "Autonomous Emergency Braking Explained", 2015. URL (`http://www.caradvice.com.au/293366/autonomous-emergency-braking-explained/`) `[Accessed APRIL2016]`.

Gruber, B. "Smart helmet gives you eyes in the back of your head", 2015. URL (`http://www.reuters.com/article/us-smart-helmet-idUSKCN0T11ZZ20151112`) `[Accessed APRIL2016]`.

Helmet Check. "What You Should Know About Motorcycle Helmets", 2015. URL (`helmetcheck.org`) `[Accessed APRIL2016]`.

H.H. Hurt, Jr. Motorcycle Accident Cause Factors and Identification of Countermeasures - Volume 1: Technical Report. 1981.

Hough, D. L. Proficient Motorcycling. 1981.

Hulshof, W. et al. Autonomous Emergency Braking Test Results. 2014.

Johnston, P. et al. Fatal and Serious Road Crashes Involving Motorcyclists, Road Safety Research And Analysis Report. 2008.

Layton, R.D. Stopping Sight Distance and Decision Sight Distance. 1997.

Ridenour, L. N. Radar Systems Engineering. 1947.

Savino, G. Autonomous Emergency Braking for Cornering Motorcycle. 2015.

Shuman, K.F. et al. Do I brake or Do I Swerve - Motorcyclist Crash Avoidance Maneuvering. 2012.

Tesla. Model S Software Release Notes v6.2. 2015.

Transport for NSW. NSW Motorcycle Safety Strategy. 2012.

Turner, P.A., Higgins, L. Intelligent Transportation System (ITS) Technologies for Motorcycle Crash Prevention and Injury Mitigation. 2008.

U.S Department of Transportation, National Highway Traffic Safety Administration. A Study of Motorcycle Rider Braking Control Behaviour. 2011.

Vu et al. Object Perception for Intelligent Vehicle Applications:: A Multi-Sensor Fusion Approach. 2014.

Wang et al. Simultaneous Localization, Mapping and Moving Object Tracking. 2007.

Widmann, G. et al. Comparison of Lidar-Based and Radar-Based Adaptive Cruise Control Systems. 2000.