DSB105

Noise map of section ‘C’ of Loughborough university campus

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Introduction

Noise maps are used to assess the sound pressure levels in a given environment. They serve to illustrate and identify areas with high noise levels which, overlaid with a floor plan of the area, gives stakeholders a graphical representation of the distribution of noise in that environment.

Region ‘C’ of the Loughborough University campus (see Appendix A) was to be examined within a 3 hour time period, and through the collection of data from predetermined locations, produce a reasonably accurate contour map of the noise environment.

The purpose of this report was to record the noise level of a section of the campus’ outdoor environment, comment on any notable features and, if necessary, use our data to suggest reasonable adjustments to make noise pressure levels more acceptable to minimize the potential for annoying individuals in the area and keep within the legal threshold for noise level.

Method

The method was decided upon in order to comply with the guidelines as set out in BS EN ISO 28802:2012, and BS EN ISO 9612:2009 (British Standards Institute, 2009, 2012).

Apparatus

Dosimeter (LD Soundtrack LxT) - records the noise level within the proximate environment and provides multiple measures, such as peak volume and average volume levels with C and A weightings applied respectively

Tripod - consistently holds the dosimeter in place, upright and level while taking recordings

Wind baffle - prevents wind from interfering with the dosimeter and distorting the results

Whirling hygrometer and psychrometer chart - temperatures were taken from the dry bulb (direct measurement of air temperature) and the wet bulb (the air temperature minus the heat lost through evaporation) of the hygrometer to calculate the relative humidity using the psychrometer chart

Pencil, paper and camera - used to record and backup data from the dosimeter

Precision Acoustic Calibrator (CAL 200) pistonphone - calibrates the dosimeter by emitting 94.0 or 114.0 dB at 1000Hz (larsondavis.com) (see Appendix C)

Software - Photoshop CS5, ArcGIS 10.3.0.4322, SPSS 22.0.0.2

Procedure

Initial Planning

1. Section ‘C’ was selected from the campus map (see Appendix A).
2. The area was found on Google Maps, and was zoomed until an appropriate scale marker was available. This scale was used in Adobe Photoshop to make a grid overlay with 20x20m squares for the map.
3. 3 minutes of recording time at each point was decided to be a good balance between getting a representative sample at each point and allowing for good coverage of the area with a number of points.
4. It was estimated that approximately 6 minutes would be spent per location, including travel, setup and recording results. With the time limit of 3 hours, this allowed for an absolute maximum of 30 points, however it was decided to be conservative in case something went wrong and/or measurements had to be retaken.
5. Choosing points in a grid pattern with 60m (3 squares) between locations resulted in an even coverage of most of section ‘C’ with reasonable resolution in under 20 points.
6. Once these main points of measurement were chosen (highlighted in red), more locations were added at the vertices of section ‘C’ that were not already covered, to replace the location that would otherwise be inside, and at locations of interest such as the other side of a building from the road and by a group of large machines. 7 points were added in this fashion (highlighted in yellow).
7. The route of measurement was chosen to minimise backtracking on the test day (see Appendix B)

Setup

1. The dosimeter’s data was cleared from previous use to avoid confusion with the new data
2. The dosimeter was set up to record daily equivalent noise level in dBAS (A-weighted with a slow sample rate) and peak noise level in dBC.
3. The dosimeter was fixed to the tripod, pointed straight up to avoid lateral bias in readings and the tripod was extended to so that the height of the top of the dosimeter was 1.65m
4. The dosimeter was calibrated using the pistonphone at 94dB.
5. a data sheet was drawn up to record both objective and subjective data. Sections for dBAS, dBCpeak and a subjective annoyance scale were created.

Data Collection

1. The first point was travelled to immediately after collection and calibration of the equipment.
2. Once the dosimeter was prepared to start recording data, the start button was pressed by one researcher while another started the timer. Immediately after, the researchers quietly moved approximately ten meters away and remained quiet for the three minutes of measurement. During this time observations were made on the surrounding area that may have affected the noise levels.

3. When the timer was approaching the three minute mark the researchers would quietly moved closer to the dosimeter, in preparation to stop the recording.
4. Once the recording had been stopped, the researcher noted the dBAS (equivalent daily noise level) and the dBCpeak (highest decibel level recorded)
5. After the objective recordings, the subjective annoyance of the noise at the location was marked on a continuous scale from 1 to 10 by each researcher, which would later be converted into a percentage.
6. Once all the data was recorded from a specific location the recording screen was reset ready for the next point.
7. This process was repeated for all 26 points of measurement except location #12, which was a restricted area.
8. The relative humidity was measured and recorded at 2:56pm at point 7 using a whirling hygrometer and psychrometer chart to determine the score.

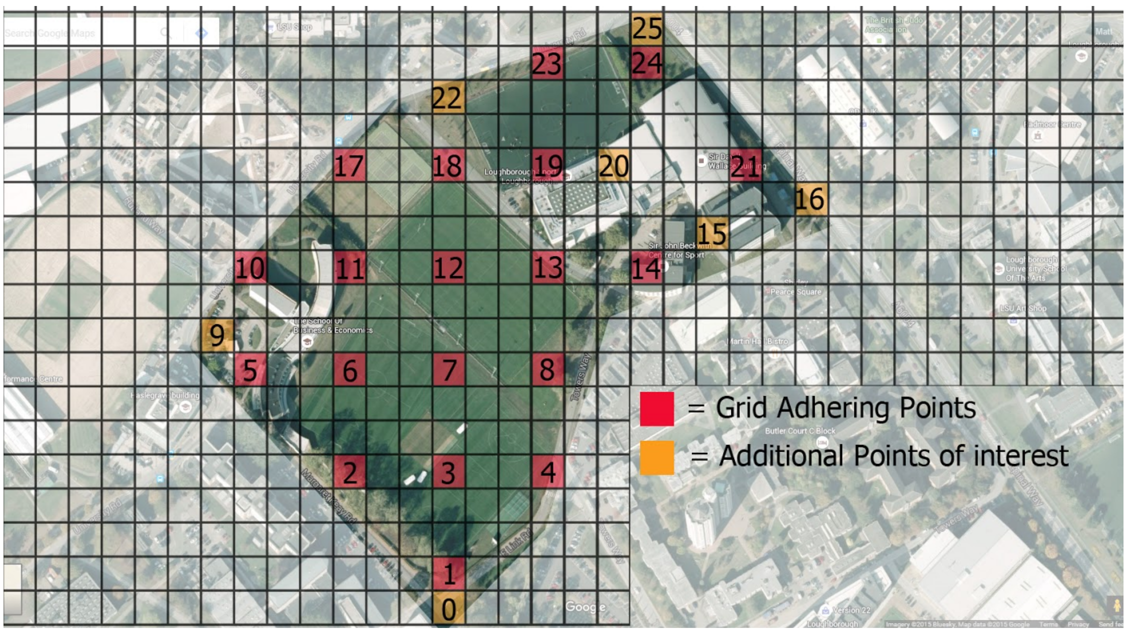

Figure 1: map of planned measurement locations

The data was interpolated by ordinary kriging with a gaussian semivariogram model rather than more simplistic inverse distance weighting (IDW). The geostatistical method was favoured based on recent research done by Taghizadeh, Zare and Zare (2013), which suggests that it provides more accurate predictions of unmeasured points than IDW or kriging with a different model. Other researchers have also used the method for noise mapping in a built environment (Tsai, Lin and Chen, 2009), contributing to its credibility for this purpose. These researchers describe kriging as “the most widely used geostatistical interpolation method”). For this study, the interpolation was done using ArcGIS.

Results

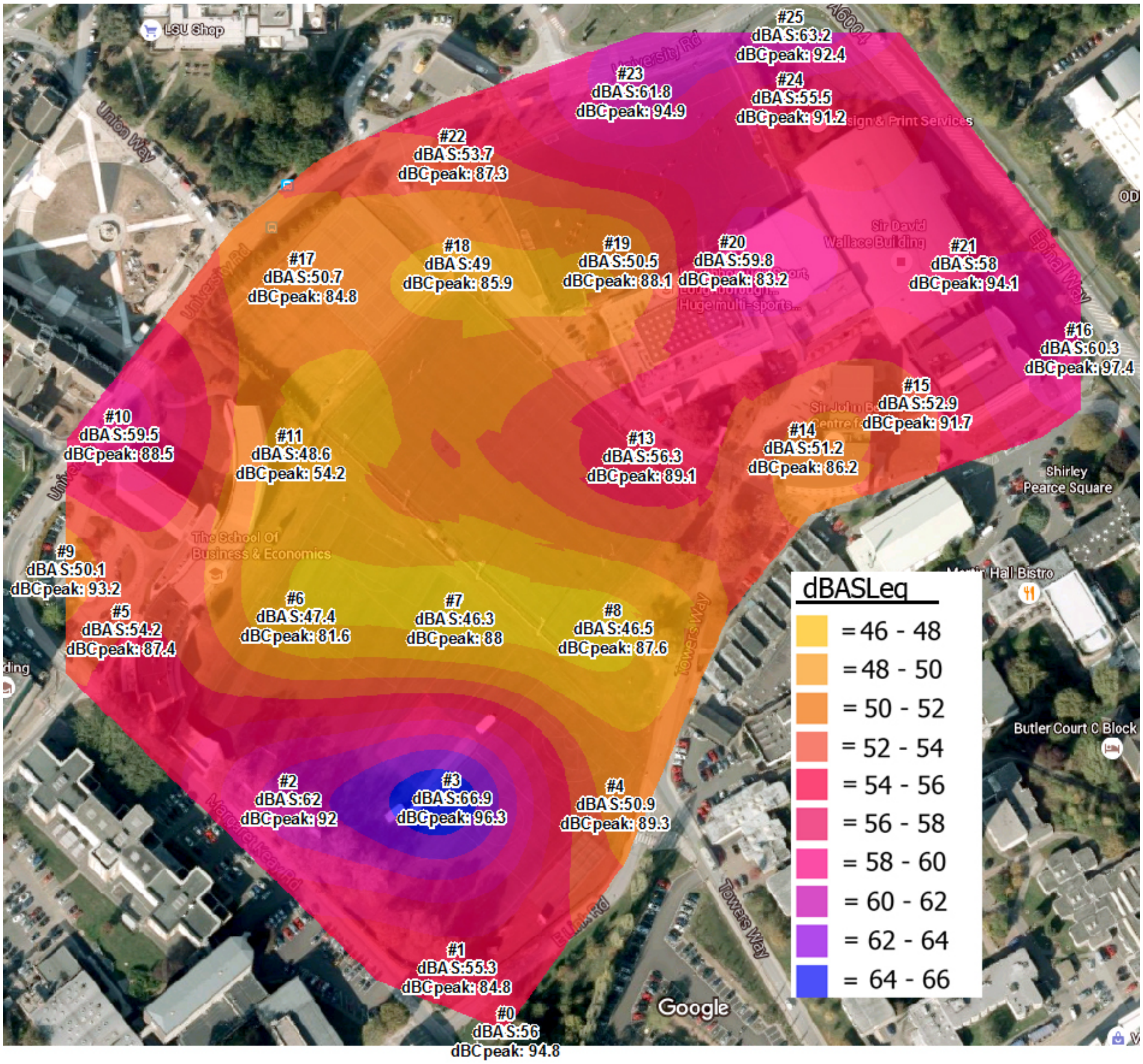

Figure 2: A-weighted noise map of a section of Loughborough campus

Having used the kriging method for the data in ArcGIS, the output was the noise map for section ‘C’ as seen in Figure 2. The location with the highest daily equivalent noise value is at point #3, at 66.9dBAS. For this recording, there was a lawnmower being operated within approximately 10m of the microphone for the majority of the 3 minute recording time, which would have greatly increased the noise level. This is not a continuous event, and so the results would not always look like this. This type of gardening happens almost exclusively when the sports pitch is not being otherwise used, and as only a small patch of a cricket field was the target of the gardening, the noise source remains around 50m away from the closest used path. As such, it is not expected to have too great an effect on other people. The operator of the lawnmower wore ear protection, minimising any negative impact on him. As is visible from the noise map, this spike of level on the field is relatively isolated (and a significant drop in volume was noted by the researchers when the lawnmower was switched off), although it does extend slightly toward location #2. While recording at location #2, a strimmer was being used along the hedge next to the path within approximately 20m from the dosimeter. Although again not a continuous event, this took place only a few metres away from pedestrians on a highly frequented pathway. Even while among the loudest locations inthe area covered, these do not come close to the action limit of 80dBALeq (daily equivalent noise level) (HSE), however they may be annoying for nearby people, as will be discussed later. As only one set of measurements were taken, these will have greatly increased the overall mapped level in the South-West of the map. As seen around locations 6-8 and 11, the fields were otherwise mostly quiet, with the lowest noise level for section ‘C’ being 46.3dBAS at #7.

Approaching the South-East road, the noise level increases slightly; there is a modest rise as one approaches the South-West and North-West roads, and near to the public North-East road is the largest area of high noise. The locations #24, #21 and #16 were recorded with the dosimeter between the road and buildings. As such, the levels there may have been contributed to by noise reflected by the buildings. Most of the area used near the road is inside, and so should be largely isolated from its noise, and much of the interpolated noise will likely be reflected before reaching there. One area for which the noise would not be reflected is the 3G field around #19. This area is between the junction of two continuously used roads and the large machines with fans at #20, with buildings that reflect the noise from both back onto the pitch, leading to one of the loudest areas of continuous use by university members. Also affected by the buildings in the North-East are #14 and #15, which, at around 8dB lower than the main road, appears to be sheltered by those buildings.

Because of the route taken, #18 and #13 were taken with a large time-gap in between. As a result, #13 was measured closer to rush hour, and the extra traffic caused a skew in the data that resulted from a non-spatial factor.

Peak noise is consistently between 80-100dBC, except for #11, which has an unaccounted for aberrantly low dBCpeak of 54.2.

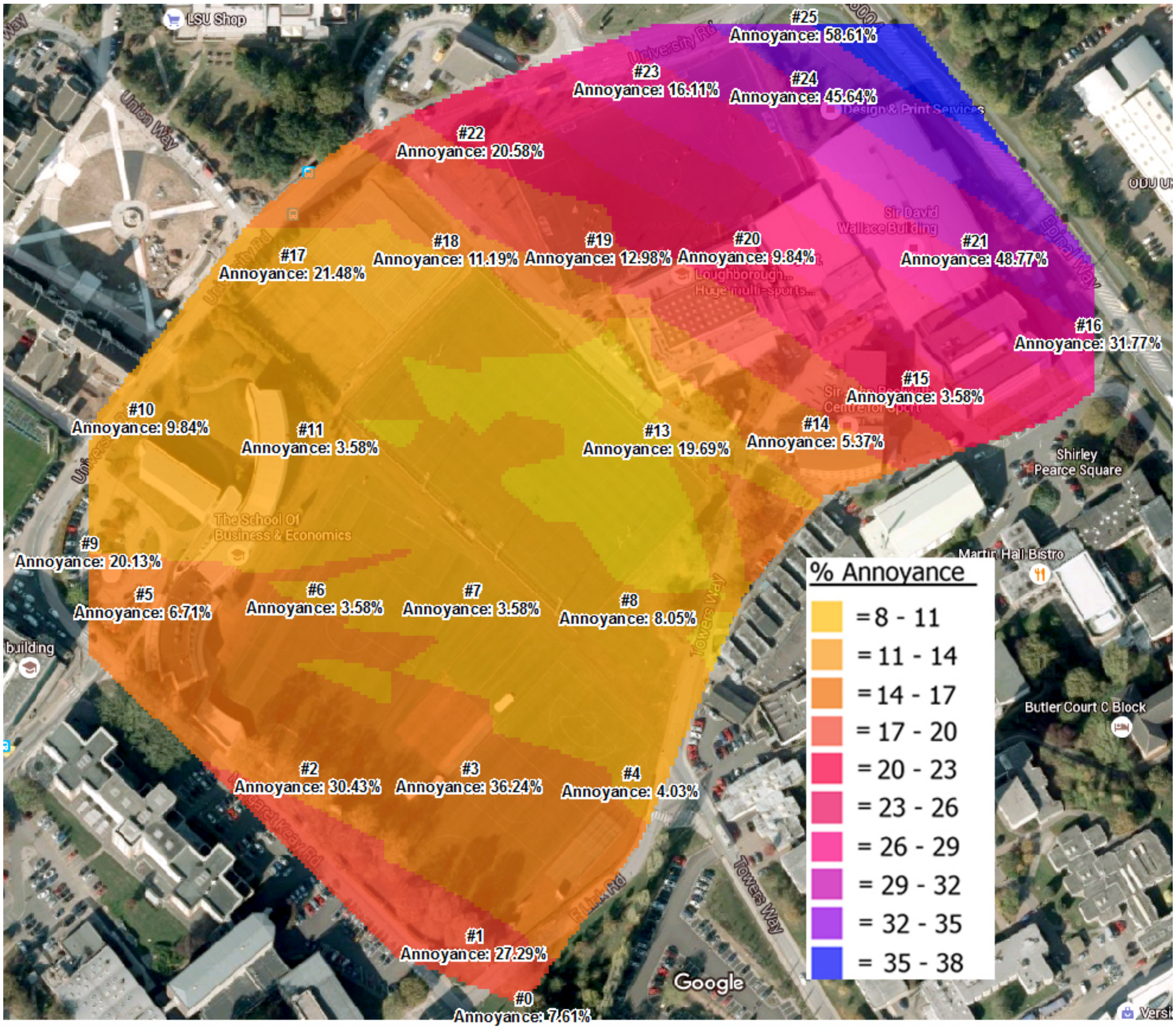

Figure 3: Annoyance map of section 'C', created with a kriging method

Figure 3 was also created via kriging as well so that a direct comparison could be made with the noise map, and as seen the areas of annoyance broadly match up with the areas of high noise level. The fields are quiet and annoyed the researchers very little, while the South-West and North-East roads were louder and caused more annoyance. Due to the way kriging works, the numerical values at some points do not match the colour band they are in. This is clear at #13, #14 and #15, where the numerical values match those of the noise map much more closely than the map contours. In this map, the kriging also brought the extreme values closer to the middle than the measured values to minimise the effect of outliers, which likely includes #25. The place of most annoyance that is also frequently used by members of the university is the 3G field next to #24, this matches with the noise level in the area as discussed above.

The weather on the day of recording was overcast with low cloud cover and little wind, which remained unchanged for the all 3 hours that were spent recording data. The measured dry bulb temperature (equal to air temperature) was 10.25℃ and the wet bulb was 9.5℃, which, using the psychrometer chart, correspond to a relative humidity of 95%. This would be expected to minimise the attenuation of noise (Harris, 1966) and so provided a ‘worst-case’ set of results in terms of weather.

Statistics

		dBASLeq	dBCpeak	Mean annoyance (%)
N	Valid	25	25	25
	Missing	1	1	1
Mean		54.6640	88.1600	18.6667
Median		54.2000	88.5000	12.9754
Std. Deviation		5.65714	8.19741	15.63571
Minimum		46.30	54.20	3.58
Maximum		66.90	97.40	58.61

Table 1: basic descriptive statistics for the noise and annoyance in section ‘C’

The maximum measured values for the dBASLeq and the dBCpeak are well below the lower action values of 80dB and 135dB respectively for workplaces (HSE). The fact that the median annoyance is lower than the mean annoyance suggests a positive skew in the data. See Appendix D for raw data.

Correlations

Before attempting to determine a correlation between the equivalent daily noise level and the mean annoyance at each location, it was necessary to ascertain if both datasets were normally distributed. SPSS was used for both of these tasks. It was calculated that while the noise level can be considered normal, the mean annoyance level cannot (see Appendix E for details). As a result, a nonparametric test must be used to determine the existence of correlation between the two variables, namely Spearman’s rho. The correlation coefficient between the dBAS value and the mean percentage annoyance was 0.637 ($p<0.001$). This would be considered a ‘moderate’ correlation by Malawi (2012).

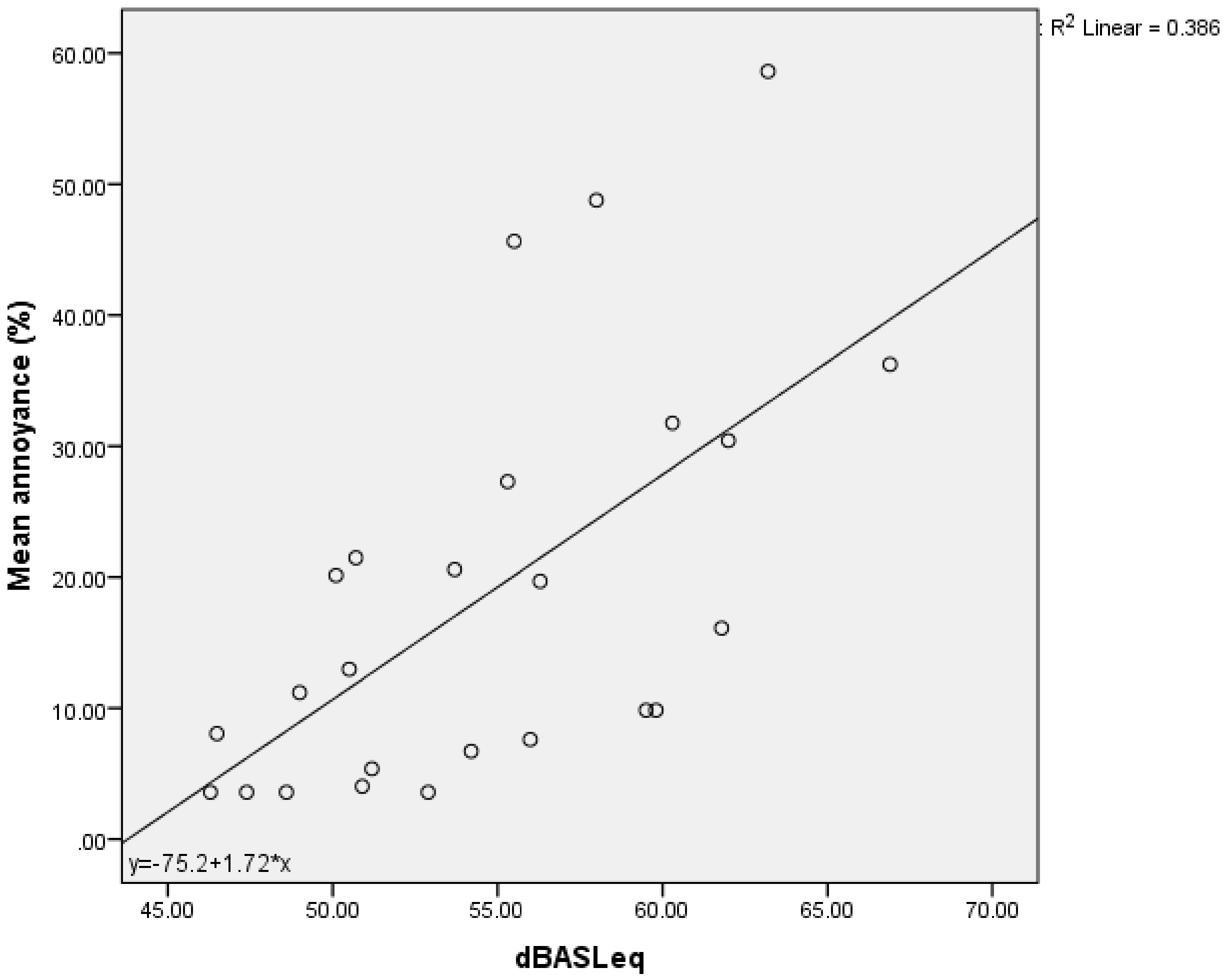

Figure 4: scatterplot with regression line of daily equivalent noise level against annoyance

As seen in Figure 4, the coefficient of determination R^2 is 0.386, so less than half of the annoyance at each location is accounted for by the noise level. Other factors, potentially including lack of accuracy of the annoyance estimation, will account for the difference.

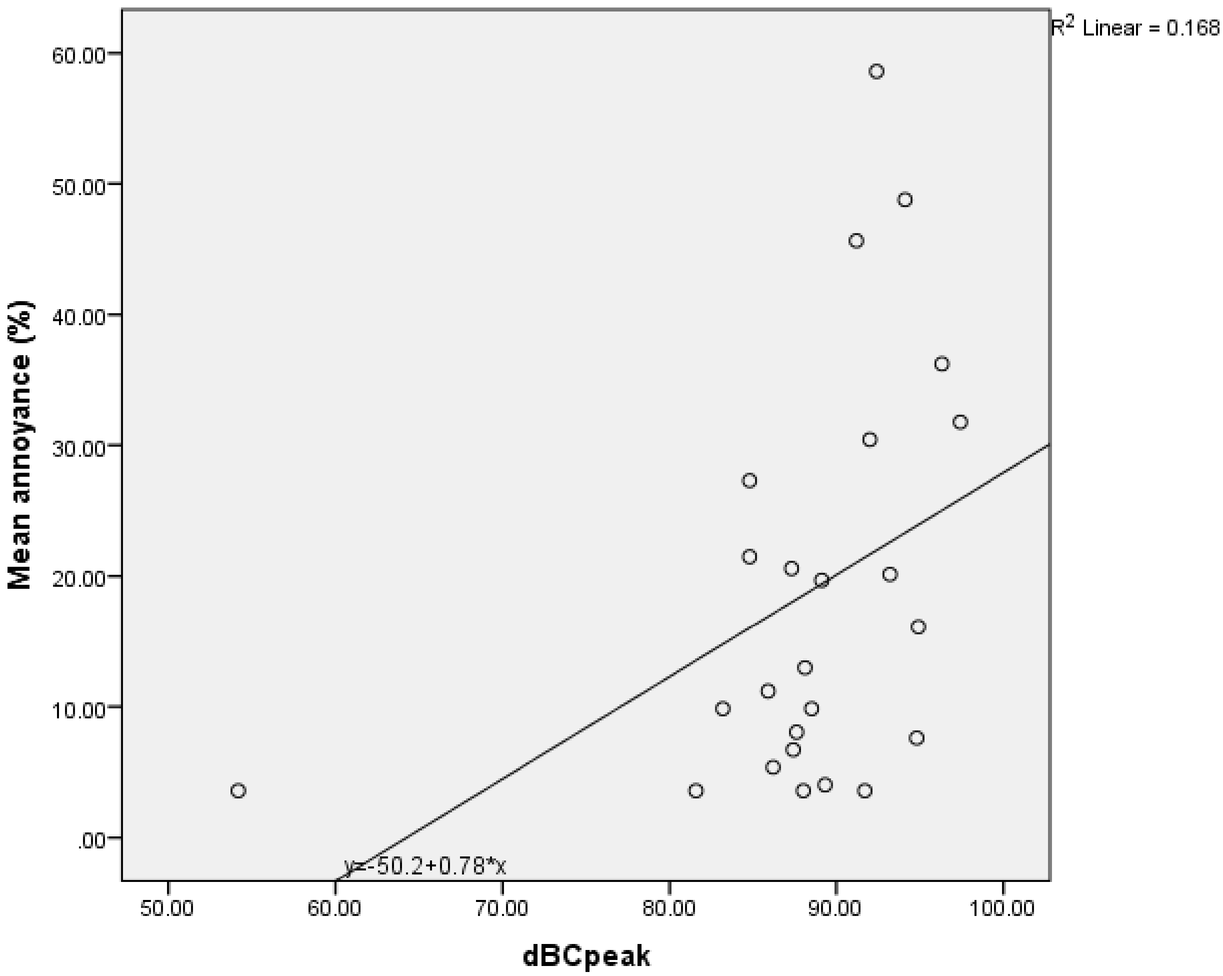

Figure 5: scatterplot with regression line of peak noise level against annoyance

The peak noise level at a location appeared to account for only a minimal amount of the annoyance felt (16.8%, as seen in Figure 5), although the correlation coefficient from Spearman's rho was 0.470 (p=0.018), which would be considered 'low' (Malawi, 2012) .

Discussion

Looking at the results of the research, there were several factors to consider.

Point 12
Point #12 on our designated areas map was located in the university's rugby grounds. Entry was restricted and therefore we were unable to collect data. There was no authority available to grant access, and so we could not collect data for that point.

Gardening & Traffic Levels
Gardening activities were being conducted during the sound collection, this would influence the external validity of the results as ground maintenance is not a daily occurrence.

Traffic varies throughout the day, and this was reflected in the results in that readings on the same road a couple of hours apart differed greatly in noise level. As a result, people operating in areas near roads are more likely to be annoyed by the noise created during periods of high traffic.

Noise maps should preferably account for the whole day, and the best way to represent this is to take readings throughout the day, multiple times per location. However, it was still possible to come to some valid conclusions given the data obtained.

Conclusion

Despite limitations in time, sufficient results were collected to suggest that the noise environment on campus is acceptable. All areas were under a legal threshold for both daily equivalent and peak noise and there is little risk of noise-induced hearing loss from either long or short term exposure.

The annoyance data also correlates moderately well with the noisemap, whereby areas with higher noise levels stimulate more annoyance in individuals, but mostly not to a degree that would warrant adjustments to the campus. It is worth noting, however, that in the Northern 3G field the noise and annoyance levels are higher relative to other areas on campus, and considering the sports field is an area which is typically used for long periods of time, it may need to be addressed to reduce potential annoyance levels. This could be implemented using noise barriers around the field, for example.

References

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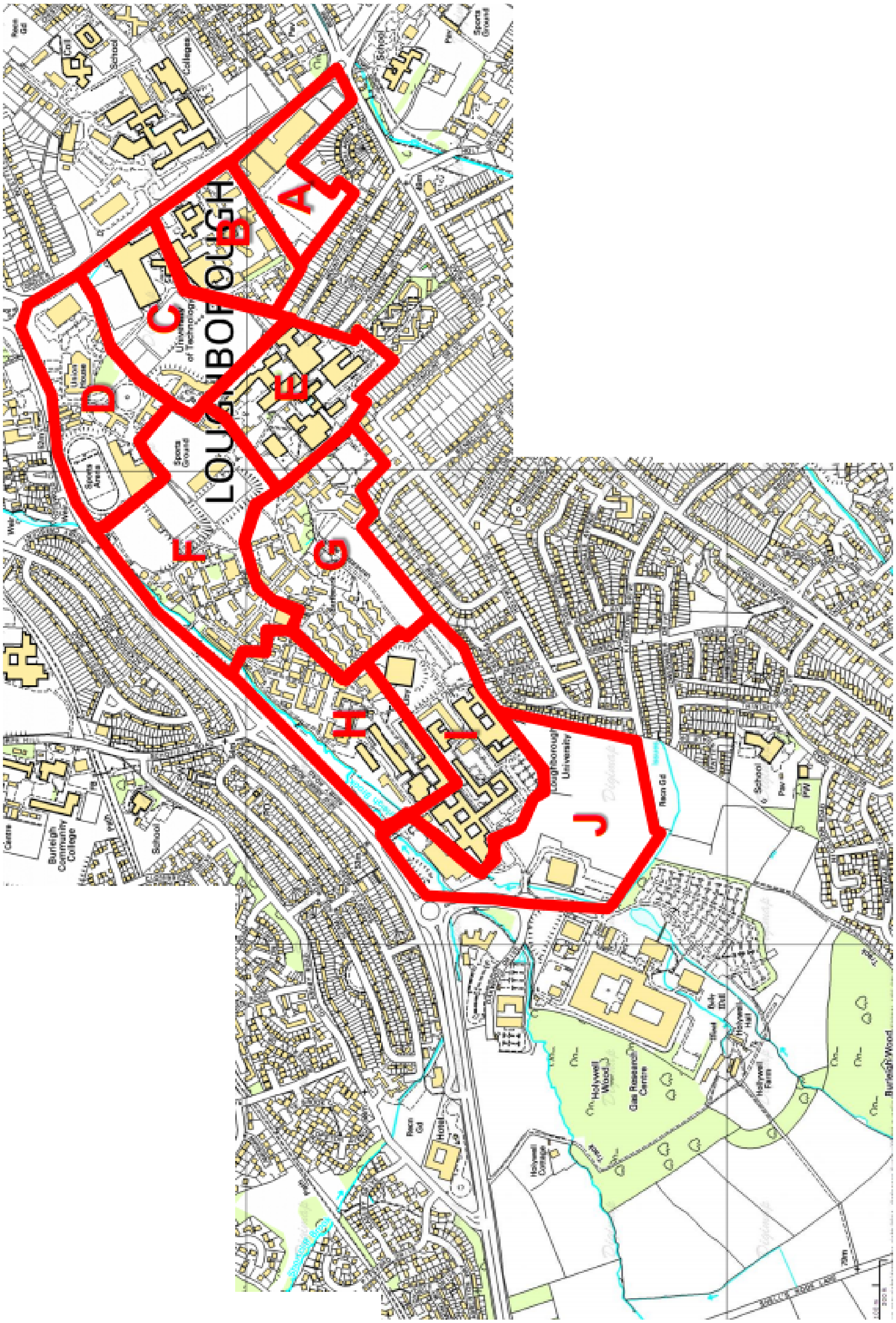
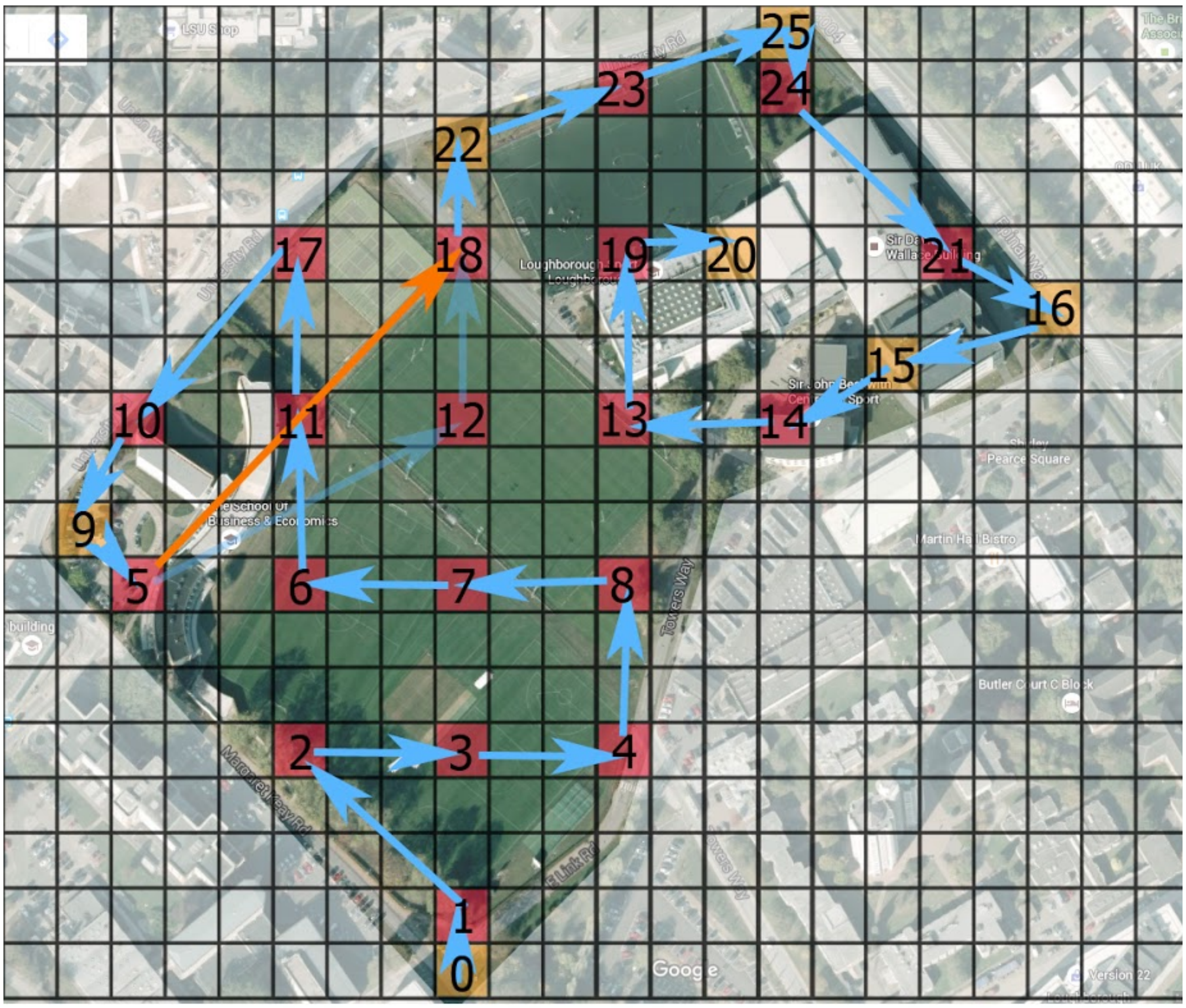
Appendix A: Area 'C' in context of university

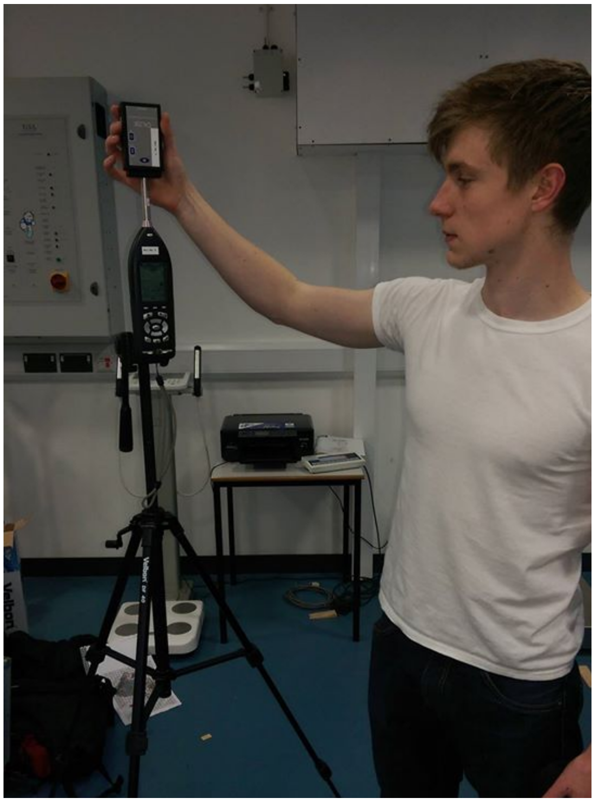


Appendix B: Map to show route taken, against route planned



The planned route is shown in blue, however point 12 was a restricted area, and so had to be bypassed on the day as shown by the orange arrow.

Appendix C: Photos of equipment use

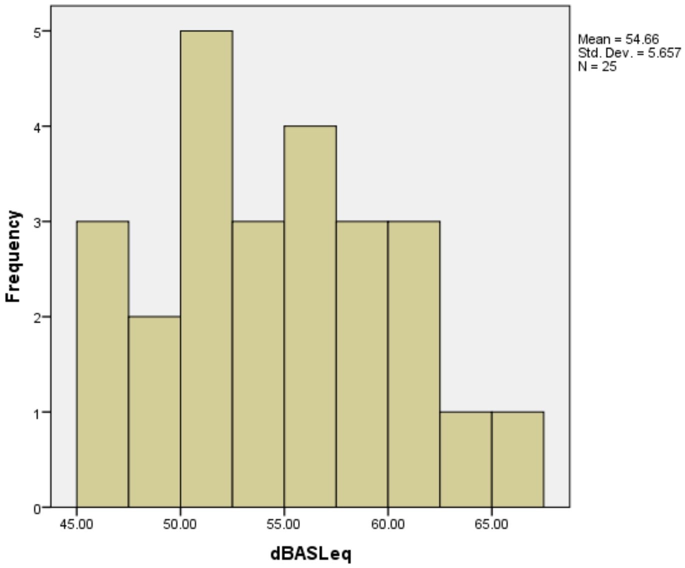


Appendix D: Raw Data

Location	DBAS	DBCpeak	Line Length (mm)	Annoyance J (mm)	Annoyance J (%)	Annoyance A (mm)	Annoyance A (%)	Annoyance M (mm)	Annoyance M (%)	Mean Annoyance
0	56	94.8	149	12	8.05%	18	12.08%	4	2.68%	7.61%
1	55.3	84.8	149	76	51.01%	34	22.82%	12	8.05%	27.29%
2	62	92	149	26	17.45%	46	30.87%	64	42.95%	30.43%
3	66.9	96.3	149	84	56.38%	72	48.32%	6	4.03%	36.24%
4	50.9	89.3	149	10	6.71%	6	4.03%	2	1.34%	4.03%
5	54.2	87.4	149	18	12.08%	12	8.05%	0	0.00%	6.71%
6	47.4	81.6	149	10	6.71%	6	4.03%	0	0.00%	3.58%
7	46.3	88	149	8	5.37%	2	1.34%	6	4.03%	3.58%
8	46.5	87.6	149	8	5.37%	4	17.45%	2	1.34%	8.05%
9	50.1	93.2	149	46	30.87%	26	25.50%	6	4.03%	20.13%
10	59.5	88.5	149	14	9.40%	38	4.03%	24	16.11%	9.84%
11	48.6	54.2	149	2	1.34%	6	4.03%	8	5.37%	3.58%
12	X	X	X	X	X	X	X	X	X	X
13	56.3	89.1	149	26	17.45%	34	22.82%	38	18.79%	19.69%
14	51.2	86.2	149	4	2.68%	16	10.74%	28	2.68%	5.37%
15	52.9	91.7	149	2	1.34%	10	6.71%	4	2.68%	3.58%
16	60.3	97.4	149	32	21.48%	64	42.95%	46	30.87%	31.77%
17	50.7	84.8	149	4	2.68%	40	26.85%	52	34.90%	21.48%
18	49	85.9	149	2	1.34%	18	12.08%	30	20.13%	11.19%
19	50.5	88.1	149	10	6.71%	20	13.42%	28	18.79%	12.98%
20	59.8	83.2	149	22	14.77%	14	9.40%	8	5.37%	9.84%
21	58	94.1	149	74	49.66%	62	41.61%	82	55.03%	48.77%
22	53.7	87.3	149	42	28.19%	40	26.85%	10	6.71%	20.58%
23	61.8	94.9	149	18	12.08%	24	16.11%	30	20.13%	16.11%
24	55.5	91.2	149	64	42.95%	76	51.01%	64	42.95%	45.64%
25	63.2	92.4	149	80	53.69%	88	59.06%	94	63.09%	58.61%

Appendix E: Statistical Analysis with SPSS

Normality testing (α=0.05)

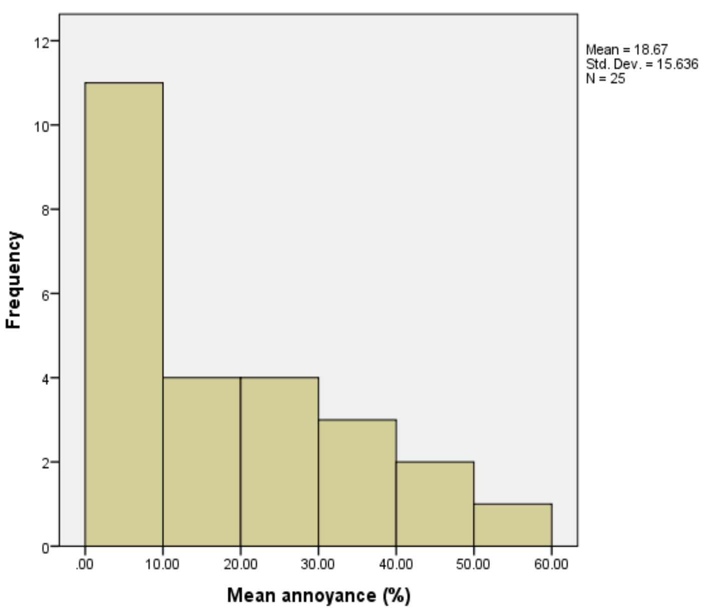


Histogram of noise level recorded

Shapiro-Wilk Results:

Statistic	0.963
Degrees of freedom	25
p-value	0.487

The histogram and the Shapiro-Wilk test together suggest that this data can be used as though it is normally distributed.



Histogram of mean annoyance level

Shapiro-Wilk Results:

Statistic	0.866
Degrees of freedom	25
p-value	0.004

Based both on the shape of the histogram and the fact that $p < \alpha$ for the Shapiro-Wilk, test, this data is not normally distributed.