SUMMARY OF ANALYSIS

Prepared for:

Mr. Heath Ryan
Unit 214C/168 Victoria Rd
Northcote, VIC 3070
Australia

By: James S. Sobek, P.E.
On: March 10, 2021

Your Reference: Motor Vehicle/Bicycle Accident March 31, 2017 – Mike Hall
Wolf Project No.: 21-0038-4937

Wolf Technical Services, Inc.◦ 13097 Parkside Drive ◦ Fishers, IN 46038
(800) 783-9653 ◦ (317) 842-6075 ◦ Fax (317) 842-6974

WOLF
Forensics and Design Engineering

13097 Parkside Drive
Fishers, Indiana 46038
800.783.9653 · 317.842.6075

wolftechnical.com

March 10, 2021

Mr. Heath Ryan
Unit 214C/168 Victoria Rd
Northcote, VIC 3070
Australia

Attn: Mr. Heath Ryan and Mr. Boyd Fraser

RE: Motor Vehicle/Bicycle Accident March 31, 2017 – Mike Hall
Wolf Project No.: 21-0038-4937

BACKGROUND

Wolf Technical Services was contacted on February 5, 2021 with regard to a fatal motor vehicle/bicycle collision that occurred on the morning of March 31, 2017 in the Australian Capital Territory (ACT).

Mr. Mike Hall was one of 70 participants in the 2017 Indian Pacific Wheel Race (IPWR, also known as the Indy-Pac), a solo, single-stage, unsupported road cycling race covering 5,500 kilometers across Australia from the Indian Ocean to the Pacific Ocean. Seventy entrants were participating in the race which had started at 06:00 AWDT (Australian Western Daylight Time) on March 18 from Fremantle, Western Australia. It was to end when the riders reached Sydney, the capital city of the state of New South Wales.

At about 06:20 AEDT (Australian Eastern Daylight Time) Mr. Mike Hall was riding traveling north on Monaro Highway, also known as NSW route B23. He was in second place in the race and was only about 325 km from the race finish at the Sydney Opera House. He was just about to pass through the Williamsdale Road intersection when he was struck from behind by a 2000 Mazda 323 Astina driven by Mr. Shegu Bobb. The car had also been traveling north on Monaro Highway. Mr. Hall suffered fatal injuries in the collision.

We were asked to determine, if possible, whether the performance of the headlights on Mr. Bobb's car complied with Australian national standards as to illumination distance. Our analysis has been conducted by Mr. James S. Sobek, P.E., of the Wolf Technical Services staff.

Our analyses are based on the materials available to us and are provided within a reasonable degree of scientific and technical certainty. Our conclusions are based on the laws of physics, on mathematical computations, on published data, and on Mr. Sobek's education, background and experience in physics, mathematics, lighting, human vision, and visibility. Our analytical methods are generally employed in the field of accident reconstruction, and are set forth in numerous texts and treatises.

CONCLUSIONS

It is our technical opinion that the headlights on Mr. Bobb's Mazda 323 were not in compliance with Australian Design Rule 46/00 Headlamps.

It is our opinion that because of the car's non-compliant headlights, the car was not roadworthy.

It is our opinion that, independent of the condition of the car's headlights, Mr. Hall's bicycle with its headlight and taillight would have been conspicuous from the perspective of motorists traveling north on the highway at the time of this collision from a distance of at least 400 meters.

It is our opinion that if Mr. Bobb's car headlights had been in compliance with Australian Design Rule 46/00, the bicycle (even without its lights) and rider would have been noticeable and appreciable as a bicyclist with rider from a distance of at least 100 meters.

It is our opinion that with compliant headlights on the Mazda 323, the retro-reflective elements of Mr. Hall's clothing and bicycle accessories would have been separately discernable from the bicycle taillight to Mr. Bobb from a distance of at least 100 meters.

It is our opinion that Mr. Bobb was not paying a reasonable amount of attention to the driving task.

EVIDENCE

Information available for our analysis has included the following:

- Collision Analysis Report prepared by Senior Constable Alan Potts
- Police scene photographs
- Google Earth Aerial Imagery of the collision site
- Extracts from police interview of Mr. Bobb
- Vehicle Standard (Australian Design Rule 46/00 Headlamps) 2006

- Topographic Map of the collision site from DeLorme's Topo North America 10.0
- Exhibit CD 29 from the Coroner's Inquest including Senior Constable Adam Potts' headlight mapping
- Computations of sun and moon position at the time of the collision from the United States Naval Observatory Multiyear Interactive Computer Almanac.
- Video of Mike Hall on March 30, 2017 as he approached the town of Cooma

DISCUSSION

Site Description

The collision site is located in southwestern Australia. Fall had just begun a few weeks before and weather was clear and cool.

Figure 1 The blue flag denotes the geographic coordinates of the collision site.

Figure 2 A larger scale of the same map

Figure 3 The yellow pin marks the collision site. Mr. Hall was just approaching Williamsdale Road northbound when he was struck from behind.

Figure 4 A closer view of the site.

Figure 5 Looking south from Williamsdale Road intersection. The approximate point of impact is marked by the yellow explosion symbol. Several pieces of bicycle debris were found in the area marked by the oval. The red arrow points to one piece of the bicycle's rear wheel.

Figure 6 Looking west from a position on the west edge of Monara Highway. The black/white sign is directly across frm the Williamsdale Road intersection. The light circle surrounds the piece of the bicycle's rear wheel marked in Figure 5.

Figure 7 Looking north along Monara Highway toward the car and bicycle at rest.

Weather and Lighting Conditions

Temperatures that morning were around 5 degrees Celsius.[1] Skies were clear overhead. The sun was 12¼ degrees below the horizon at the time of the collision and would not rise that morning until almost an hour later at 07:15 local time. The moon was 58 degrees below the horizon. There is no street lighting in the area. It was a clear starlit sky.

The road orientation at the collision location is tangent at an orientation about 10 degrees west of due north. For the previous one-half kilometer, the road slope had been on a slight downhill run, falling about 7 meters over that distance.

The road was composed of blacktop and was marked with retro-reflective white pavement markings. Snow-plowable raised retro-reflectors were set in the pavement alongside the pavement lines. White guide posts were positioned along the shoulder on both sides of the road. These delineators had retro-reflective delineator strips (red on the left side of the road; white on the right side) positioned about one meter above the shoulder in which the posts were imbedded. The road markings were in good condition.

[1] 41 degrees Fahrenheit

The Bicycle

The bicycle frame itself was silver. The rubber tires were black as viewed from the rear. The seat was black. Mr. Hall had equipped the bicycle with a dynamo-powered lighting system which consisted of Exposure Revo Redeye 800 lumen LED handlebar-mounted headlight and a seat-post-mounted Supernova E3 Tail Light 2. The two lamps were powered by a dynamo driven by the front bicycle wheel.

On the evening before the collision a car with a driver and passenger had approached Mr. Hall from the rear as he was riding toward Cooma. As the car came toward the bicycle, the passenger in the car began to record a video from the passenger's seated position. As their car got alongside him, the driver and passenger held a brief conversation while he was riding. The approach video started when Mike was about 48 meters ahead of the car and continued while they were alongside the bicycle. We have extracted several frames from that video to document the features that were apparent. It should be pointed out that during the entire video, the car's headlights were on passing beam (low beam).

The first frame of the video clearly shows a bright bluish-white patch of light centered on the left fog line of the pavement and an intense red light taillight above the white pavement patch and moving north with it. The red light was so intense that the picture elements where its image was focused became saturated and presented it as white. This is a common property of a digital camera. Human visual systems will still see the light as red.

Figure 8 The first frame of the approach video taken on March 30, 2017. At this time the bicycle was on the fog line about 60 meters in front of the car.

Shortly afterward, as the car approached, a left-right waggle of the bicycle's headlamp pattern caused by lateral dynamics of the rider and bicycle became evident as it swayed left and right across the fog line.

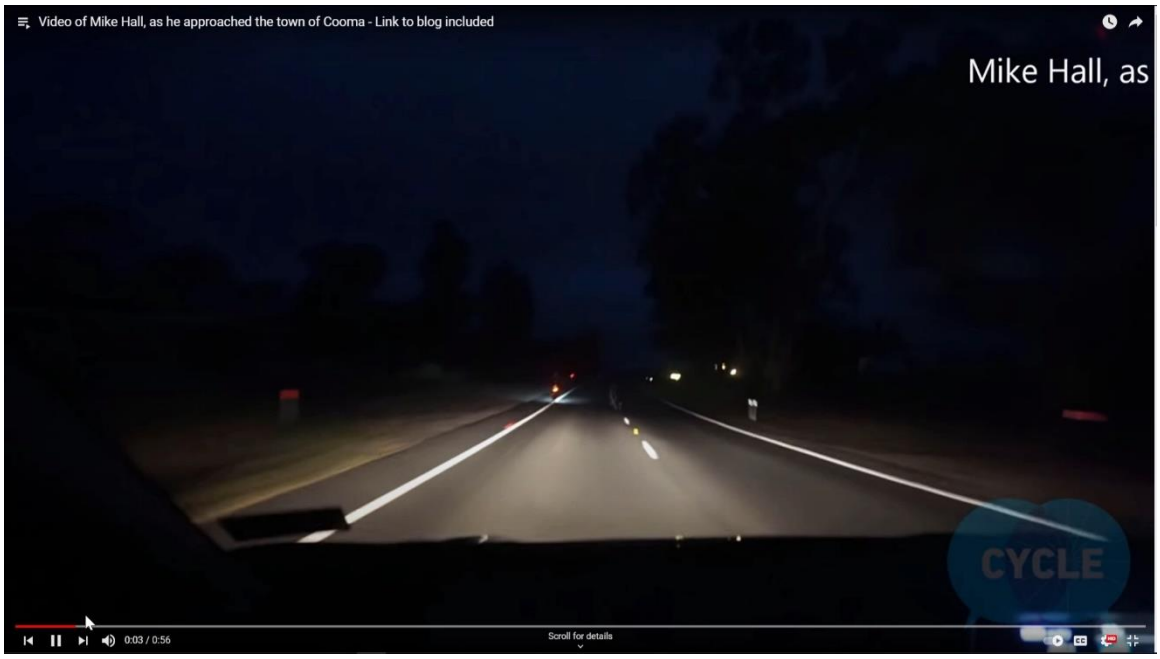


Figure 9 This frame is 3 seconds into the video. The left-right motion of the bicycle's headlight pattern has become noticeable by this point.

As the car got closer, the retro-reflective bands on Mr. Hall's pant legs became visible as did the silver retro-reflective shoulder yoke on his jacket and the silver retro-reflective band around the lower rim of his helmet. The biological motion of his legs alternately moving up and down made it clear that this was not a static rider, but one who was pedaling and making way northward along the road.

The combination of all the visual elements that the bicycle and rider presented to approaching motorists was conspicuous. The moving bright blue-white illumination pattern on the pavement and white edge line combined with the intense red taillight were in themselves only interpretable as a bicycle and rider. Combining that with the retro-reflective materials on the bicycle and the rider, no one who was paying a reasonable amount of attention to the driving task could have failed to understand that Mr. Hall, a cyclist and his bicycle were on the road ahead.

Figure 10 The retro-reflective elements of Mr. Hall's clothing are clearly seen. The up-down motion of the silver band on his right pant leg is obvious, although the left one was hidden in shadow at this point.

Mr. Bobb's 2000 Mazda 323 Astina

Mr. Bobb's car was equipped with two original equipment headlights. The headlamps were halogen-tungsten technology with a driving beam and passing beam setting.[2] During interviews with investigating Australian Federal Police (AFP) Senior Constable Adam Potts, Mr. Bobb was asked whether he had been operating the headlamps in driving beam or passing beam mode. He answered that he was operating on low beam, that he drives mostly on high beam, "when I'm near any town or when there's a car, it's on low." He also said that when he approaches Williamsdale (Road), he turns his headlights from high to low because "you don't know if there's a car coming."

In his statement when asked how the lights on his Mazda 323 compared to those of other cars he had driven, he said that they were a "little different." He said, "I've always wanted to – to change those headlights, but I didn't have the money for it – on the Mazda – because it was that dull – you can't – you can't see anything to, like reach under, say, um, a meter, or two meters because you can't see anything…" He indicated that by that, he meant that you can't see much past a meter or two meters on low beam.

When he was asked if it is safe to drive at a hundred kilometers an hour if you can't see very far, he answered, "I've been doing it every day, but that day, I don't know what's – what was wrong with my headlights, or it was that cold I don't – I don't know."

[2] In U.S. terminology, the driving beam is high beam and the passing beam is low beam.

The left front corner of the Mazda 323 collided with the rear wheel of Mr. Hall's bicycle. When the car came to rest, the bicycle's rear wheel was still imbedded in the car's left headlamp assembly.

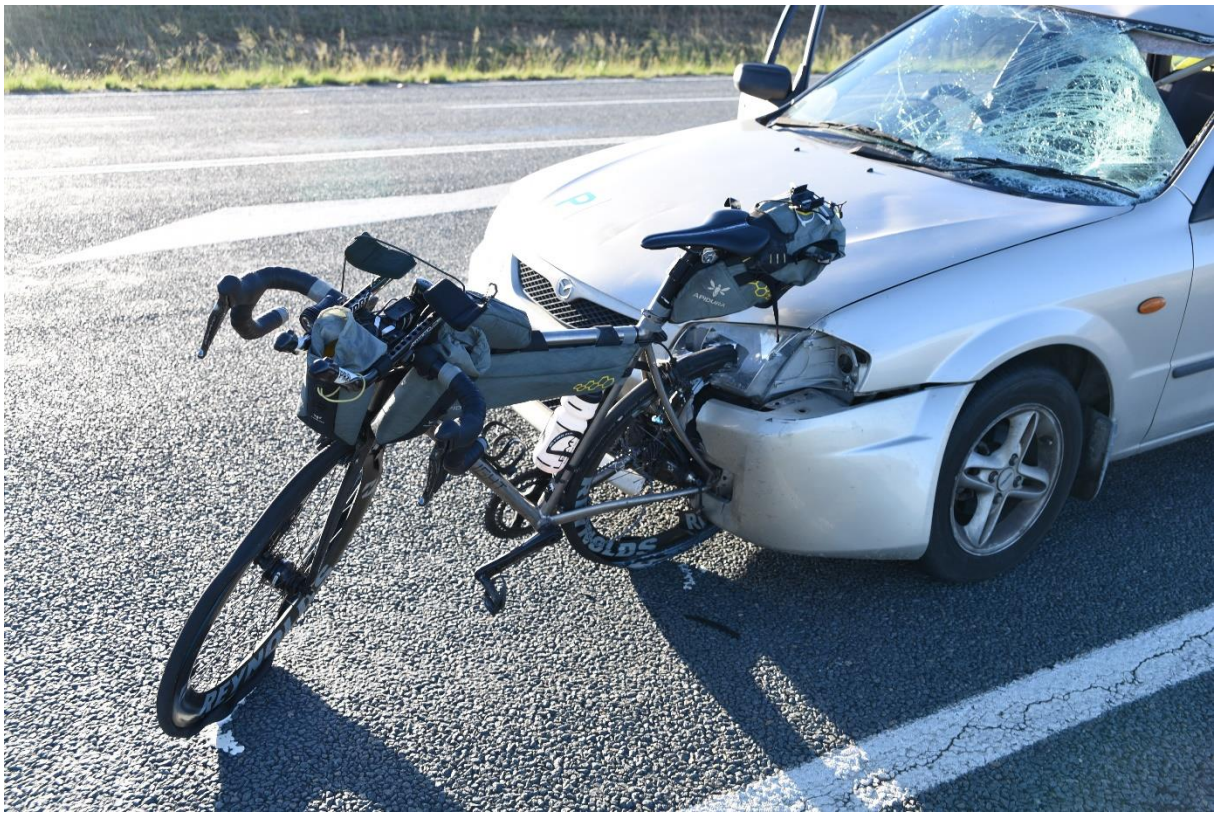


Figure 11 A police scene photograph showing the bicycle and car at rest.

As part of the police investigation, Senior Constable Potts performed a headlamp mapping process on the remaining right headlamp to document its illuminance pattern. A statement from Senor Constable Potts was provided by the Australian Federal Police. We have received a copy of that statement. In that statement, he wrote:

- "I conducted the testing by placing the vehicle in a darkened area of the Traffic Operations Centre and eliminating ambient light to simulate conditions experienced on a road at night."

- "I used a fully charged vehicle battery and placed it into the vehicle to power the headlights. The headlights were turned on using the vehicle's own systems, projecting the headlights over a flat asphalt area."

- "Of note only the right side headlight was working as the left had sustained damage during the incident. The headlights were left on low beam to further simulate the conditions at the time of the incident."

- "I used a 'Digitech Professional Digital Light Meter' to measure the effective illuminance that the headlight provided. This was measured in the units of 'Lux'. A unit of one Lux is equal to one Lumen per square metre."

- "Using this light meter in conjunction with a Trimble S3 total station I created a scale map of the effective illuminance of the headlight."

- "I mapped two areas of this illuminance with an area of light between 15 – 20 Lux and a further area between 5 – 15 Lux."

- "Research has shown that drivers need between 15 – 20 Lux illumination before recognizing a darkly clad object and approximately 5 Lux to respond to a greyish object." (Here he references page 4 of SAE 2013-01-0787 by J. Muttart et. al.)

- "I later measured the distance from the front of the vehicle to the end of the 15 – 20 Lux illuminance area. This distance was measured to be 13 metres."

- "I also measured the distance from the front of the vehicle to the end of the 5 – 15 Lux area. This was measured to be 15 metres."

- As stated earlier the left side headlight ws damaged during the incident and as such was not functional during this test. Previous tests show that a single headlight beam patterns were similar in shape to a two headlight low beam pattern just smaller. (Here he references page 7 of SAE 2013-01-0787 by J. Muttart et. al.)

We have requested the model number and serial number of the meter that was used, specifics of the procedure used and the last calibration date for that meter. We have been told that the police will not provide that information.

<u>Headlamp Design and Performance</u>

Australian Design Rule 46/00 Headlamps (ADR 46/00) prescribes the photometric requirements for headlamps which will provide adequate illumination for the driver of the vehicle withough producing undue glare for other road users. While there are two headlamps on automobiles, trucks and other vehicles on the road, the standard addresses the performance of a single headlamp. When two lamps, each in conformance with the standard, are installed on a vehicle, the incident illumination at some particular point on the roadway ahead of the vehicle will be the arithmetic sum of the illuminances from each lamp at that point.

Paragraph 6. Illumination of ADR 46/00 requires that "Headlamps shall be so made that…they provide adequate illumation without dazzle in the case of the passing beam and **good illumination in the case of the driving beam."**

Paragraph 6.1.1 states that the illumination provided by the headlamp shall be checked on a vertical screen set at a distance of 25 meters in front of the headlight and at right angles to its axis. The test locations within the beam are detailed in Annex 6 of ADR 46/00. That diagram is shown below.

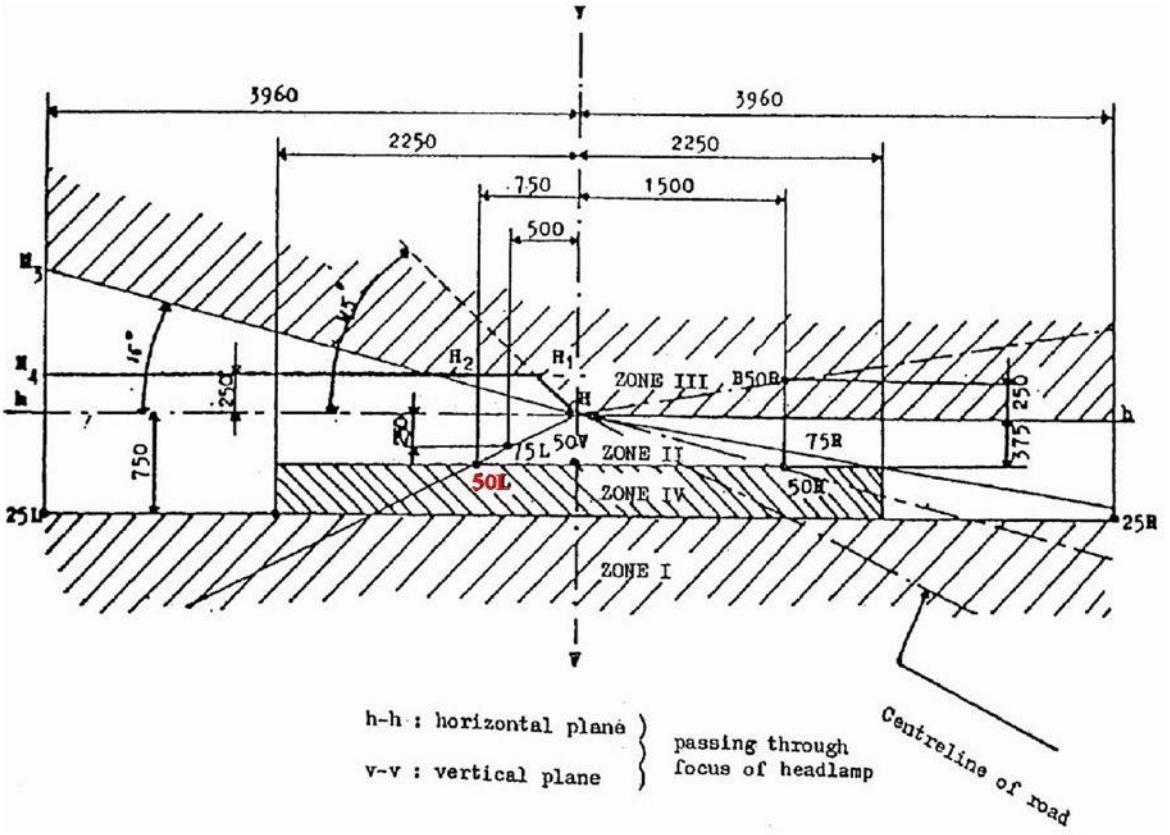


Figure 12 Page 189 of ADR 46/00 Annex 3B showing the measurement screen for illuminance measurements. Point 50L, shown in red is to be used for left-hand drive vehicles.

Table 2

Point on measuring screen		Required illumination in lux	
SB units for right-hand traffic	SB units for left-hand traffic	Minimum	Maximum
B 50 L	B 50 R	-	0.3
75 R	75 L	6	-
50 R	50 L	6	-
25 L	25 R	1.5	-
25 R	25 L	1.5	-
Every point in Zone III		-	0.7
" " " " IV		2	-
" " " " I		-	20

Figure 13 Passing beam illuminance requirements. This table is from paragraph 6.3 on page 19 of ADR 46/00. For left-hand traffic, a lamp must produce at least 6 lux at point 50L.

The minimum required illuminance at position 50L is 6 lux.

Light and all other electromagnetic radiation obey a mathematical relationship known as the Inverse Square Law which relates the illuminance, E, produced by a point source having intensity, I, illuminating an object at radial distance, R. The law states that the illuminance, E, onto an object at distance, R, produced by a point source with intensity, I, varies inversely with the distance.

Stated in equation form, the law looks like this:

$$E = I/R^2$$

Where E is illuminance in lux, I is intensity in candela and R is distance (or range) in meters. Rearranging to solve for intensity, the equation becomes:

$$I = E \bullet R^2$$

The basic property of this principle is that with a given lamp, doubling the distance decreases the illuminance onto the target by a factor of four.

Thus, a source that produces 6 lux at 25 meters distance has an intensity of 3751 candela. So, the ray that illuminates point 50L on the test screen must have an intensity of at least 3751 candela.

It must be understood that this requirement applies to a single headlight, not the pair that is normally installed on a car.

Senior Constable Potts performed headlight mapping on the remaining headlamp on the right side of the Mazda 323. He produced a scale diagram which shows the result of that mapping.

He stated that he measured "areas of light between 15 – 20 Lux and between 5 – 15 Lux." This statement is not entirely clear.

When one makes an illuminance measurement, the measure is the value shown when the meter is positioned at a specific point in space. Headlight mapping is traditionally done with the illuminance meter input surface pointed at the car's light(s) and at some elevation with respect to the ground surface on which the car is located. The meter traces the path that produces a constant illuminance value. Such a track is called an *isoilluminance* curve, or if we use the illuminance units, it would be called an *isolux curve*. Senior Constable Potts' statement does not make it clear exactly what he did nor what the included diagram actually represents.

Based on what we can make of Senior Constable Potts' statement, he seems to have first traced out the line **on the pavement** where the meter read between 15 lux and 20 lux. He then traced out another line where the meter read between 5 lux and 15 lux. But, neither of these is an

isolux curve. His phraseology of saying "between A and B" is just not clear and is not consistent with measuring an isoilluminance curve.

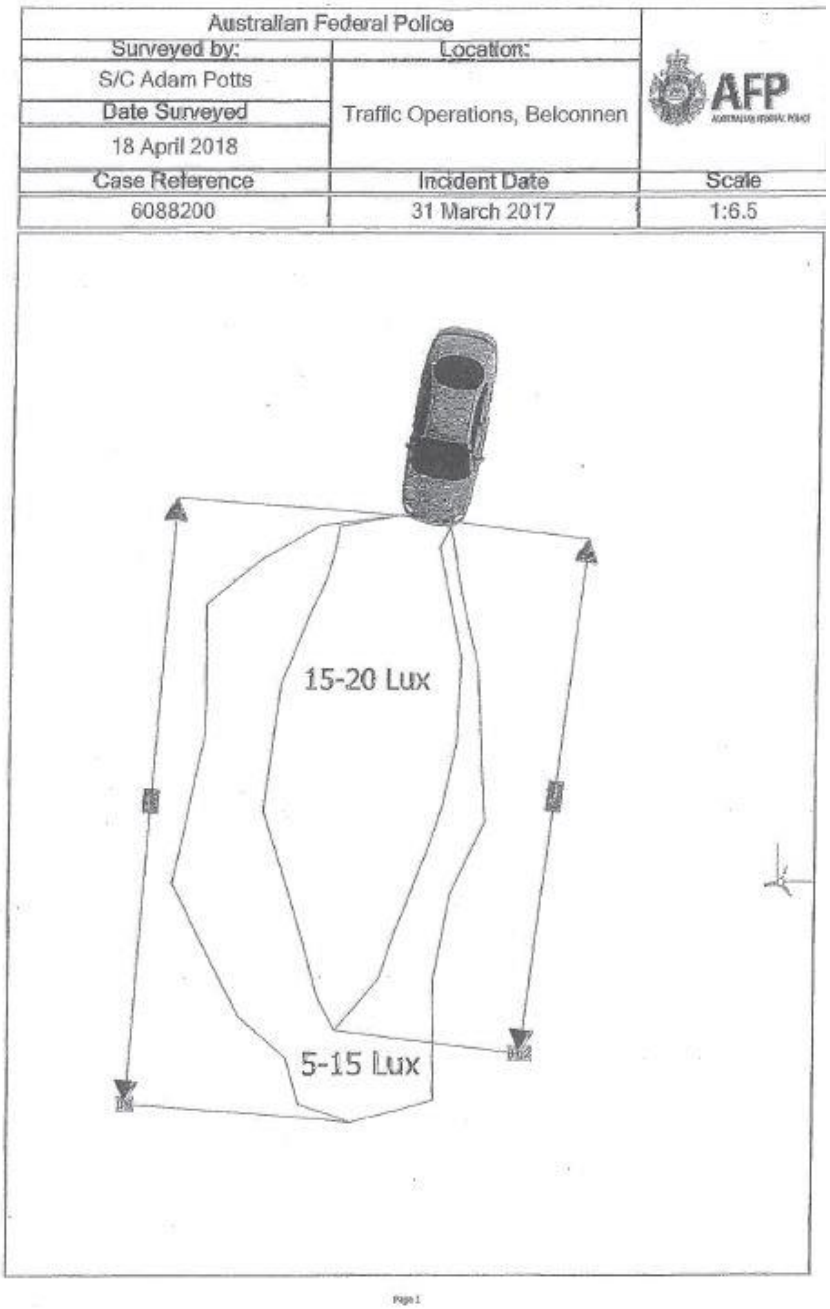


Figure 14 The scale diagram that S/C Potts produced from his data.

Senior Constable Potts refers in his statement to an SAE paper[3] published in 2013 by Jeffrey Muttart and others. He infers from that paper that 5 lux onto a gray object will be required before a driver can recognize that object. It should first be pointed out that the objects in question in that research were unlighted pedestrians, not bicycles with taillights and headlights.

In the accident reconstruction world, most investigators prefer to use 3 lux as that threshold value. That 3 lux value is often referred to as the *twilight threshold* because at the end of civil twilight under clear skies, illuminance onto a horizontal plane is about that value. But, since Senior Constable Potts has selected 5 lux, we continue with that value.

As best we can tell, Senior Constable Potts determined that the right headlamp of the Mazda 323 would only produce 5 lux at 15 meters. Inserting that into the inverse square law, we find that the intensity of the right lamp on the ray that he was measuring was 1125 candela, less than half of the required 3751 candela.

Again using the inverse square law, at 25 meters distance, one lamp with intensity of 1125 candela will only produce 1.8 lux. And two lamps, both with that same intensity will produce only 3.6 lux onto a target at 25 meters.

It should be pointed out that Mr. Bobb's interview answers were that he could only see two meters in front of his car when he was on low beam. And while not specifically saying so, he implied that the left headlamp was much worse than the right lamp. Therefore, it is not really proper to double the results from the right lamp.

What we can say based on how Senior Constable Potts described his measurements is that the Mazda 323 driven by Mr. Bobb did not comply with ADR 46/00 and it was therefore not roadworthy.

With such poor headlights the retro-reflective elements of Mr. Hall's bicycle and clothing and the road markings would have been far less apparent than they would have been when illuminated by a set of properly functioning headlights.

SUMMARY

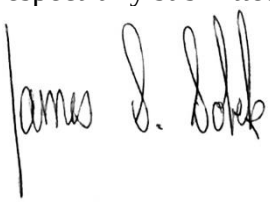
Mr. Hall and his bicycle were conspicuous to anyone who was paying attention to the driving task. He should have easily been seen first because of the active lighting on his bicycle and then later by the return from his retro-reflective helmet, jacket and leggings. We can only conclude that Mr. Bobb was extremely inattentive to the driving task. His choice to drive his car when he knew that the headlights were inadequate and not in compliance with traffic law made his behavior just that much worse.

[3] SAE 2013-01-0787 by J. Muttart et. al.)

ADDITIONAL WORK

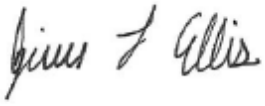
The information contained in this report and the conclusions reached are based on information available at the time this report was prepared. We reserve the right to amend and/or modify this report if any new and/or significant data that could have an impact on this investigation becomes available. We recommend that if any additional statements, depositions, photographs, evidence or other information documenting this incident become available, that they be supplied to Wolf for our review so that we may render any further opinions in any future report, deposition, or testimony.

Respectfully submitted,



James S. Sobek, P.E.

Reviewed by,



Jessica L. Ellis, P.E.

WOLF
Forensics and Design Engineering

13097 Parkside Drive
Fishers, Indiana 46038
800.783.9653 · 317.842.6075

wolftechnical.com

March 10, 2021

Mr. Heath Ryan
Unit 214C/168 Victoria Rd
Northcote, VIC 3070
Australia

Attn: Mr. Heath Ryan and Mr. Boyd Fraser

RE: Motor Vehicle/Bicycle Accident March 31, 2017 – Mike Hall
Wolf Project No.: 21-0038-4937

Neither the Corporation, its consultants, contractors, officers, directors nor any of the corporate staff involved in this investigation have any financial or related interest with respect to any of the persons or organizations indicated in this report. Our letters and reports are for the exclusive use of the client to whom they are addressed. The client further agrees that Wolf Technical Services, Inc., its consultants, contractors, officers, directors and staff shall be held harmless from any claims, suits or other proceedings, losses, costs or damages, including reasonable attorneys' fees arising out of any negligent, willful or wanton use of the letters, reports, and other work product submitted in this case. Our letters and reports apply to the samples tested and are not necessarily indicative of the qualities of apparently identical or similar products. The conclusions and results reached in this investigation are based in part upon data supplied to us, and we are not responsible for the authenticity or accuracy of such data.