2016

You'll face me: an investigation into improving puffin crossing safety by controlling PDU placement

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Abstract

The main aim of this project is to analyse and possibly alter a puffin crossing in order to increase pedestrian comfort and safety by making the pedestrian display unit (PDU), the box with the red and green man lights, more visible and the pushbutton easy to reach and press. A literature review was carried out to determine pedestrian field of view and standard puffin crossing component sizes and two zones were determined; the visible and blind zone. As the names would suggest, the visible zone at the puffin crossing is the area in which the pedestrian can see the PDU in their field of view and the blind zone is where the pedestrian has to twist beyond their comfortable range of motion in order to see the PDU. Surveys were carried out at two different sites that had placed the PDU at slightly different distances from the edge of the road. The two sites had different sized blind zones and data was collected, recording where a pedestrian would stand and whether or not they looked at the PDU before crossing. It was determined through statistical analysis that Site 2, with the smaller blind zone, had more people looking at the PDU and therefore was safer. An exact distance for the PDU to be placed 0.26m back from the kerb face was recommended and guidelines on how to achieve this without infringing on current regulations for the placement of the signal head were provided. This outlines the use of brackets, cranked poles or completely separate poles for the puffin crossing PDU, pushbutton and signal head.

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Nomenclature

H_a	Alternate Hypothesis
H_o	Null Hypothesis
K_1	Expected number of people looking at PDU at site 2
n_1	Sample size observed at Site 1
n_2	Sample size observed at Site 2
$\hat{p}$	Combined proportion of pedestrians looking at PDU from both Sites
$\hat{p}_1$	Proportion of pedestrians looking at PDU at Site 1
$\hat{p}_2$	Proportion of pedestrians looking at PDU at Site 2
x_1	Number of pedestrians who looked at PDU at Site 1
x_2	Number of pedestrians who looked at PDU at Site 2
z_c	Critical z value
α	Significance level

1. Introduction

The main focus of this project is to analyse and recommend changes to the puffin crossings in the UK in order to make the pedestrian display unit more easily visible when the crossing is in use.

The aims of the project that have been adjusted from the interim report:
- To improve pedestrian safety when using a puffin crossing.
- Make puffin crossings more comfortable and easy to use.

The objectives of the project post interim report:

- Identify findings from literature review and compile a list of information on the specification of the current exact layout and sizing of a puffin crossing.
- Find sites in and around Plymouth that conform to the standardized specification.
- Carry out data collection at the site(s) in order to determine whether where pedestrians stand correlates with whether they look at the PDU or not.
- Analyse the data to determine changes that would help make the PDU more visible and ultimately the crossing safer.
- Design theoretically and empirically informed recommendations for the installers of puffing crossings to allow pedestrians to clearly see the pedestrian display unit (PDU) and the road without having to twist or alternate what they are looking at.
- Design the recommendations to conform to current regulatory requirements or reform the guidelines based on findings.

2. Literature review

2.1. Puffin crossing components

(Aggregate Industries , 2014)
This online PDF document is a data sheet for the different types of tactile paving used in the UK. It describes all the sizes, the colour and the spacing between the blisters.
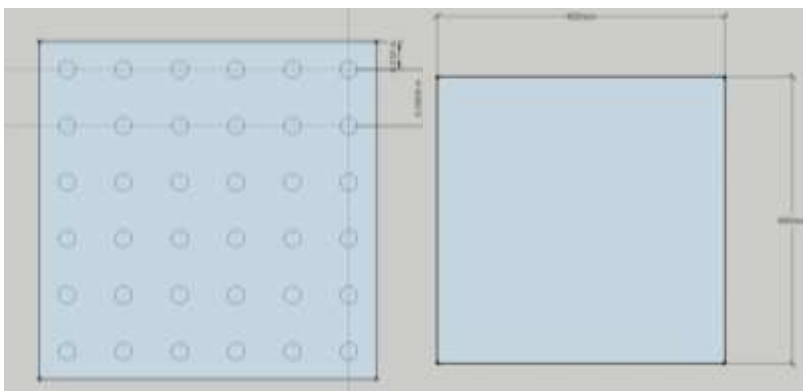
Figure 1: Puffin crossing tactile paving dimensions

Key findings:
- Most commonly used tactile paving slabs at puffin crossings are 400mm by 400mm.

(Aggregate Industries, 2013)
This is also an online PDF document from the same company that manufactures and supplies components for infrastructure in the UK. This PDF outlines the sizing of kerb blocks as it was noticed that different kerb blocks are used on different roads and can affect the placement on the PDU.

Key findings:
- The main types of kerb blocks used are either 150mm wide or 255mm wide. Around Plymouth city centre and the university, mainly the wider variant is used.

2.2. Pedestrian viewing range

Key findings
- (Howard & Rogers, 1995) found that binocular field of view for most people was 114°.
- (Doriot & Wang, 2006) show the standard ranges of left and right rotation in the neck, the lowest being that of elderly men.
- A rotation range of 40° left and right for the neck will be assumed. This should accommodate a wide range of pedestrians

2.3. Regulation restrictions

(Ladyman & Allister, 2006, pp. 31-32) outline the placement of the PDU pole and the reasoning behind.

Key findings:
- The PDU pole must be no more than 500mm from the tactile paving edge.
- The PDU should not be more than 500mm back from the kerb edge.
- The Pole should be placed such that the signal head (traffic lights) has at least 450mm clearance from the edge of the road.

There are ways of achieving the minimum 450mm clearance as shown in the Ladyman and Allister document.

2.4. Statistical analysis

This research used (Jeffreys, 1961)**,** (Yale, 2014)**,** and (Wuensch, 2014) to carry out two significance tests on the data collected. Both (Yale, 2014) and (Wuensch, 2014) use the P value to determine if two sets of results are significantly different from each other. (Jeffreys, 1961) outlines a different method and the drawbacks of the P method. He also explains that even though the P method has its drawbacks, both methods usually come to the same conclusion.

Key findings:

- How to carry out a 2 proportion z test.
- How to carry out a binomial significance test.
- Drawbacks of the P method of significance testing.

3. Experiment

3.1. Approach
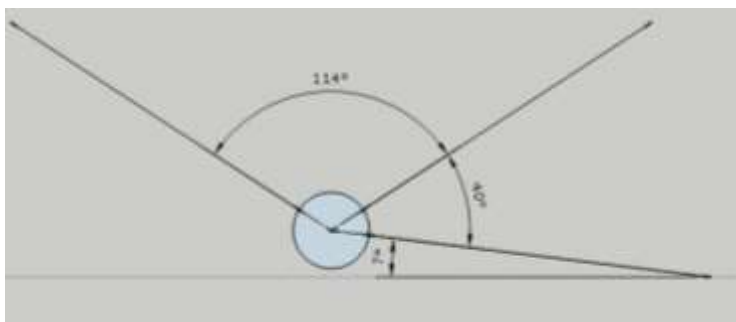
Figure 2: The assumed field of view of a pedestrian

Figure 2 shows the 114° FOV along with an added 40° to account for the head turning to the right taken from Doriot and Wang (2006). This makes a line at an angle of 7° to the horizontal.

Drawing a line from the PDU at 7° into the waiting area where pedestrians wait to cross will divide the crossing into 2 sections:
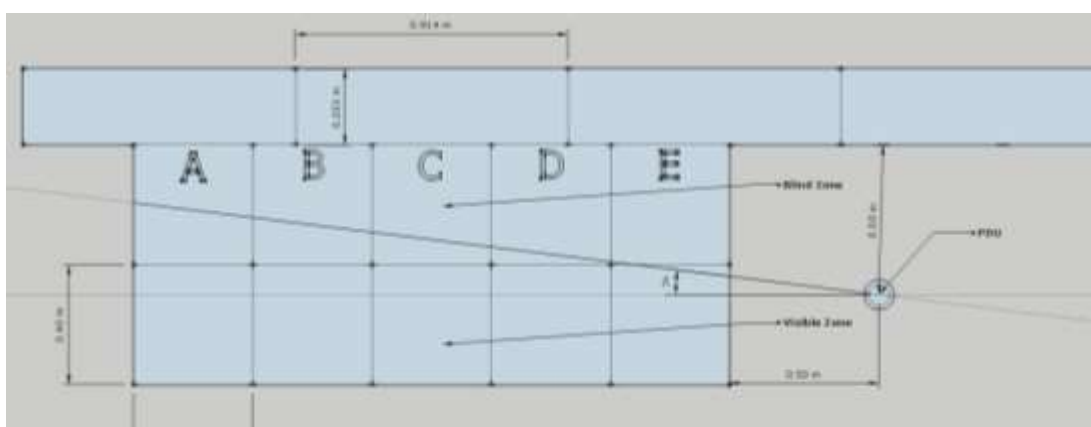
Figure 3: Standard puffin crossing layout

As shown in Figure 3, the crossing is divided into two main sections. A pedestrian standing in front of the line is considered in the blind zone and cannot see the PDU without twisting awkwardly or turning away from the road. A pedestrian standing south of the line should be able to see the PDU clearly and safely use the puffing crossing.

The rows of blisters along with the way that the crossing can be divided using the tiles as markers can be used to determine exactly where people are standing.
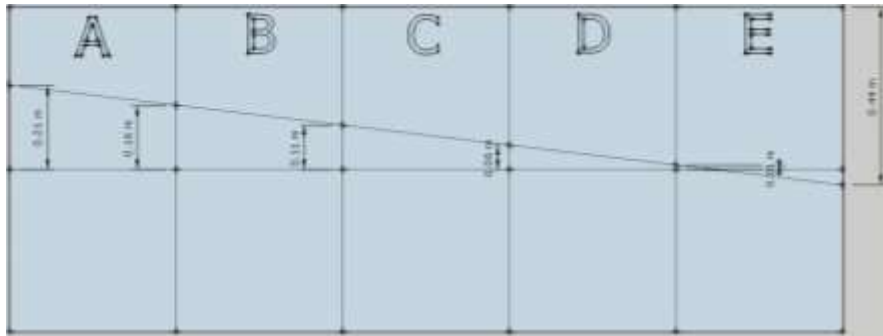
Figure 4: Distance between the tactile paving and the boundary between the visible zone and the blind zone

Figure 4 shows the distance between the bottom of each tile and the boundary line. This was calculated using the following formula:

$$h = \left[tan(7°) * \left(0.5 + (x * 0.4)\right)\right] - 0.1$$

The height is determined by tan(7°) multiplied by the horizontal distance to the edge of the tactile paving. The PDU is 0.5m away from the edge of the paving and the tactile tiles are 0.4m wide so the horizontal distance is 0.5m added to the number of tiles multiplied by the tile width. X is the number of tiles.

Using the blister spacing values, the approximate row of blisters for the boundary line can be calculated:

$$Section\ A = \frac{210mm - 33mm}{66.8mm} + 1 = 3.65 \approx Half\ way\ up\ the\ tile$$

$$Section\ B = \frac{160mm - 33mm}{66.8mm} + 1 = 2.9 \approx 3^{rd}\ row\ of\ blisters$$

$$Section\ C = \frac{110mm - 33mm}{66.8mm} + 1 = 2.15 \approx 2^{nd}\ row\ of\ blisters$$

$$Section\ D = \frac{60mm - 33mm}{66.8mm} + 1 = 1.4 \approx 1^{st}\ row\ of\ blisters$$

$$Section\ E = \frac{10mm}{33mm} = 0.3 \approx Edge\ of\ tile$$
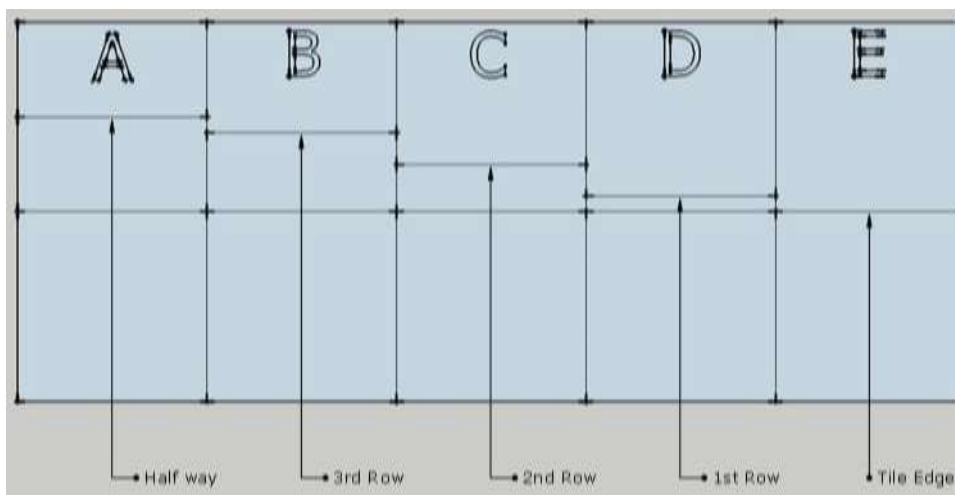
Figure 5: Estimated blister rows for visible and blind zone division

Figure 5 shows the boundary line between the visible and blind zone that has been adjusted to match the blister rows. This will make it much easier to determine whether the pedestrian is standing in the visible zone or the blind zone by looking at which row they stand on and in which section (A, B, C, etc.).

3.2. Sites

Two main sites were analysed when trying to decide where to carry out the data collection. The main criteria for the sites was to have a puffin crossing that conformed to regulations and was regularly used at all times of the day by a wide range of pedestrians in order to gain as much data as possible from a variety of pedestrians. The sites should conform to regulations as most sites in the UK do and observing sites that don't, will produce skewed data that may not represent the average puffin crossing in the UK.

3.2.1. Site 1: Cobourg Street

This site is just south of the Plymouth University and is used regularly throughout the day by students, university staff and members of the public traveling to the city centre and Armada shopping centre.

Figure 6: Cobourg Street with crossing highlighted reproduced from Google Maps.

[69]

Figure 7 (Google, 2015), shows the puffin crossing with the two ends circled. There is also a centre island in the middle of the road as this is a staggered crossing. The experiment was done from the south side as this tends to be the busier side in the morning when students and staff are traveling into the university.

Figure 8: Ground level photograph of Cobourg Street

Figure 8 shows the south side crossing at Cobourg Street. The crossing is 7 tiles wide (3m). Anyone standing in the 2 extra tiles to the left of section A will be assumed to be in the visible zone unless they stand on the kerb.

3.2.2. Site 2: Mutley Plain

This site is north of the university around all the shops and fast food restaurants on an area called Mutley Plain. This site should have fewer students in the data and more variety in age due to the distance from the university.

Figure 9: Staggered crossing on Mutley Plain reproduced from Google Maps

Figure 9 (Google, 2015) shows the staggered crossing at Mutley Plain. This crossing however has a slightly altered design. The PDU pole is placed slightly further forwards and nearer to the edge of the pavement compared to the crossing at Cobourg Street. The pole has been placed 0.5m from the edge of the road rather than the edge of the tactile paving. The varying kerb block widths at different puffin crossings may have resulted in the difference in designs. This means the blind zone at Mutley Plain is significantly smaller than at Cobourg Street.
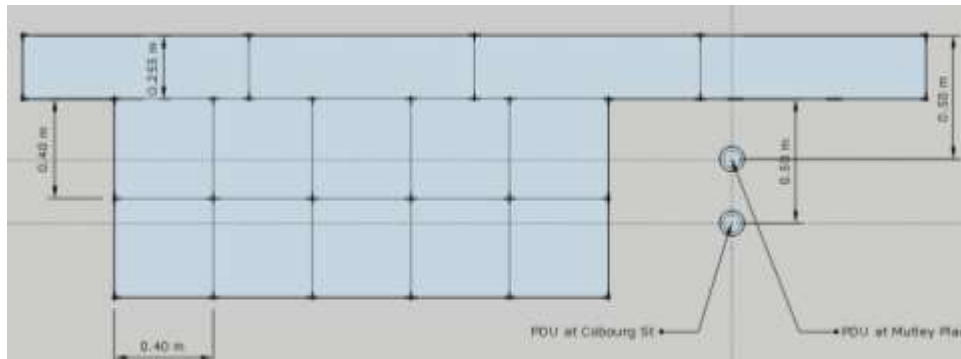
Figure 10: Comparison between Site 1 and Site 2

3.3. Design

Figure 10 shows the difference in pole placement between Mutley Plain and Cobourg Street. The data is to be gathered from Cobourg Street and then compared to Mutley Plain. The effects of a smaller blind zone can be analysed and compared to the larger blind zone on Cobourg Street and conclusions can be drawn as to whether or not a more visible PDU encourages more people to use it and therefore makes the crossing safer. The data from Site 1 (Cobourg Street) will be collected in Table 1 and Table 2:

Table 1: Data collection table for where pedestrians stand

	A	B	C	D	E
Blind Zone					
Visible Zone					
Total					

Table 2: Data collection table for whether or not PDU is looked at

	Looked at PDU	Didn't look at PDU
Blind Zone		
Visible Zone		
Total		
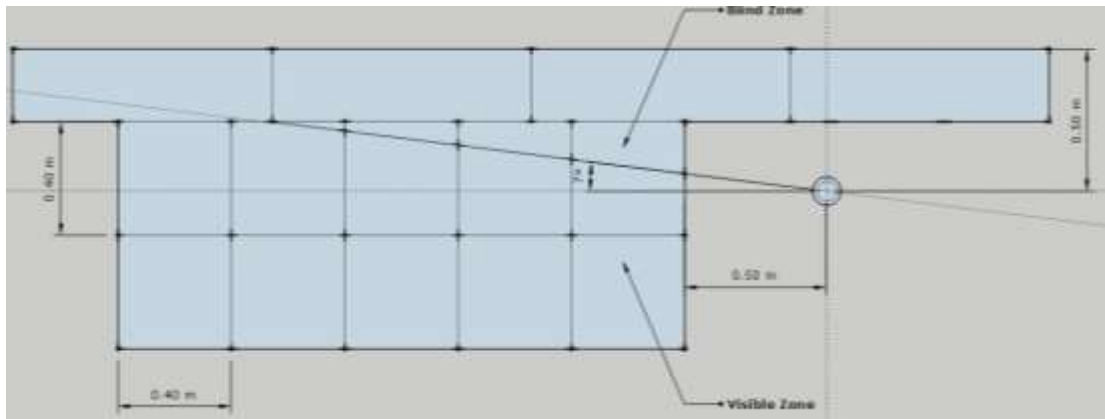
Figure 11: Site 2 Layout

Figure 11 shows the significantly smaller blind zone on Mutley Plain. Since the blind zone is much smaller, it is much easier to determine whether or not a pedestrian is standing in the blind zone or not. If a pedestrian is in section E and forward of the halfway point of the front row of tiles, then they would be considered in the blind zone. Table 1 becomes unnecessary and only Table 2 is required for the data collection at this site. Appendix A shows the complete data collection sheets with the data included.

3.4. Risk assessment
A standardized risk assessment was carried out using guidelines supplied by Plymouth University. This involved using a risk severity and likelihood matrix to determine the overall risk rating.

Figure 12: Matrix used to determine risk rating

Figure 12 (Plymouth University, 2014) shows the matrix used to determine risk rating. Due to this only being a data collection based experiment, the risk rating for all the hazards were low.

The main hazards anticipated during the survey were:
1. Being hit by traffic swerving on to the pavement.
2. Being hit by traffic while using the puffin crossing.
3. Slippery surfaces which could result in falling and injury.
4. Being noticed by pedestrians who object to being observed.

Hazards 1 and 2 have high severity but are not likely due to safety barriers around the crossing and appropriate facilities to cross the road safely. This gives them a low risk rating.

Hazards 3 and 4 have a low-very low severity rating; however they are likely to possible. This still puts them in the low risk rating category. Pedestrians noticing and objecting is the most likely hazard but should be avoidable as standing a fair distance from the puffin crossing should make being spotted unlikely. Even if the observer is spotted and a member of the public objects, it can be explained that no personal data is being recorded, just where they are standing and whether or not they use the PDU. The full risk assessment is shown in Table 7 12.2 Appendix B.

3.5. Experiment limitations
Due to the fact that the data collection was carried out by one person who had limited time to complete this project, the data was only collected once from each site. Ideally, this survey should be run multiple times at multiple puffin crossings across the whole of the UK. Doing this would make it easier to spot anomalies and also provide a much wider range of pedestrians to observe. Only very general trends can be determined from the data collected at Cobourg Street and Mutley Plain.

Even though an effort was made to gather data from sites that would provide a diverse group of pedestrians to observe, the data from Cobourg Street mostly included students of the age range 19-25 and the data from Mutley Plain mostly included the elderly and young mothers. The students were easy to spot as they exited the student accommodation on Cobourg Street. The mothers were also easy to spot as they had their children with them.

This discrepancy in age range may have skewed the results as a mother taking a morning walk to the shops acts very differently to a student running late to lectures when using a puffin crossing. As noted during the surveys, students were seen crossing without looking on Cobourg Street while on Mutley Plain mothers with prams made an effort to stand well back to make sure their children were not near the edge of the road when waiting for the green man on the PDU to light up.

3.6. Data analysis

3.6.1. Cobourg Street
The survey started on Wednesday 18/02/15 at 9:35am and ended at 10:30am. Conditions were good and it was easy to see the whole puffin crossing. The data was collected from the south side of the crossing as more people were heading into the university rather than out of it.

Table 3: Cobourg Street sector data

Graph showing the distrbution of Pedestrians across individual sectors at Site 1

(bar chart — *Puffin Crossing Sector* on y-axis, *Number of Pedestrians* on x-axis, with legend: Visible Zone, Blind Zone)
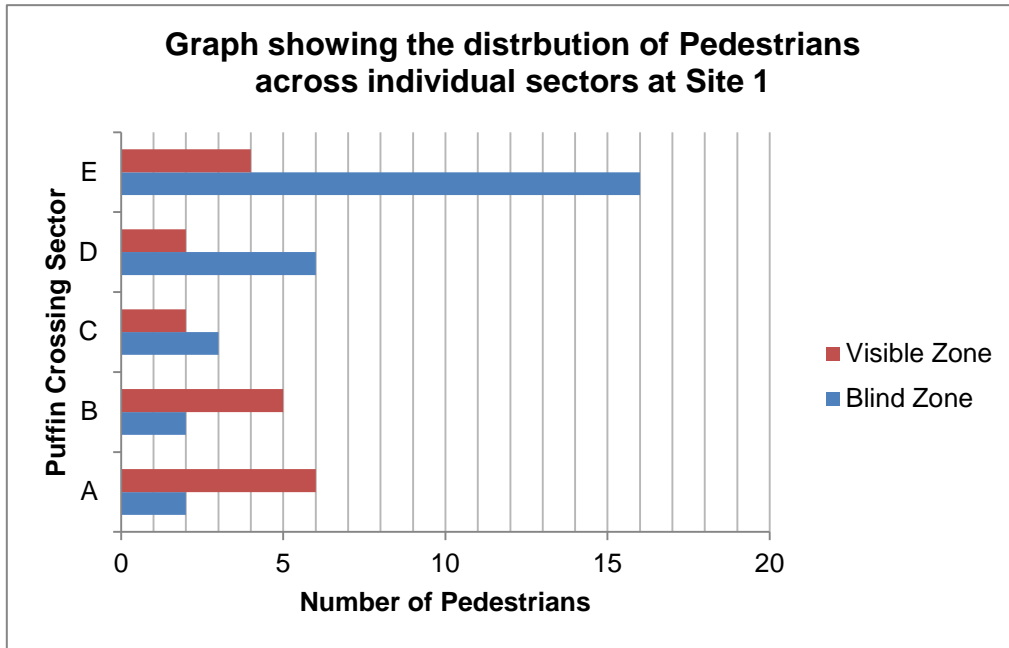
Table 4: Cobourg Street data

Graph showing the number of pedestrians who looked at the PDU at Site 1

(bar chart — categories "Didn't look at PDU" and "Looked at PDU", *Number of Pedestrians* on x-axis, with legend: Visible Zone, Blind Zone)
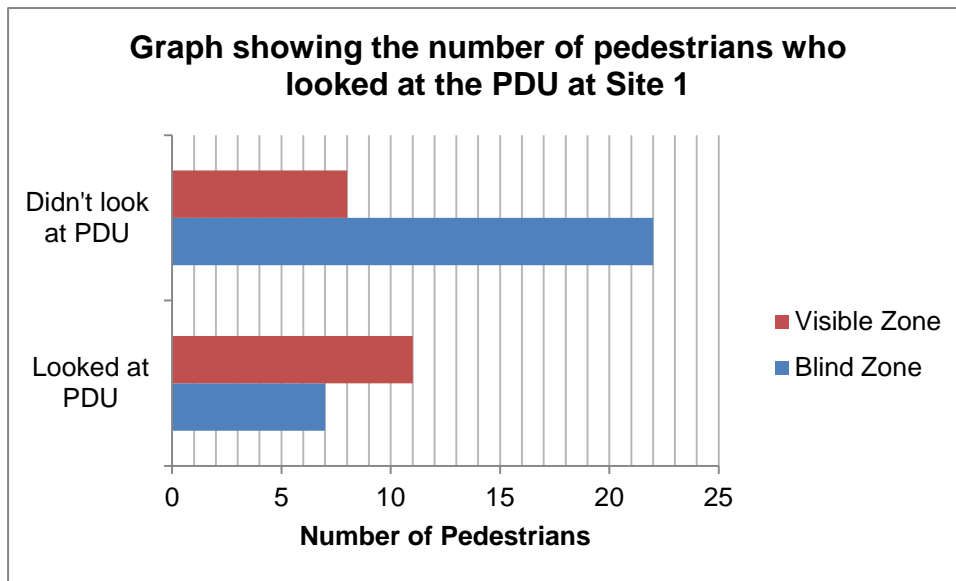
Table 3 and Table 4 shows the data collected at Cobourg Street. There were 58 people observed during the 1 hour period. There are some obvious conclusions that can be drawn just by looking at the values:

- From Table 3 it is clear that there are substantially more people standing in the blind zone compared to the visible zone. This was very clear during the data collection as a lot of pedestrians would stand as close to the edge of the kerb as possible and look at traffic or the traffic lights mounted across the road as an indication for when it was safe to cross.

- An alarming number of people would not look at the PDU when crossing. Usually pedestrians would wait for traffic to stop and then cross. This isn't surprising as the PDU was out of their field of view due to the fact that they had stood in the blind zone.
- One of my comments noted during the experiment: "People did use the tiles as an indication where to stand". This meant that pedestrians would almost exclusively stand on the front row of tiles or even on the kerb block to be as close to the edge as possible.
- Section E had the single highest number of pedestrians in. This is not surprising as it is the section closest to the PDU and was where most pedestrians would stand and wait after pushing the button to cross.
- Sections A and D had the second most pedestrians standing in them. Section D was where the pedestrians who wanted to cross stood when section E already had someone standing in it. Section A had people stood in it as there was a push button to the left of it but no PDU.

Main observations:
- Occasionally a pedestrian would run across the road without stopping or looking at the PDU as they had spotted a gap in traffic. This happened around 9:55am-10:05am as students were rushing to get to their lectures on time.
- Vast majority of pedestrians were students judging from the student accommodation they exited.

3.6.2. Mutley Plain
The data collection on Mutley Plain started on Wednesday 11/03/15 at 10:00am and ended at 11:00am. The time and day of the week was kept similar to the survey at Cobourg Street. Since Mutley Plain has a more visible PDU with a smaller blind zone, it is expected that there will be more pedestrians stood in the visible zone and that there will be more pedestrians looking at the PDU.

Table 5: Mutley Plain data

Graph showing the number of pedestrians who looked at the PDU at Site 2
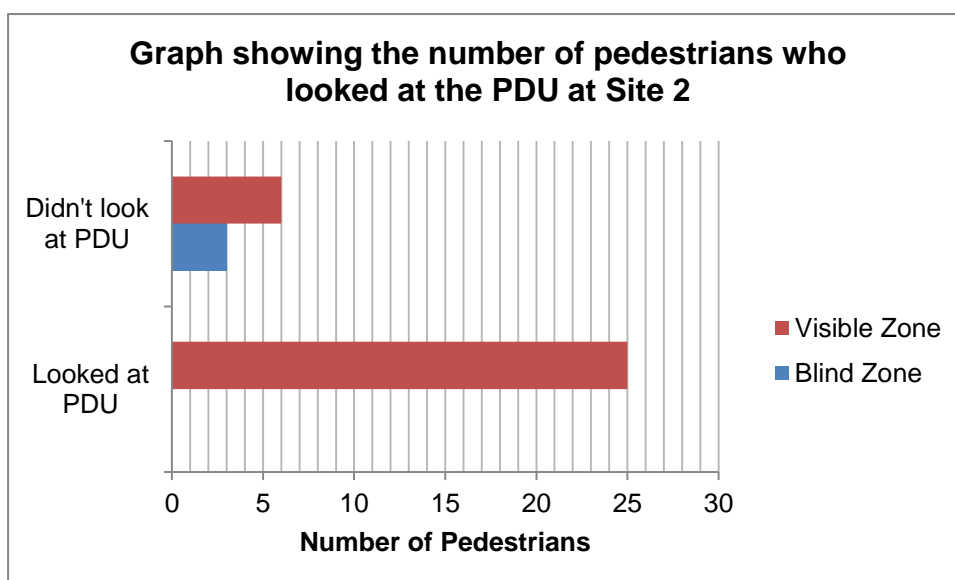
There were fewer pedestrians (34) observed at Mutley Plain compared to Cobourg Street. Main conclusions drawn are:

- Table 5 shows that there were 3 pedestrians that stood in the blind zone and none of them looked at the PDU. These pedestrians used the traffic stopping at the crossing as an indicator as where to cross.
- Most people stood well in the visible zone. This may be because the visible zone was larger and that the main types of pedestrians were mothers with prams.
- There were very few people who didn't look at the PDU. These pedestrians were observed following others across the road.
- This data is very promising as it gives the impression that a smaller blind zone encourages more people to look at the PDU. However a significance test will need to be done in order to determine whether or not the data from Mutley Plain is significantly different from Cobourg Street and therefore whether or not the smaller blind zone makes a discernible difference.

The full data sheets from both days can be found in Table 6 in section 12.1 Appendix A – Raw Data from sites 1 and 2.

3.6.3. Significance tests
In order to determine whether or not the difference between the results from Site 1 and Site 2 are due to randomness or because of an actual environmental difference such as the PDU being more visible, a significance test needed to be carried out.

A significance test with regards to the data from Site 1 and Site 2 involved calculating the probability of obtaining the results from Site 2 assuming that the proportions of where people stood were the same as the proportions for Site 1. If the probability was lower than a predetermined significance value, then it will be assumed that obtaining the results from Site 2 by chance was highly unlikely and therefore the results were a direct result of an environmental change.

3.6.3.1. Z-test for two population proportions
A significance test, as outlined in (Yale, 2014), starts off with a null hypothesis (H_0). For the Site 1 and Site 2 data, the null hypothesis (H_0) was that the proportion of people looking at the PDU at Site 1 ($\hat{p}_1$) was the same as the proportion of people looking at the PDU at Site 2 ($\hat{p}_2$). $\hat{p}_1$ can be calculated by dividing the number of people looking at the PDU at Site 1 by the total number of people observed at Site 1.

$$\hat{p}_1 = \frac{18}{48} = 0.375$$

$$Null\ Hypothesis\ (H_0){:}\ \hat{p}_1 = \hat{p}_2 = 0.375$$

An alternative hypothesis (H_a) also needs to be defined. This is the hypothesis that will be accepted if it is proved that it is highly unlikely that the null hypothesis (H_0) is true. The alternative hypothesis (H_a) is that there were a higher proportion of pedestrians looking at the PDU at site 2 ($\hat{p}_2$) compared to the proportion of pedestrians looking at the PDU at Site 1 ($\hat{p}_1$).

$$\hat{p}_1 < \hat{p}_2$$

$$Alternative\ Hypothesis\ (H_a):\hat{p}_2 > 0.375$$

Before the test can be carried out, a significance level (α) has to be defined. This will act as a bench mark in order to determine whether or not to reject the null hypothesis (H_0). The significance level (α) chosen is 5%. Using a standard normal distribution table from (University of Florida, 2015), this translates to a z value of -1.645. This z value is called the critical z value (z_c) because the calculated z value from the significance test needs to be lower than z_c in order for the alternative hypothesis to be accepted. The z value is calculated using the following formula (Loveland, 2011):

$$z = \frac{(\hat{p}_1 - \hat{p}_2)}{\sqrt{\hat{p}(1 - \hat{p})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

Where $\hat{p}$ is:

$$\hat{p} = \frac{x_1 + x_2}{n_1 + n_2}$$

x_1= Number of pedestrians who looked at PDU at Site 1
x_2= Number of pedestrians who looked at PDU at Site 2
n_1= Sample size observed at Site 1
n_2= Sample size observed at Site 2
$\hat{p}_1$= x_1/n_1= Proportion of pedestrians looking at PDU at Site 1
$\hat{p}_2$= x_2/n_2= Proportion of pedestrians looking at PDU at Site 2
$\hat{p}$= Combined proportion of pedestrians looking at PDU from both Sites

Substituting the values into the above equations gives a z value of -3.219. This relates to a probability of 0.0006.

The probability of obtaining the results from Site 2 assuming the null hypothesis is true, is 0.0006= 0.06%. This is much lower than the significance level (α) and therefore the null hypothesis can be rejected and thus the alternative hypothesis is accepted. The full calculations can be seen in **Error! Reference source not found.** in section **Error! Reference source not found. Error! Reference source not found.**.

3.6.3.2.   Binomial test
Another way of calculating whether or not the data from Site 2 was significantly different from Site 1 is by using the binomial distribution to calculate probability of obtaining the data from Site 2 with Site 1's proportion. The assumed proportion is the proportion of people looking at the PDU at Site 1 ($\hat{p}_1$), this is 0.375. Since it is assumed $\hat{p}_1=\hat{p}_2$, the expected number of people looking at the PDU at Site 2 (K_1) was $\hat{p}_1$ multiplied by the sample size from Site 2, n_2:

$$K_1 = \hat{p}_1 * n_2 = 0.375 * 34 = 12.75 \approx 13\ People$$

The actual number of pedestrians looking at the PDU at Site 2 (K_2) was included as part of the recorded data. The actual value was 25 people.

Like the two proportion z test, a significance level (α) has to be chosen. The chosen value is 5% or 0.05. Using the binomial distribution, the probability of getting 25 or more successes out of a 34 person sample size where it is assumed that there is a 0.375 probability of success was calculated.

$$P(x \geq 25) = P(x = 25) + P(x = 26) + P(x = 27) + \cdots + P(x = 34)$$

Where:

$$P(x = K_2) = \binom{n_2}{K_2} \hat{p}_1{}^{K_2} (1 - \hat{p}_1)^{n_2 - k_2}$$

This was done in Excel by doing 1-P(x<25) using the function:
=1-BINOM.DIST(24,34,0.375,TRUE). The TRUE command ensured that the probability was cumulative and the probability of each value was added up. From the calculations:

$$P(x \geq 25) = 0.0000214$$
$$P(x \geq 25) \ll \alpha$$

The probability of obtaining the results from Site 2 assuming that $\hat{p}_1 = \hat{p}_2$ is much lower than the significance level. Therefore it can be assumed that the null hypothesis is incorrect and that these data is significantly different enough for the alternate hypothesis to be accepted.

3.6.4. Issues with the P test method

Hypothesis testing has two main different schools of thought on how they should be approached. The method used in this report that involves rejecting and accepting null and alternative hypothesis was popularised by (Fisher, 1925) and uses P values. H. Jeffreys was against this method as he says on page 385 (Jeffreys, 1961):

> "What the use of P implies, therefore, is that a hypothesis that may be true may be rejected because it has not predicted observable results that have not occurred. This seems a remarkable procedure."

Jeffreys outlines that the P value allows for hypothesis to be accepted even when the data itself differs from the predicted results. Jeffreys viewed the use of P as paradoxical as it involved comparing the actual data to a predicted set of data to determine whether or not the law/hypothesis p was derived from is true. This is why Jeffreys viewed it as paradoxical, as P is used to prove itself.

Jeffreys does go on to say about the P test on page 388:

> "…it's only justification is that is gives some sort of a standard which works reasonably well in practice, but there is not the slightest reason to suppose that it gives the best standard."

The P test was chosen for the sets of data from Site 1 and Site 2 precisely because of the standardised method that was easy to follow. Furthermore the number of parameters collected in the data was fairly low and the huge discrepancy between the sites made it so that the significance test produced definitive results and clearly

indicated that the 2 sites were operating on different conditions. $\hat{p}_1$ most definitely does not equal $\hat{p}_2$.

4. Conclusions

From the literature review, information was found outlining the exact sizing of a puffing crossing, the placement of the PDU pole and the reasoning behind why it has to be set a certain distance back and finally the size of individual components used in a puffin crossing, such as the tactile paving tiles and the kerb blocks. This was outlined in section 2 Literature review.

Information on the comfortable field of view for all pedestrians was established using medical studies. This was calculated to be 114° with no head movement with an extra 40° added on to either side to account for comfortable neck twist.

From the literature review, enough information had been gathered to draw a puffin crossing layout and calculate exactly where a pedestrian could and could not stand in order to comfortably see the PDU. This was the first objective of this project.

Two main sites were identified in Plymouth which could were used to carry out surveys at. The sites themselves mostly conformed to the guidelines written by (Ladyman & Allister, 2006) however Site 2 was slightly different and had the PDU placed more towards the kerb, resulting in a smaller blind zone. These sites could now be used to determine where pedestrians tend to stand when crossing the road. The second site could be used to determine whether or not a smaller blind zone would increase the visibility of the PDU and increase the number of pedestrians looking at it. This was part of the second objective.

The surveys were carried out and some main conclusions were formed:
- Pedestrians tend to use the tactile paving or kerb as an indicator as where to stand. This was shown in section 3.2.1 Site 1: Cobourg Street where pedestrians were noted to be standing very close to the edge and also the data shows much more people standing on the front row of tiles.
- Site 1 with the larger blind zone, showed mostly people standing inside the blind zone and not looking at the PDU before crossing.
- Site 2 showed the opposite, with more people looking at the PDU.
- Using significance tests, it was determined that the data from both sites is statistically different.
- Since the data statistically different, the data from Site 2 was determined to be caused by the smaller blind zone and more visible PDU though the demographic of pedestrians at Site 2 may have played a role in the different results.
- Main conclusion of the report and survey is that reducing the blind zone increases the PDU visibility, results in more pedestrians looking at it and therefore a safer and easier to use puffin crossing

4.1. Guidelines for placement

The PDU needs to be placed closer to the kerb in order to reduce the blind zone and increase the number of pedestrians looking at it. The PDU should be placed such

that at least half of the tile to the left of it is in the visible zone. This means that only pedestrians who stand dangerously close to the kerb will be in the blind zone. The PDU should remain 0.5m horizontally from the crossing; this will keep it in arms reach for pedestrians but also won't get in the way when pedestrians are trying to walk across. Since moving the PDU closer to the kerb will make it more difficult to press the button for some pedestrians such as mothers as their prams will be too
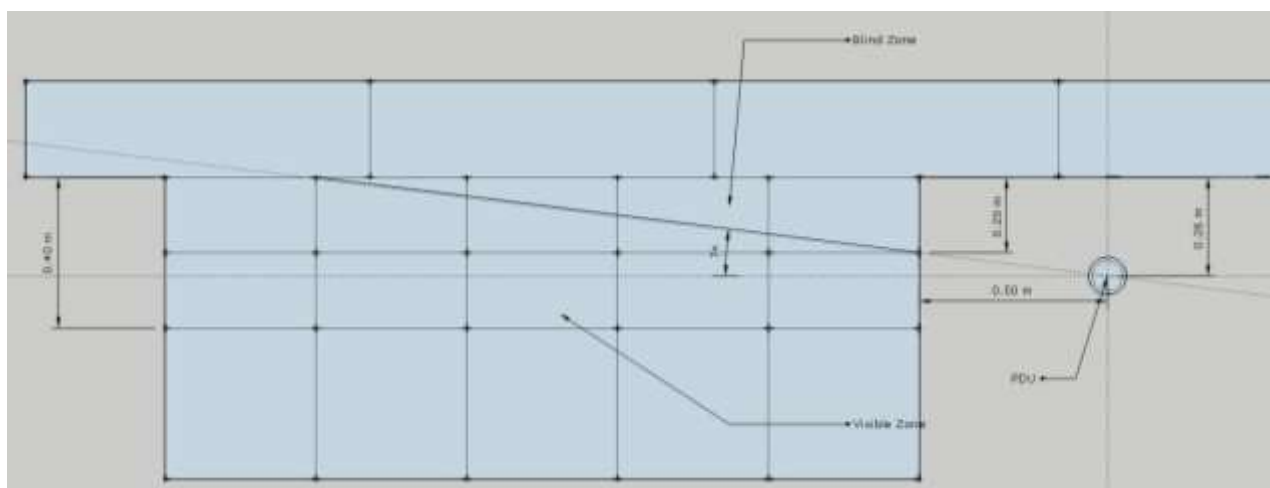
Figure 13: Recommended PDU placement

close to the edge of the road, it is advised that the PDU and pushbutton module are separated and the pushbutton module placed on a smaller pole and kept 0.5m back from the edge of the kerb.

Figure 13 shows the recommended placement of the PDU. With this layout, most of the first tile to the left of the PDU is in the visible zone. The PDU is place 0.26m back from the edge of the kerb. This is 0.515m back from the edge of the road when the wide variant of kerb block is used. A minimum clearance of 0.45m between the signal head and the edge of the road should still be kept; this can be achieved by using brackets or cranked poles.

Since mounting the signal head, the PDU and the pushbutton on the same pole can create problems as all three components need to be a different distance from the edge of the road, it may be better to mount 3 separate poles for each component in order to keep the correct distances. The pushbutton would be mounted the furthest back so pedestrians can easily reach it without stepping too close to the road. The signal head would then be mounted second in order to maintain the minimum clearance with the road and so that it does not overhang into the road and interfere with passing traffic. Finally the PDU will be mounted closest to the road, facing back into the pavement in order to give the maximum visible zone and be easy to see.

(Ladyman & Allister, 2006) in Puffin Crossings: A Good Practice Guide says:

> "DfT guidance is to set PDUs and PBs on poles with a minimum of 500mm clearance from the kerb face but some authorities provide a second (usually short) pole and PB on the left hand side of the crossing set back 800mm from the kerb face to assist motorised pedestrians and wheelchair users. There can be problems locating the pole in the correct position and setting the pole with up to 600mm clearance works well in practice."

I would recommend that this is changed to include:

- The signal head pole is placed such that the signal head has a 0.45m clearance with the edge of the road.
- The PDU is placed no more than 0.26m from the kerb face in order to maximise visibility to pedestrians.
- The pushbutton should be placed 0.6m from the kerb face to maximise accessibility and to make it easier for motorised pedestrians, wheelchair users and mothers with prams to press.
- All three components (signal head, PDU and pushbutton) can be mounted on separate poles that may be cranked or use brackets in order to achieve the correct clearances.

5. Recommendations for further development

This project provides many paths for further development and work. Since the survey only covered two sites in Plymouth, there could be more surveys carried out across more sites all over the UK. These surveys could also record the exact placement of the PDU in order to see how many sites comply with regulations. The increased number of sites will also increase the range of demographic of pedestrians observed.

Another area that could be investigated, is having cranked poles for the PDU that branch off the pole that holds the signal head. Some basic structural analysis would need to be carried out in order to determine whether or not the pole would remain upright and be able to withstand pedestrians leaning on it. A finite element analysis (FEA) may be carried out for a clearer idea of the maximum and minimum stresses.

Many people are still used to the pelican crossings where the red and green men were on the far side of the road. This setup allowed for them to be visible regardless of where the pedestrians stood. Public information and how children are taught to cross the road may need to be looked into to ensure the puffin crossings are properly explained and that the PDU should be prioritised as the primary indicator as when to cross.

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Appendices can be seen in Supplementary files in the list of Article Tools.