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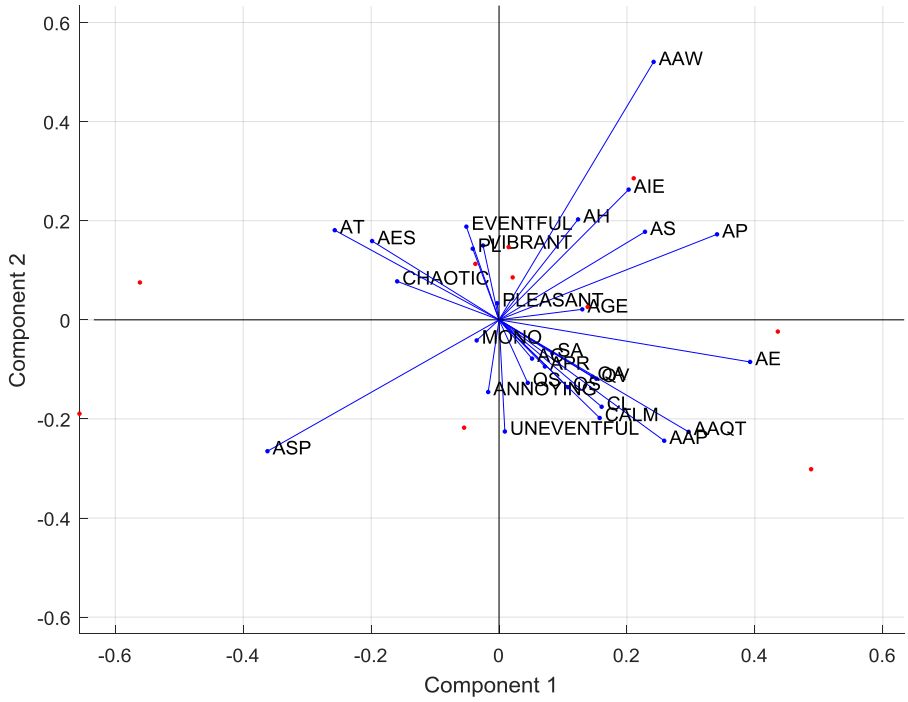

Identification of Acoustic Indicators to Enable Certain Activities

The influence of sound on perception and social interaction in public spaces

Erasmus Project in the Master's program in Sound and Vibration

M.E.DOHMEN

Department of Civil and Environmental Engineering
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CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2017
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Cover:

Principle component analysis, displaying component 1 and 2 with red markers indicating the measurement locations. For more on the principle component analysis, see Chapter 4, Section 4.5.

Chalmers reproservice/ Department of Civil and Environmental Engineering Göteborg, Sweden 2017

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ABSTRACT

Urban spaces are designed to facilitate certain activities. When designing the space, the sound environment is often not considered. However, sound may have an influence on the perception of the space and how a space is used. In this project the relationship between sound, perception and social behavior will be investigated. To do this, a series of sound measurements and questionnaires have been conducted in the center of Gothenburg, Sweden. With these data the relation between the soundscape and the use of a location is investigated. The relation between the various types of perception of a space (overall, visual and sound) has been analyzed. Based on the ratings for the quality of the overall area, visual aspects and sound aspects clusters can be seen of similar locations with the same quality ratings. The quality ratings have little relation to measurable acoustic indicators. However, they do display a relation with activity choice. To create a more complete view of what influences the perception and use of a space, a principle component analysis was made. From this three components can be found explaining 79% of the variance. The three components can be clustered under: tranquil green, socially active and sound level. Indicating that sound has an influence on the perception and use of a location. It is however, not the dominating one.

Key words: sound environment, public space, area quality, activities, principle component analysis

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Preface

In this study the relationship between acoustic indicators, perception and social behavior is studied. Measurements in the form of questionnaires and sound measurements were performed from mid-April 2017 to mid-June 2017. The project is part of an Erasmus exchange program with the technical university of Eindhoven. The project is part of the Department of Civil and Environmental Engineering, Chalmers University of Technology, Sweden.

This project has been carried out with Jens Forssén and Laura Estévez Mauriz as supervisors. All measurements have been carried out in the city of Gothenburg.

I would like to thank Lars Hansson for all the technical support during my research and my friends and fellow students Christin Meier, Almaelisa Giovannucci and Zelin Zong for helping me conduct the questionnaires. I would also like to thank my supervisors. Laura, for also helping me with conducting the questionnaires, and Jens and Laura for helping with the analysis and calculations. I would not have come this far on my own.

Eindhoven, June 2017

Maud Dohmen

Notations

Roman upper case letters

AAP	Activity parks and trees
AAQT	Activity quietness
AAW	Activity watercourses
AC	Activity cultural heritage
AE	Activity escape stress
AES	Activity vibrant street life
AGE	Activity group exercise
AH	Activity hang out
AIE	Activity individual exercise
AP	Activity picnic/BBQ
APR	appropriateness of the sound to the environment
AS	Activity socialize
ASP	Activity shopping
AT	Activity travel
Bi	Center frequency of the 1/3 octave band i
BT	Location 7 Botanical garden
CI	Confidence interval
CL	Cleanliness
DK	Location 2 Domkyrkan
E	Eventfulness
G	Center of gravity of the spectrum
HK	Location 6 Hagakyrkan
JT	Location 9 Järntorget
KPM	Kungsparken waterside
KPM cloud	Location 4 Kungsparken waterside cloudy day
KPM sun	Location 3 Kungsparken waterside sunny day
KPR	Location 5 Kungsparken roadside
L_{Aeq}	Equivalent sound pressure level A-weighted
L_{den}	Day-evening-night level

LDF	Loudness diffuse field
L_{eq}	Equivalent sound pressure level
Li	Unweighted sound level in dB of frequency i
L_{max}	Maximum sound pressure level
L_{min}	Minimum sound pressure level
L_n	Percentile value n%
OP	Location 10 Odinsplats
OS	Organization of the surroundings
P	Pleasantness
P10	L10, percentile value
P5	L5, percentile value
P50	L50, percentile value
P90	L90, percentile value
P95	L95, percentile value
PC	Principle component
PCA	Principle component analysis
PL	Perceived loudness
QA	Overall area quality
QS	Sound quality
QV	Visual quality
RS	Location 8 Rodasten
SA	Safety
TG	Location 1 Trädgårdsföreningen

Roman lower case letters

a	Annoying rating
ca	Calm rating
ch	Chaotic rating
dB	Decibel
dBA	A-weighted decibel
e	Eventful rating

m	Monotonous rating
p	Pleasant rating
u	Uneventful rating
v	Vibrant rating

1 Introduction

Urban spaces are designed to facilitate certain activities. When designing the space, the sound environment is often not considered. However, sound may have an influence on the perception of the space and how a space is used. In this project the relationship between sound, perception and social behavior will be investigated. To do this the concept of soundscapes will be used. The soundscape is the acoustic environment understood or perceived by people within a specific context"(Jeon & Hong, 2015).

The intention is to place activities within the urban environment into the frame of soundscaping. What sounds are needed or need to be avoided when a space is designed for a specific activity? Is this possible to predict?

The ultimate goal is to find sound indicators, physical measurable values, to relate to activity choice. In that way a tool can be provided to urban planners to design a holistic environment where visual and sonic components are coherent and serve the activities that are designed to take place at the location.

To come to this, the following research question is used:

What is the influence of different soundscape attributes on the perception of an urban space and the social activities/behavior within it?

With the sub questions:

- What is the relationship between the overall quality, visual quality and sound quality?
- Are there clusters to be recognized, i.e. are there locations with similar quality ratings and therefore also similar activities?
- What is the relation of these clusters to physical quantities?
- What is the relation between activities and physical quantities?

This report begins with a literature study on soundscapes, their components, their connection to the urban environment and their effect on people and behavior in Chapter 2. Chapter 3 elaborates on the method of making the questionnaires, performing the measurements and the base used for the analysis of the results. In Chapter 4, a summary of the questionnaire and measurement results will be given per location. Later in the chapter, the results will be compared to each other and the results will be discussed. Chapter 5 contains general remarks about the project and the method. Finally a total conclusion is drawn in Chapter 6, were the research questions will be answered.

2 Literature Study

2.1 Current regulations

The acoustic environment in urban areas is controlled in regulations with a maximum allowed level. In most cases first the design is made and then checked against the regulations that apply. However, regulations only apply to the facades of residential buildings (and in some cases open space, such as a garden, which is connected to the house). This limits the possibilities to design a sound environment which would suit the desired activities of the urban space. By introducing regulations in the form of a maximum level (or by using the concept of soundscapes) also for non-residential spaces, the quality of the urban environment can be improved.

2.2 Why use soundscapes?

To make a complete design for urban spaces the auditory and visual perception of the space needs to be coherent and these factors have to support the intentional use of the space. By just following the sound levels in regulations this result will most likely not be achieved. A soundscape is more specific and can be tuned to the use of the space. It not only considers level but also the types of sound sources and psychoacoustic parameters (Yang & Kang, 2005). Depending on the use of the space different types of (desired) soundscapes can be defined (Aletta, Filipan, Puyana Romero, 2016):

- Background soundscape, the soundscape does not contribute to the experience of the space. The sounds should not be noticed. For example, a busy square.
- Supportive soundscape, the soundscape supports the function of the space, congruent with the vision of the space. For example, a park.
- Focused soundscape, the soundscape is the reason of being in the place, the acoustics are important. For example, an amphitheater.

In a background soundscape the sound will be processed in a holistic way, it is considered as a whole. When only background noise is considered, no specific event can be isolated. In a supportive or focused soundscape, a descriptive listening would be the case. Here, the specific acoustic events can be isolated, the interpretation of these sound sources is dependent on psychological and cultural factors (Kang & Zhang, 2010). A specific acoustic event could be church bells, this is a soundmark (the sonic equivalent of landmark in a landscape (Rehan, 2015)), it can be part of the cultural history which defines the city and is therefore appreciated. However, a specific acoustic event could also be coming from a construction site.

2.3 Defining Soundscapes

A soundscape is, as stated before, much more than the maximum sound pressure level. It is influenced by variation in sound level, type of sound source and various psychoacoustic parameters (loudness, sharpness and roughness) (Yang & Kang, 2005). A soundscape can be defined as "an acoustic environment understood or perceived by people within a specific context"(Jeon & Hong, 2015). The context here referrers to: the place/location, the urban morphology, the non-auditory sensations, the social and cultural actors and the personal dimension. Each of these factors will be discussed in upcoming paragraphs.

Axelsson et al defined soundscapes in the form of a classification system with the help of the rating of pleasantness and eventfulness of a location, see Figure 1 (Axelsson, Nilsson, Berglund, 2010).

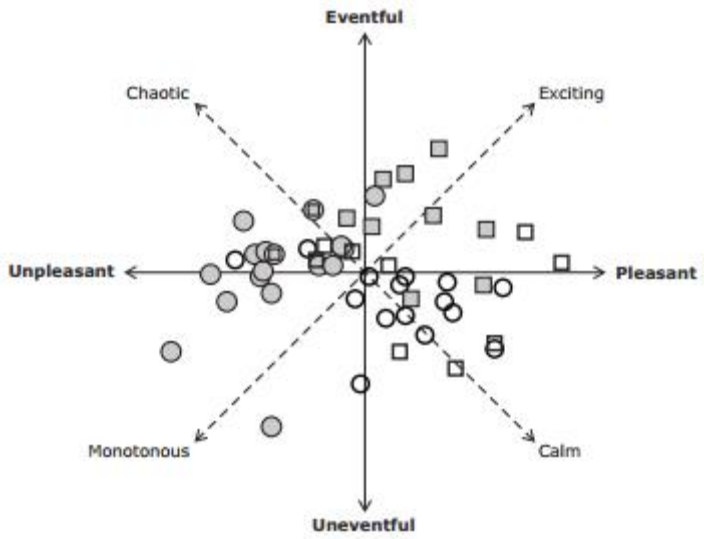


Figure 1. Classification system of soundscapes based on the principle components Eventful and Pleasant (Axelsson et al., 2010)

2.4 Soundscapes and Location

The visual perception of a location and the auditory perception are connected. The pleasantness of the soundscape is related to the overall impression of the location (Hong & Jeon, 2016). However, the perception of sound and visual information are in a constant battle. Attention to the visual form reduces the perception of sound and vice versa (Yang & Kang, 2005). Therefore, it can be said that higher noise levels at a location with a high esthetic quality will be more accepted.

The visual information also provides an expectation for the soundscape (Viollon, Lavandier, & Drake, 2002). If the sound is not appropriate to the visual environment and the intended use, the judgment of the soundscape will be more negative.

The presence of vegetation can also reduce the feeling of annoyance and the perceived noise level. Even though the vegetation is not functioning as a real noise barrier (Farina, 2014).

Based on only visual information, the type of location can be determined by its attractiveness, simplicity, enclosure, harmony and by the fact if it is visually interesting or not (Hong & Jeon, 2015; Jeon & Hong, 2015).

2.5 Soundscape and Urban Morphology

In the case of this research the locations are only assessed locally and not on a larger scale, making the local (visual) impression of the location more important than the urban morphology.

The urban morphology gives the character of a location on a larger scale assessing its building height, building volume ratio, height-to-width ratio, building density, vegetation density, road density and road width (Hao, 2014) or ratio's between buildings and ground area (Berghauser-Pont & Haupt, 2010).

The urban form and the perception of sound are connected in the way that the urban form influences how the sound propagates. The height of the buildings, the variation of height in buildings, roof shape and street layout are among things that influence the propagation of sound (Hao, 2014). A highway can be located far from a location but can still be heard depending on the urban form. Within a street a canyon effect can occur when the buildings are high compared to the street width. A canyon effect is the increase of noise level due to multiple reflections from buildings on both sides of a street. (Echevarria Sanchez, Van Renterghem, Thomas, & Botteldooren, 2016). Such locations were not assessed in this research.

2.6 Soundscape and Non-Auditory Sensations

Meng et al (2013) investigated the effect of environmental factors on the evaluation of the subjective loudness and the acoustic comfort in underground shopping streets. The influence of temperature was found to be insignificant on both the subjective loudness and the acoustic comfort. When perceived humidity, brightness evaluation and visual evaluation were high, the subjective loudness was low and the acoustic comfort was also high

(Meng, Kang, & Jin, 2013). Some of these factors may not apply for the outdoor situations studied in this report. It is expected that the presence of sunshine will also play a role in the evaluation of the soundscape, similar to the effect of brightness in the study of Meng et al. (2013). In this case, the locations under investigation are all located in Gothenburg, which has a relatively cold climate. Based on experience, people will look for places in the sun to do their outdoor activities. However, in warmer climates people will more likely seek shade as an escape from the heat. It is expected that culture differences play a large role in the influence of non-auditory sensations.

2.7 Soundscape and Socio-Cultural factors

As stated above, the effect of climate can be of influence for the evaluation of an environment. Beside this, our previous experience plays an important role with certain locations. We expect a certain soundscape in a certain location, and that expectation is partly based on prior experiences of similar locations. These expectations can differ at each social group or culture (Bruce & Davies, 2014). Comparing a park in India to a park in Gothenburg will be very different.

Other social factors that could influence the perception of the soundscape are: age, gender, education level, income and occupation.

Meng et al (2013) stated that the influence of age was insignificant; Yu et al (2010) did find a correlation between age and the preference of natural sounds. With increasing age the preference for natural sounds also increases (especially for bird songs). For other sounds the influence of age is rather low.

For the education level, it was found that the higher the education level, the lower the acoustical comfort. This is more significant when mechanical sounds are present. People with a higher education level are also slightly more annoyed by noise. A similar thing can be seen for people with a high income, most likely because a high education level mostly ensures a high income (Meng & Kang, 2013).

No significant difference was found in the judgment based on gender or occupation (Meng & Kang, 2013).

2.8 Soundscape and Personal Dimension

Every individual will perceive sound in a different way. The way we perceive sound depends on cultural and social interpretation (Kang & Zhang, 2010). Our sensitivity to noise plays a large role (mainly in annoyance) Farina (2014).

As stated before, there are different ways people listen to a soundscape. Kang et al (2010) describe two types; holistic and descriptive listening. In holistic listening only the background noise is considered and no specific event can be isolated. In descriptive listening specific events can be isolated and the interpretation of these sound sources strongly depends on psychological and cultural factors (Kang & Zhang, 2010). Farina (2014) mentions similar methods of listening with some additional information based on findings from Truax in 1994. Farina (2014) states that there are three levels of listening; listening research, listening readiness and background/distractive listening. Here, listening research and background listening are comparable to descriptive and holistic listening. Listening readiness is described as "*the listener attention is directed elsewhere, but is ready to receive meaningful information*" (Farina, 2014).

Finally the perception of sound is depended on the judgment of appropriateness of the sound and the habituation of the individual perceiving the sound (Farina, 2014).

2.9 Effects of the Types of Sound within a Soundscape

Three categories of sounds can be defined; natural sounds, human sounds and mechanical sounds. The acoustic comfort is greatly related to the type of sound that dominates the soundscape (Brown, 2011;Nilsson, 2007). Nilsson (2007) states that to create a good sound environment, adverse sounds like traffic, should be kept below 50dB. Other sound, which we find pleasant, can have a higher level and the soundscape will still be judged as comfortable (Kang & Zhang, 2010). In terms of loudness and level, we are more tolerant for pleasant sounds.

Soundscapes that are dominated by human sounds are judged more eventful than soundscapes without (Axelsson et al., 2010). Also human sounds affect the adaptation of people more than the natural sounds do; it is hard to not listen to human sounds and make them into background noise. This is because the sound has an application to the listener; the listener could take part in creating the sound environment. Birdsong for example does not have this effect (Viollon et al., 2002). Relaxation in a place dominated by human sound is therefore most likely not possible, because active listening takes place.

The overall preference of the soundscape is positively correlated with natural sounds, negatively with mechanical sounds and there is no significant negative or positive correlation with human sounds (Liu, Kang, Behm, & Luo, 2014). Sounds do have to be appropriate in the overall context in which they are perceived otherwise they are perceived as noise and therefore, negatively

related to the perception of the sound environment (Carles, Lo, & Barrio, 1999).

2.10 Soundscape, Behavior and Activity

As stated by Brown et al (2011): soundscapes can facilitate certain activities in two different ways; directly and enabled. In other words the activity is an outcome directly provided by the soundscape or an outcome that is enabled by the soundscape, along with other dimensions of the place. A location is not always chosen by consciously thinking about the soundscape (Brown, 2011). For certain activities other facilities are also needed, for example a playground when going out with children.

People do expect to be able to use a particular soundscape for a certain activity and obtain certain information within them, for example a calm soundscape can be used for relaxing and sound events with a low level can be heard (Bruce & Davies, 2014).

The effect of the soundscape on behavior and psychological responds depends on; psychological reactance, awareness of your own sound production and mood. Psychological reactance can occur in two ways; one could modify the unwanted sound or the sound source and avoid them (behavioral control), or tolerate the sound, adapt and not try to control the soundscape (cognitive control). A form of behavioral control can be putting on headphones or relocating (Davies et al., 2013).

The effect of the awareness of our own sound production has mostly to do with our social norms, and the way a behavior is found acceptable to a place. Here, the way the sound is produced, the awareness of the sound and the feelings about it are important. For example in a quiet environment (library, museum, park) people will behave in a quieter way because it is thought of to be inappropriate to make a lot of noise (Davies et al., 2013).

Finally, there is the mood that people are in. It has been found that when the soundscape and one's emotional state are in harmony, the soundscape is judged more positively (Davies et al., 2013).

Lavia et al. (2012) found that there is a strong relationship between sociotopes (area with a specific set of social activities) and soundscapes. So there is an overall agreement on which sets of sounds are appropriate in what set of social and recreational activities (Lavia et al., 2012).

The city of Gothenburg provides maps where several locations are marked with the designated social activities, determined by the municipality (Göteborgs stad, 2006). In this project the sociotop categories will be compared with the actual activities that take place on the location and with

the perceived soundscape. It can be seen that certain aspects of the soundscape trigger certain activities and if there is a pattern between soundscape type and activities (similar to the findings of Lavia et al.).

2.11 Measurement values

One must be careful not to confuse the soundscape with the acoustic environment. Whereas the soundscape exists only through human perception and is not a physical phenomenon like the acoustic environment (Aletta, Kang, & Axelsson, 2016). This does not mean that they are not connected. The largest difference is that the acoustic environment can be measured and defined in values like level (sound indicators). To define the soundscape sound descriptors are needed, these describe how the acoustic environment is perceived, like perceived loudness. These descriptors cannot be defined by physical, measurable values, however they can be determined by conducting questionnaires or interviews with the users of the spaces and estimated using sound indicators. By analyzing the correlation between the values of sound indicators and sound descriptors the proper sound indicator can be chosen to predict the sound descriptor.

It is important to remember that no single indicator can provide enough information about the whole soundscape. To understand the human perception, the outcome of the indicator or a combination of indicators must be specific to a certain location and therefore, discrimination between different locations can be made. To capture the essence of perception we must know something about level, spectrum and variation in time (Can et al., 2016). Also the presences of tonal components are important because they can increase perceived annoyance.

Sound indicators exist in different categories, some are directly measurable, and others have to be calculated.

The first category is the statistical indicator. Statistical indicators are classical energetic descriptors. They give information about the total sound level and do not take the temporal structure of the sound into account (e.g. equivalent level Leq or day-evening-night level Lden). Other statistical indicators are the percentile descriptors. They describe the dynamic range of the sound level. However, it fails to characterize the rhythm of the sound level variations (e.g. minimum or maximum sound pressure level Lmin/Lmax, n-percentile exceeded sound level L_n or spectrum information) (Can et al., 2016; Kogan, Turra, Arenas, & Hinalaf, 2016).

The second category is the psychoacoustic indicator. Psychoacoustic indicators elaborate more on how the sound is perceived by humans (Farina, 2014; Sottek, 2017). Indicators are loudness; the perceived magnitude of a

sound, measured as roughness; the degree of modulation, measured as sharpness; the ratio of high frequency level to overall level, and tonality; the prominence of tonal components (Sottek, 2017).

The third category is the emergence indicator. Emergence indicators provide more information on the variance in the sound by using noise events the percentage of time, a sound exceeds a given threshold can be defined (Can et al., 2016).

In Table 1 suggested pairs of sound descriptors and their sound indicators can be seen as purposed by (Aletta et al., 2016; Can et al., 2016).

Table 1. Suggested pairs of sound descriptors and indicators (Aletta et al., 2016) (Can et al., 2016)

Descriptor	**Indicator**
Noise Annoyance	Combination of loudness, sharpness and fluctuation strength
Pleasantness	Combination of roughness, sharpness and tonality
Quietness/tranquility	Emergence
Perceived affective quality	Pleasantness-eventfulness model (see figure 1)
Soundscape quality	Combination of level, temporal variance and sound source types
Appropriateness	Based on experience, no indicator available
Perceived loudness	Level/Loudness
Rhythm of sound	Roughness

In this project the main focus will be on statistical indicators. Regarding psychoacoustic indicators only loudness is used due to lack of resources. The emergence of sound is not taken into account.

3 Method

3.1 Location choice

In total, measurements were performed and questionnaires were conducted at ten locations. These locations were chosen based on their average level which was indicated on the noise maps from the city of Gothenburg (Göteborgs stad, 2013), their number of activities which was indicated on the sociotop maps (Göteborgs stad, 2006), from the city of Gothenburg and their visual character (park, urban, etc.). To categorize the locations five visual characters were determined:

1. Urban
2. Urban with vegetation
3. Non-urban with vegetation
4. Near water
5. Near water and vegetation

A 3D graph was made combining level, number of activities and visual category. The goal was to choose locations in such a way that the spread over the graph was large. Meaning that at each visual category, the average level and the number of activities were represented. The final chosen locations can be seen in Figures 2 and 3. Each visual category and each average level category indicated on the noise maps are represented. There is also a large spread in number of activities. However, a location with a high average level and a high number of activities is missing. This could be a first indication that with a higher the level, fewer activities are possible.

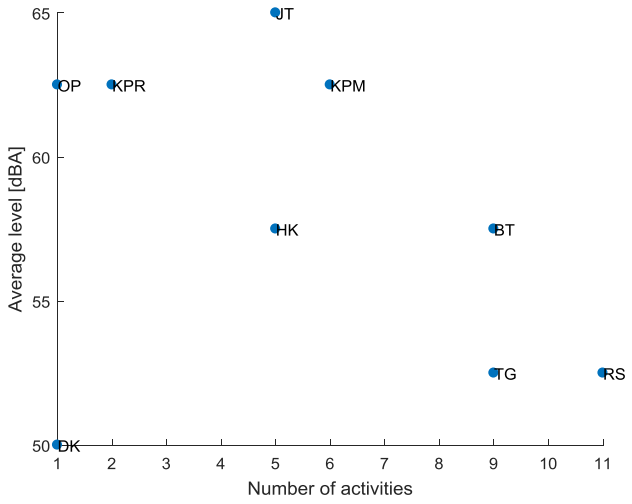


Figure 2. Number of activities displayed against the average level per location

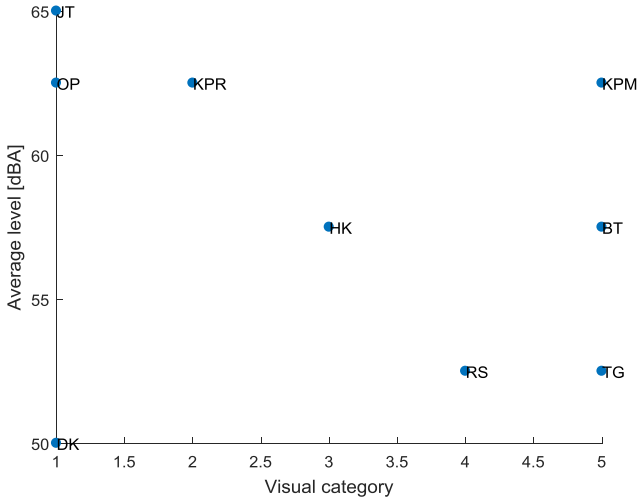


Figure 3. Visual category displayed against the average level per location

3.2 Data collection

3.2.1 Questionnaires

The questionnaires used in this research are based on questionnaires used in soundwalks previously performed by the Division of Applied Acoustics at Chalmers University of Technology (Estévez Mauriz, Zachos, Forssén, & Kropp, 2016). Additional questions were added based on research performed by Kang et al. (2005, 2010, 2013) and based on the soundwalks performed within the course Human Response to Sound and Vibration, within the Master Program in Sound and Vibration at Chalmers University of Technology (Sottek, 2017).

Questionnaires were conducted simultaneously with sound measurements in sets of 20-25 minutes. The guideline was to collect around 30 questionnaires per location. If this was not possible within the 20-25-minute timeframe, more measurement sets were made per location.

At the location, actual users of the space were approached and asked if they wanted to fill in a questionnaire. The questionnaire was presented as part of a research regarding the quality of public spaces in Gothenburg, to avoid bias on the sound aspects. This approach was chosen above a soundwalk. In this way, information is gained about the actual use of the space by the people that (frequently) come there. The questionnaire was presented in both English and Swedish upon request. The English questionnaire can be seen in Appendix A.

The first part addresses the purpose of the users coming to the location; their travel method, duration of stay and first impression of the space (overall area quality, visual quality and sound quality). After, the users are asked to rate a

set of activities on the applicability to the location. Then, more indebt questions about the perception of the location are asked (organization of the surroundings, cleanliness, etc.). Next, a set of adjectives is given (pleasant, chaotic, etc.). The users are asked to rate these adjectives regarding applicability to the sound environment. Finally the users are asked to list a top 5 of the most prominent sound sources. For the quality questions a 11-point scale was used. For the other rating questions a 5-point scale was used. More about the scaling in Section 3.3.1.

It was attempted to perform all measurements during the weekends (Friday afternoon, Saturday, Sunday), between 14:00-16:00 and when possible, with similar weather conditions. However, due to bad weather conditions during several weekends, the measurements in the Botanical Garden and Odinsplats (location 7 and 10) were performed on a weekday.

3.2.2 Sound measurement

At the locations, sound recordings and acoustical indicator data were acquired using the Chalmers in-house developed acquisition tool named TAMARA and a B&K 2260 sound level meter and microphone submitted to calibration. TAMARA output is read through the software Matlab. As stated before, recordings were made in 20-25-minute samples. A large poster was setup on the measurement site displaying the text: "Help improve city quality! Chalmers research study, Department of Civil and Environmental Engineering" to inform the people that the study was a research study and not something commercial. In Figure 4 the measurement setup can be seen.

Figure 4. Measurement Setup

3.3 Data processing

3.3.1 Questionnaires

The data of the questionnaires is summarized in Excel. The questionnaires are reviewed on their completeness. Incomplete questionnaires are only used when average values are assessed. In some analysis steps, involving Matlab, incomplete data can cause errors. In these steps the incomplete data sets are not considered. The questionnaires filled in by users without normal hearing, are not considered.

In the questionnaire the scales "not applicable – slightly – moderately – very – perfectly" and "not at all – slightly – moderately – very – extremely" (Sottek, 2017; Estévez Mauriz, Zachos, Forssén, Kropp, 2016) are used these scales are transferred to a numerical scale of 0-1-2-3-4. This can be done according to Rohrmann, who proved that these words have an equal distance from each other (Rohrmann, 1978). The scale of "strongly agree – agree – neither agree, nor disagree – disagree – strongly disagree" is given the numerical scale of +1 – +0.5 – 0 – -0.5 – -1. This is done to provide an average rating for questions 4-6 and 8-14. Question 1 "How often do you visit the location?" and question 7 "How close is the location to your house?" are displayed as a pie graph with the percentage of people who chose each option. Question 2 indicating the average duration, is averaged for all the answers in minutes. In question 3 indicating the purpose of the visit, the number of times an activity is chosen is counted, and finally, the activities are ranked from most to least chosen. For question 8, a similar activity ranking is provided based on the average ranking value given. In question 15, naming of the most prominent sound sources, the answers are evaluated and counted on each position in the ranking. Some answers are grouped together like "cars" and "traffic" or "fountain" and "water". The one with the most counts on ranking 1 becomes 1 in the final ranking etc. for the five positions. Answers that were only given ones in the whole set are grouped under "other".

The general information is represented in an average age, percentage of sex, percentage of education type and percentage of occupation type (e.g. healthcare, education, etc.). The general information is not discussed in the report, but can be found in Appendix B.

For questions 4-6 and 8-13 the total average value, standard deviation and 95% confidence interval are calculated. All values are normalized to a scale of 0-1. With the adjectives of question 14 the eventfulness and pleasantness can be calculated with Equation 1 and 2 (Sottek, 2017). These provide the coordinates to place the location in a framework according to Figure 1.

$$P = \frac{\left(\sqrt{2} * (p - a)\right) + (ca - ch) + (v - m)}{4 + \sqrt{8}} \quad (1)$$

$$E = \frac{\left(\sqrt{2} * (e - u)\right) - (ca - ch) + (v - m)}{4 + \sqrt{8}} \quad (2)$$

With:

P pleasantness

E eventfulness

p pleasant rating

ch chaotic rating

v vibrant rating

u uneventful rating

ca calm rating

a annoying rating

e eventful rating

m monotonous rating

The adjective scales from question 14 were also used to make rose-pie graphs representing the number of people giving a specific rating to an adjective. This type of representation was previously used by the Division of Applied Acoustics (Estévez Mauriz, Zachos, Forssén, Kropp, 2016). To realize these graphs the scale of -1 to 1 was normalized to a scale of 0-4. The colors in the rose-pie indicate the amount of answers. The darker the color, the higher is the amount of people giving the rating.

3.3.2 Measurements

As stated in Chapter 2.11, the focus of this project is on the statistical indicators with only one psychoacoustic parameter, loudness. TAMARA provides all relevant statistical indicators. In addition to the standard statistical indicators from TAMARA ((equivalent) levels, percentile values, spectrum) the center of gravity of the sound spectrum is calculated, see Equation 3. The center of gravity of the spectrum is a good indicator for the degree of traffic noise pollution in the soundscape. It can be used as an indicator for area quality (De Coensel & Botteldooren, 2006;Brambilla, Gallo, & Zambon, 2013).

$$G = \frac{\sum_i \left[10^{\frac{L_i}{10}} * B_i \right]}{\sum_i \left[10^{\frac{L_i}{10}} \right]} \qquad (3)$$

With:

Li unweighted sound level in dB

Bi center frequency of the 1/3octave band

3.4 Analysis

For the analysis of the results, a combination of Excel, SPSS and Matlab software is used. The relationship between the overall area quality (QA), the visual quality (QV) and the sound quality (QS) is assessed first. The average values for the quality ratings are represented in separated graphs, created using SPSS. On the x-axis, the locations are ranked from the lowest to the highest quality rating. Clusters of locations with the same quality ratings are analyzed on their similarities regarding the organization of the surroundings (OS), cleanliness (CL), safety (SA), the appropriateness of the sound to the location (APR), perceived loudness (PL), visual category from Chapter 3.1 and most prominent sound sources. Also, the correlation between these variables and the quality ratings are compared.

A first step is made towards coupling the measurement values to the answers in the questionnaire, by looking at the correlation coefficients between the variables, coupling the activity ratings to the quality ratings. This is done by looking at the increase or decrease in the rating of applicability of an activity when the quality rating of a location increases.

Finally a principle component analysis (PCA) is performed to get a total picture of the relation between the locations, their activity ratings and the ratings for the overall quality. The correlation between the principle components (PC's) and measurement values is analyzed to see if there is a relationship and if a PC could possibly be replaced with a physical value.

Specific steps in creating the analysis will be discussed in Chapter 4.

4 Analysis of the results

Due to the many aspects addressed in this project, to keep a clear overview, the present chapter combines the analysis method, the results and the discussion per analysis step. Results will be analyzed and discussed according to the order stated in Chapter 3. First, a summary of the questionnaire and measurement results will be given per location.

4.1 Results summary

4.1.1 Location 1: Trädgårdsföreningen (TG)

Figure 5. Measurement location in TG, close to the fountain

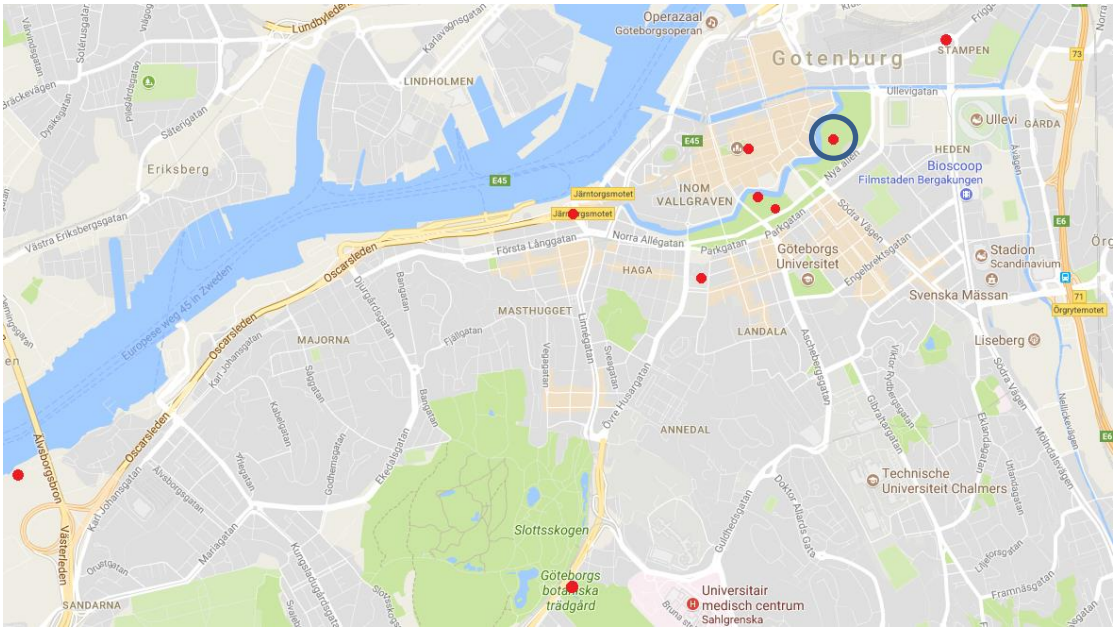


Figure 6. Measurement location TG on map indicated with a blue circle

Trädgårdsföreningen is a large park situated near the central station in Gothenburg. It has a playground, restaurants and a large greenhouse. The measurements were performed at the fountain close to the playground. The ground at the measurement site consists of gravel and grass and is

surrounded by trees. In Figure 7, a summary is given of the "rating questions" of the questionnaire.

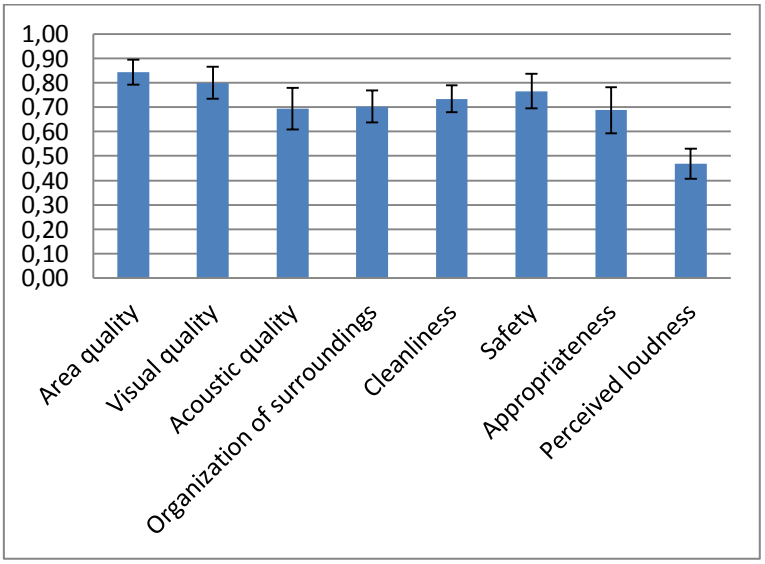


Figure 7. Summary of rating questions TG, normalized values

As can be seen, the rating for perceived loudness is low compared to the other variables. This can be due to the presence of vegetation, which can reduce the feeling of annoyance and the perceived noise level (Farina, 2014). The rating for visual quality is closer to the rating of the overall quality than the sound quality is. This can indicate that the visual quality has a larger influence on the judgement of the overall quality.

Table. 2 Summary of municipality and measurement data TG

Noise level indicated on noise map municipality:	50-55 dBA
Noise level measured in a single number of LAeq:	57 dBA
Sociotop indicators:	Cultural history Picnic Water adventure Flowering Events Green Game Walking Rest

In Table 2 it can be seen that the municipality indicated an average sound level between 50-55 dBA here. The measured single value for LAeq is 57 dBA. Given that the municipality only takes into account traffic noise and not the sound from, for example the fountain, the prediction is quite accurate.

Also, the chosen activities by the municipality for this location can be seen. Comparing these with Figure 8 (purpose of people visiting the location) and Figure 9 (rating for applicability of several activities to the location), some resemblance can be seen. The three main purposes of people coming to TG are "walking", "nature" and "tranquility" corresponding with the sociotops "walking", "flowering/green" and "rest". High rated activities are "appreciation of parks and trees", "socializing" and "hanging out" corresponding to the sociotops "green", "picnic", "game" and "events" possibly.

The soundscape in this location, looking at the activities performed must be a supportive one. Enabling the users to experience tranquillity and rest. Figure 10 shows the spectrogram of the measurement. As can be seen there are high levels in the lower frequencies. Comparing this to the top three most prominent sound sources indicated by the users (1) Water, 2) Children, 3) Talking/birds), the high low frequency content is most likely due to the fountain and the higher density in the 800Hz range due to the human voice.

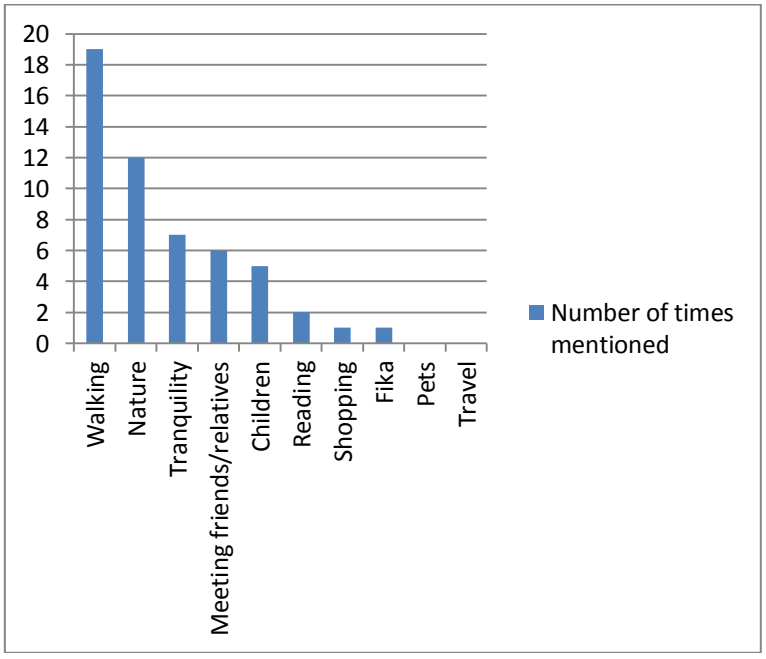


Figure 8. Purpose of users coming to TG

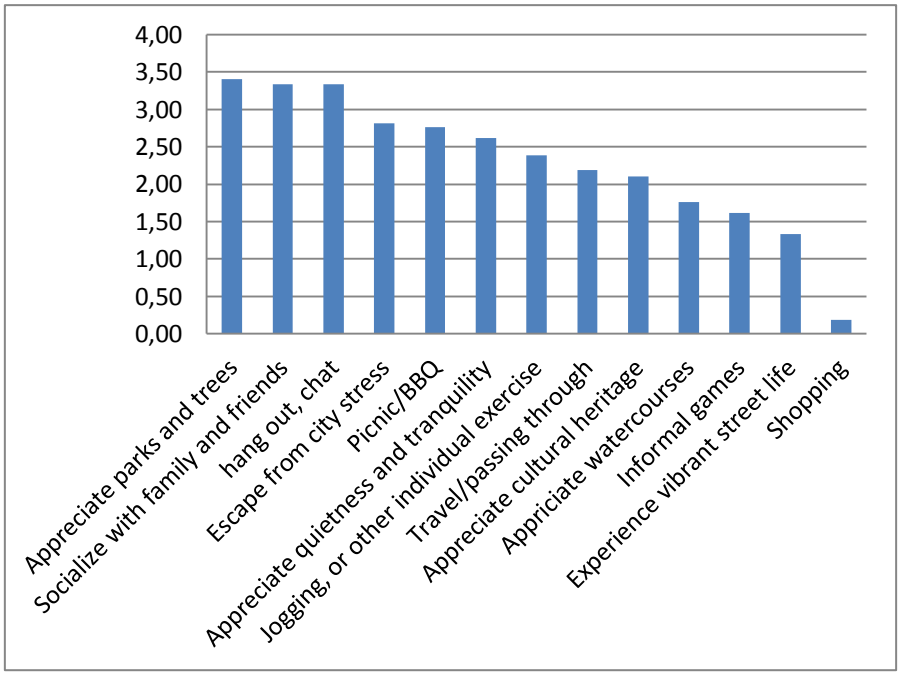


Figure 9. Rating for applicability of activities to TG, on a scale from 0-4

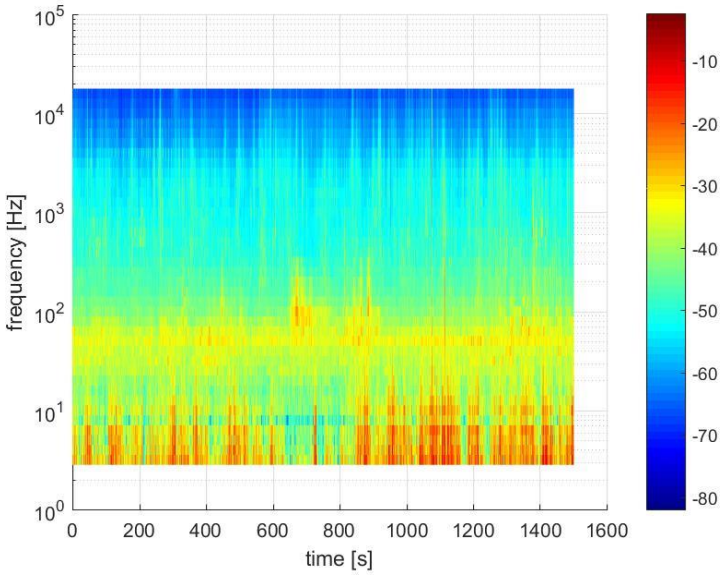


Figure 10. Sound spectrum of recording made in TG

In Figure 11, the results for the adjective scales can be seen. A high number of people rated the place as "pleasant" and "calm", whilst "chaotic" and "annoying" are lower rated adjectives. Also "vibrant" and "eventful" have higher ratings compared to "uneventful" and "monotonous". With this information and the use of Equation 1 and 2 (Sottek, 2017), the soundscape can be placed in the quadrant of "calm" (pleasant and uneventful) according to Axelsson (2010).

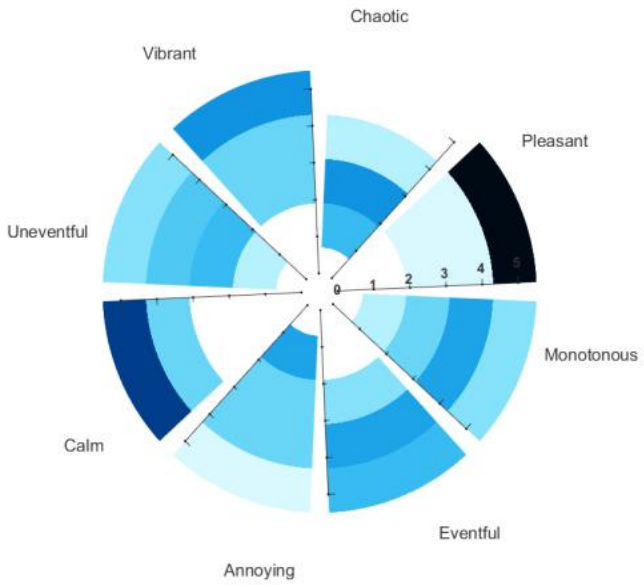


Figure 11. Rose-pie graph for adjective scales regarding TG with colour density indicating the amount of people answering: darker colours indicate a higher number of people.

4.1.2 Location 2 Domkyrkan

Figure 12. Measurement location in a shopping street near DK

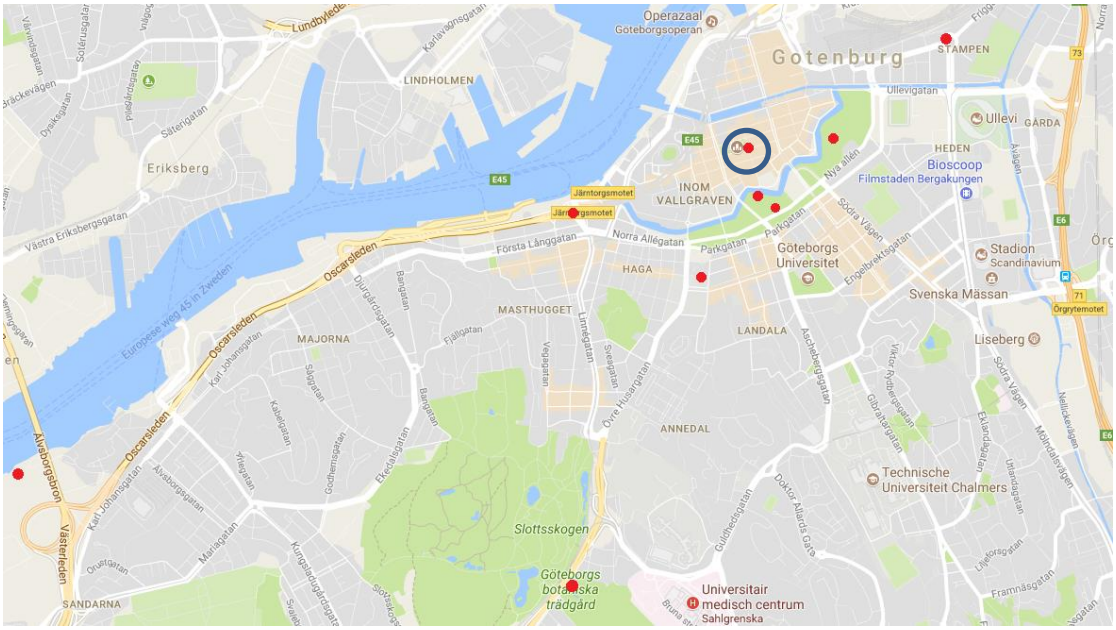


Figure 13. Measurement location DK on map indicated with a blue circle

The second measurement location is a shopping street located in the city center, next to a popular church in Gothenburg. A small park surrounds the church, however the questionnaires were conducted outside this park area, in the actual shopping street. In Figure 14 a summary is given of the "rating questions" of the questionnaire.

As can be seen, the overall quality of the area, the visual and the acoustic quality of the location are rated equal. The perceived loudness is quite low compared to the measured LAeq value (see also Table 3). This can be due to the type of sound sources. The top 3 sound sources indicated by the users are: 1) Birds, 2) People, 3) Traffic. As birds are considered natural sound sources, a higher sound level is tolerated (Kang & Zhang, 2010), which could explain the lower values for perceived loudness.

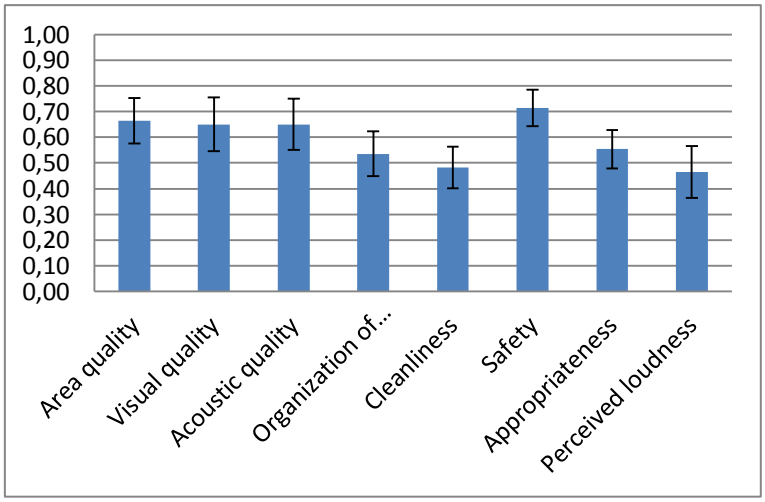


Figure 14. Summary of rating questions DK, normalized values

Table 3. Summary of municipality and measurement data DK

Noise level indicated on noise map municipality:	<50 dBA
Noise level measured in a single number of LAeq:	61 dBA
Sociotop indicators:	Not indicated

In Table 3 it can be seen that the municipality indicated that the level in this street should be below 50 dBA. However the measured value is much higher. This can be explained by the fact that the measurement location is located in a pedestrian area and the traffic noise that is taken into account when making the noise maps is only one of the minor sound sources that are observed in this area. During the measurements numerous birds and seagulls were present in the park next to the measurement equipment, partially responsible for the high sound levels.

Regarding the sociotop maps, the municipality indicated no activities. Looking at the main purpose indicated by the users, it could be seen that the main activities at the location are "shopping", "walking" and "meeting friends", see Figure 15. The users indicated the location as being most suitable for "shopping", "passing through" and "experiencing vibrant street life", see Figure 16.

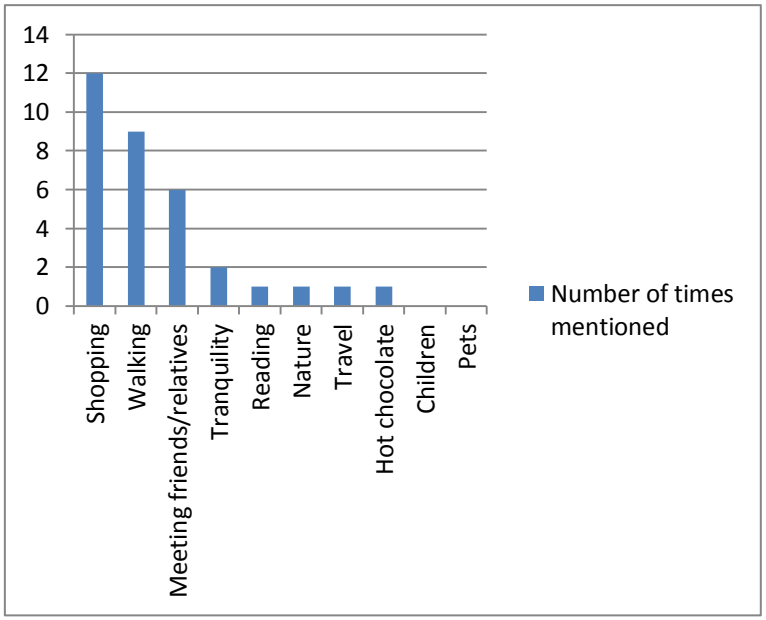


Figure 15. Purpose of users coming to DK

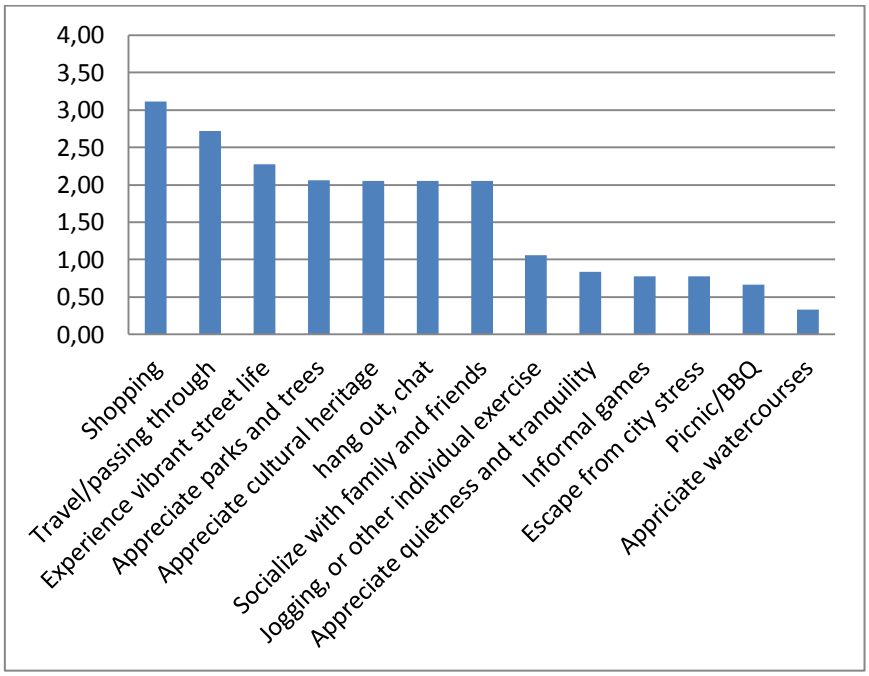


Figure 16. Rating for applicability of activities to DK, on a scale from 0-4

In Figure 17, the sound spectrum shows a wide variety in frequency content over time. In the lower frequencies the distant traffic noise, in the mid frequencies human sound and in the mid and higher frequencies bird song.

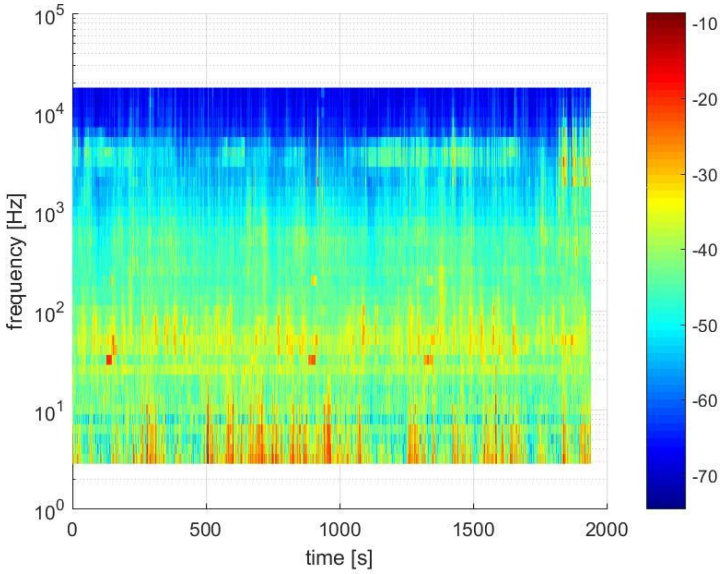


Figure 17. Sound spectrum of recording made in DK

In Figure 18 the results for the adjective scales can be seen. The adjectives with a high rating are "pleasant", "vibrant" and "eventful", making it indeed suitable to experience vibrant street life. With this information and the use of Equation 1 and 2 (Sottek, 2017), the soundscape can be placed in the quadrant of "exciting" (pleasant and eventful) according to Axelsson (2010).

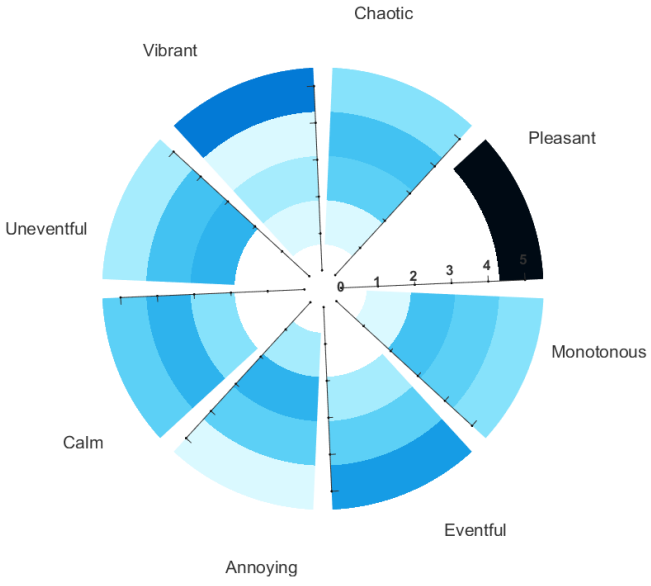


Figure 18. Rose-pie graph for adjective scales regarding DK with colour density indicating the amount of people answering: darker colours indicate a higher number of people.

4.1.3 Location 3 Kungsparken Waterside, Sunny Day (KPM sun)

Figure 19. Measurement location in Kungsparken, near the canal

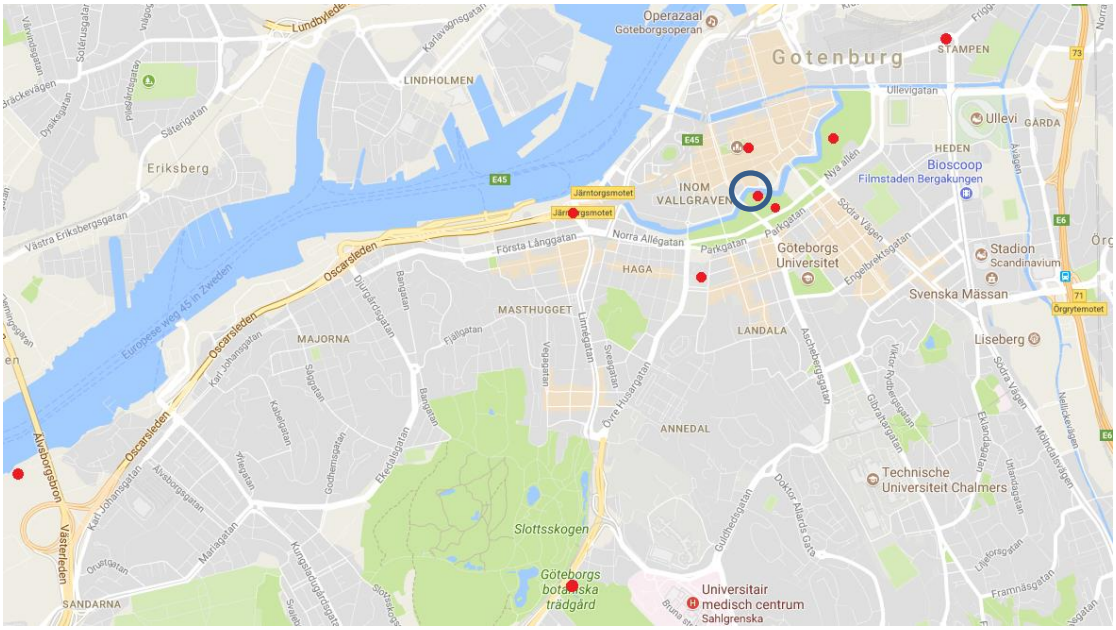


Figure 20. Measurement location KPM sun/cloud on map indicated with a blue circle

Kungsparken is a park located between a canal and a main road. There is a ground level difference between the road and the canal and therefore the park is slightly sloped. In this park, multiple measurements were done because of its unique location with on one side a nice view of the water and on the other side the road. Also the effect of weather conditions was addressed on this location. The results below are from measurements conducted on a sunny day (similar to the other measurement locations). In Figure 21 a summary is given of the "rating questions" of the questionnaire.

Similar to the first location, the perceived loudness rating is low compared to the other variables. This could again be explained by the presence of vegetation. The visual quality of the area is slightly higher than the overall quality. It could be that the lower acoustic quality influenced the decrease in overall quality compared to visual quality. This because the sound environment was mainly dominated by mechanical sounds (traffic), which are less tolerated than natural and human sounds.

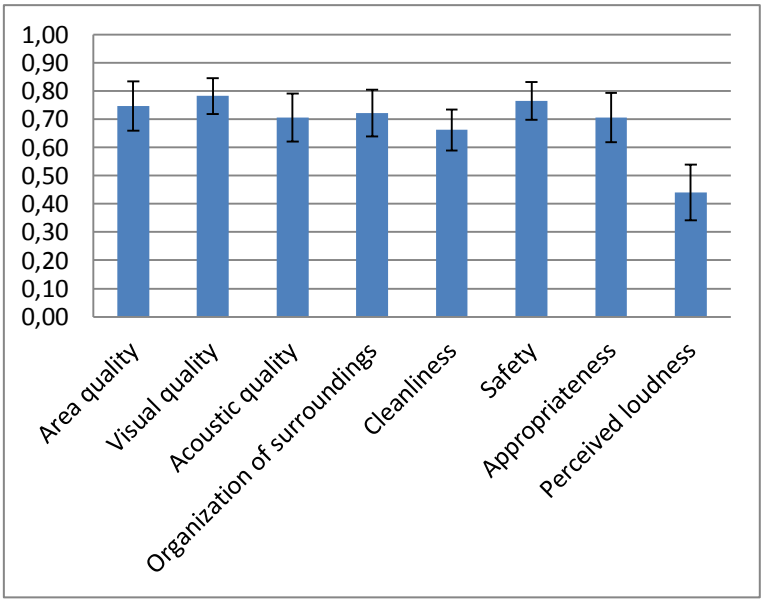


Figure 21. Summary of rating questions KPM sun, normalized values

Table 4. Summary of municipality and measurement data, KPM sun

Noise level indicated on noise map municipality:	60-65 dBA
Noise level measured in a single number of LAeq:	56 dBA
Sociotop indicators:	Green Meeting people Picnic Walking Water adventure Rest

In Table 4 it can be seen that the municipality indicated an average level between 60-65 dBA here. The measured single value is lower. This could be due to a lower number of vehicles on the road since the measurements were performed during the weekend.

Activities indicated by the municipality partly coincide with the purpose of coming to the location chosen by the users. The main purposes were: "meeting friends", "nature" and "walking", (see Figure 22) which agree with the sociotops "green", "meeting people" and "walking". However, when looking at the activity ratings in Figure 23 it can be seen that "picnic" and "appreciation of watercourses" (water adventure) get lower ratings than other

activities (see Figure 23), indicating that the users of the space find the location less suitable for these activities.

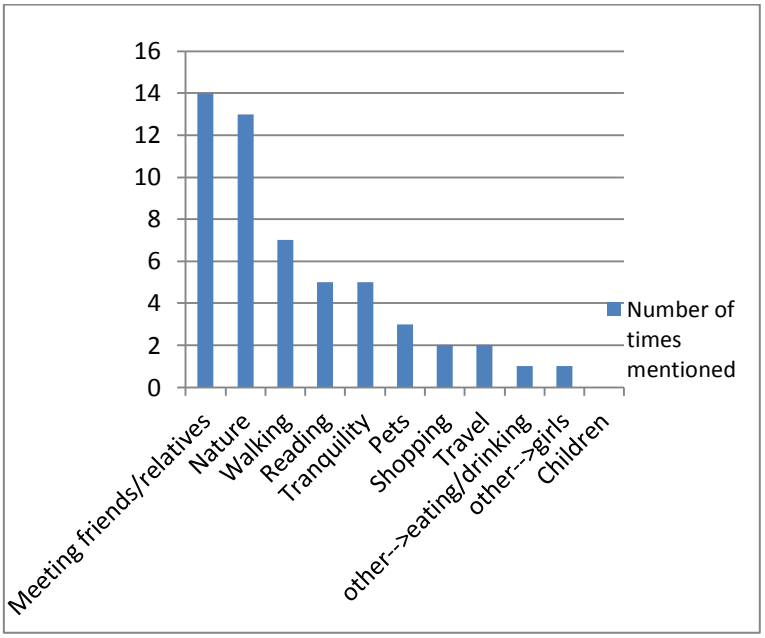


Figure 22. Purpose of users coming to KPM sun

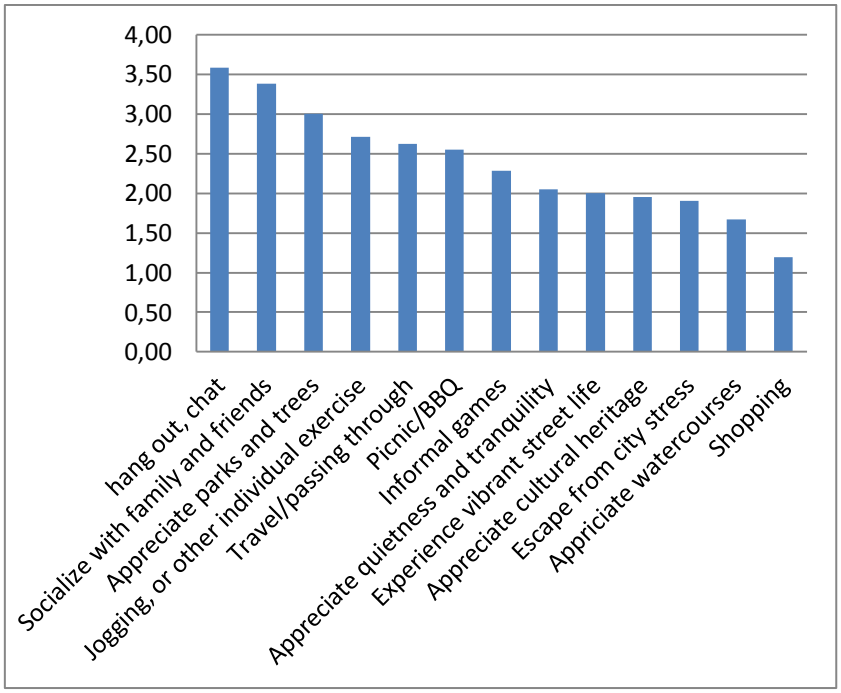


Figure 23. Rating for applicability of activities to KPM sun on a scale from 0-4

In Figure 24 the sound spectrum can be seen. There is a clear low frequency content and very little energy is contained in the higher frequencies. The top 3 sound sources indicated by the users are: 1) Traffic, 2) People, 3) Birds. The bird song is not as clearly visible here as it was in location 2, Domkyrkan.

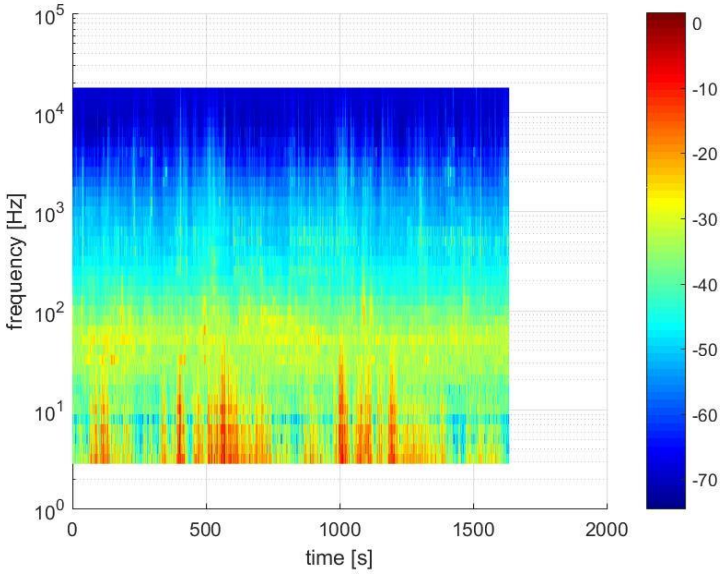


Figure 24. Sound spectrum of recording made in KPM sun

In Figure 25 the results for the adjective scales can be seen. The adjectives with a high rating are "pleasant" and "calm".With this information and the use of Equation 1 and 2 (Sottek, 2017), the soundscape can be placed in the quadrant of "calm" (pleasant and uneventful) according to Axelsson (2010).

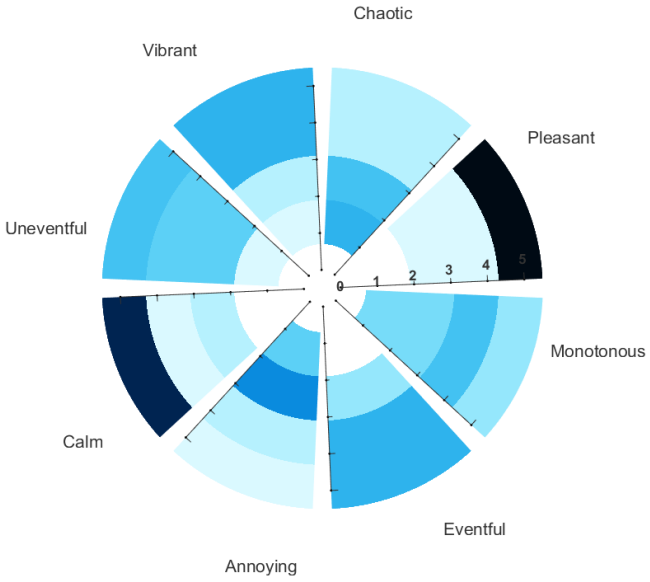


Figure 25. Rose-pie graph for adjective scales regarding KPM sun with colour density indicating the amount of people answering: darker colours indicate a higher number of people.

4.1.4 Location 4 Kungsparken Waterside, Cloudy day (KPM cloud)

Figure 26. Measurement location in Kungsparken, near the canal

Measurements were performed a second time at the previous location, but on a cloudy day. This was done to see the influence of weather conditions on the perception of a location. In Figure 27 a summary is given of the "rating questions" of the questionnaire.

The rating of the overall, visual and acoustic quality has significantly descreased compared to the previous measurements. Overall, visual and sound quality average values in KPM sun were 0.75; 0.78; 0.71 correspondingly, while in KPM cloudy were 0.62; 0.60; 0.52. The rating for the perceived loudness on the other hand has signigficantly increased, from 0.44 in KPM sun to 0.57 in KPM cloud. These results may be coupled to the research that Meng et al. performed in underground shopping streets. When the brightness is high, the acoustic comfort was high and the perceived loudness low (Meng et al., 2013). In this case, the brightness outside has significanlty descreases due to the absence of direct sunlight, hence the acoustic quality rating goes down and the perceived loudness goes up.

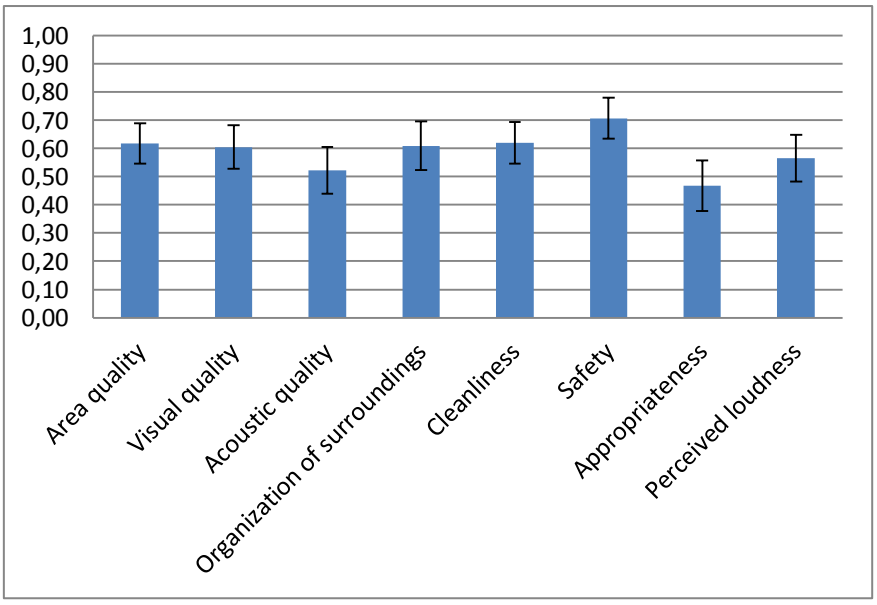


Figure 27. Summary of rating questions, KPM cloud, normalized values

Table 5. Summary of municipality and measurement data, KPM cloud

Noise level indicated on noise map municipality:	60-65 dBA
Noise level measured in a single number of LAeq:	60 dBA
Sociotop indicators:	Green Meeting people Picnic Walking Water adventure Rest

In Table 5 it can be seen that the measured level agrees well with that indicated by the municipality. The same relationships with the sociotops indicated by the municipality can still be appreciated (see Figure 28). However, the main purpose of the users in these weather conditions has changed. During a cloudy day, the main purposes were "walking" and "travel", while in sunny conditions socializing and staying in the place for a longer time plays a larger role. Also the appreciation of parks and trees gets a lower rating with a cloudy day (2.44) than with a sunny day (3.00), see Figure 29. Given this fact and the lower visual quality in Figure 27, it can be said that brightness also influences the visual perception/appreciation of a location.

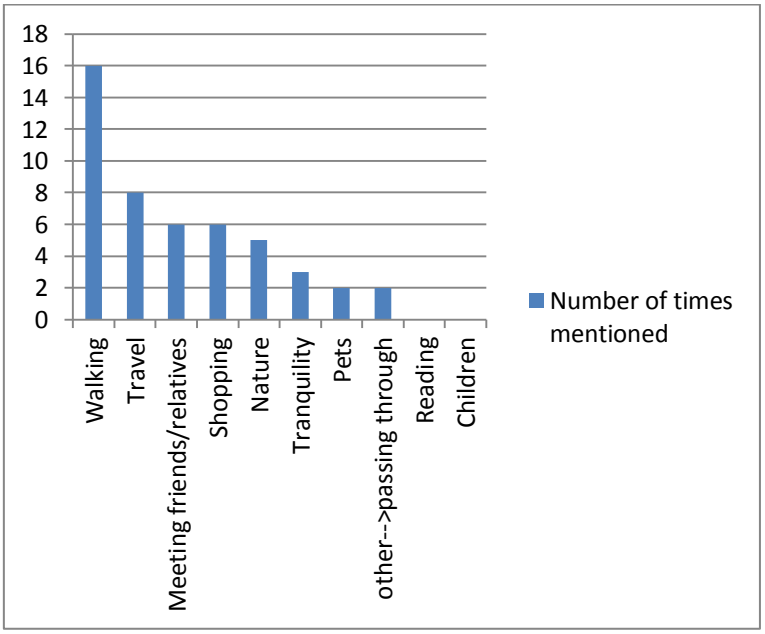


Figure 28. Purpose of users coming to KPM cloud

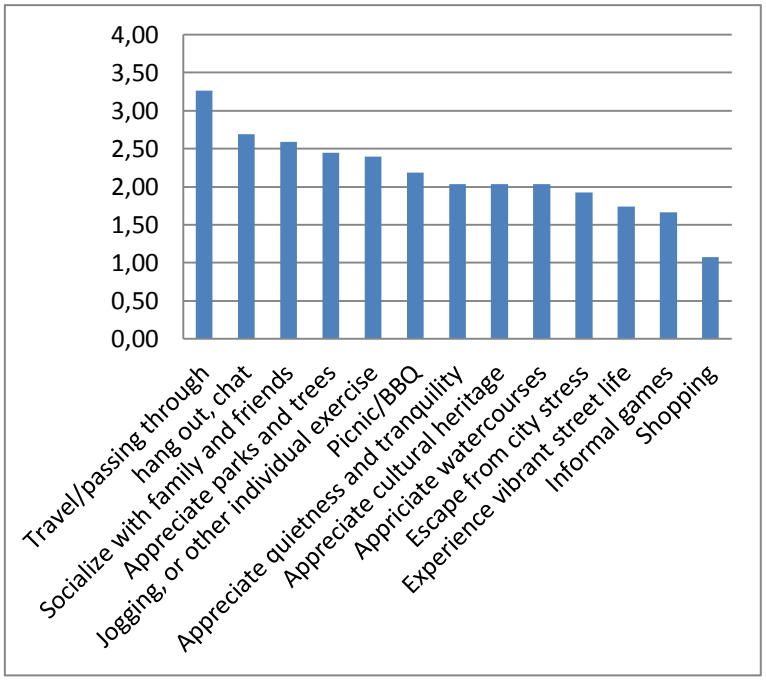


Figure 29. Rating for applicability of activities to KPM cloud, on a scale from 0-4

The top three sound sources that were chosen by the users are: 1) Traffic, 2) Birds, 3) People, which is similar to the last measurement (KPM sun), however, as less people were present, a shift for the sound source people to the third place and the sound source birds to the second occurred. In the spectrum (Figure 30) it can be seen that there is more energy in the low frequencies than in the previous measurement (KPM sun). Sound with low frequencies is mainly produced by mechanical sources, like traffic. The increase in energy in the low frequencies can be explained by the fact that there could have been more cars on the road along the park during the measurement. Also, the level was higher in KPM cloud (+4dBA compared to KPM sun). Since there were no additional sources present compared to the previous measurement, an increase in traffic could also explain the increase in level.

In Figure 31, the results for the adjective scales are summarized. The adjectives with a high rating are "pleasant" and "chaotic", but also a high amount of people chose "calm". These adjectives seemed to contradict each other, however, how we perceive sound is subjected to social-cultural and personal factors and it may be said that if the visual aspects of a location are not dominating, (i.e. not winning the battle of attention against sound) these factors start playing a role. Since users of a space may have different backgrounds and are in a different emotional state, judgment of the sound environment may differ With this information and the use of Equation 1 and 2 (Sottek, 2017), the soundscape can be placed in the quadrant of "calm" (pleasant and uneventful) according to Axelsson (2010).

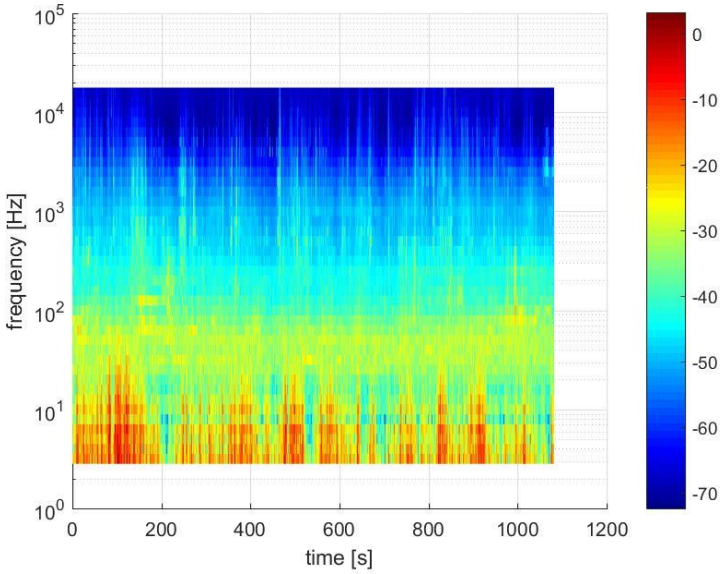


Figure 30. Sound spectrum of recording made in KPM cloud

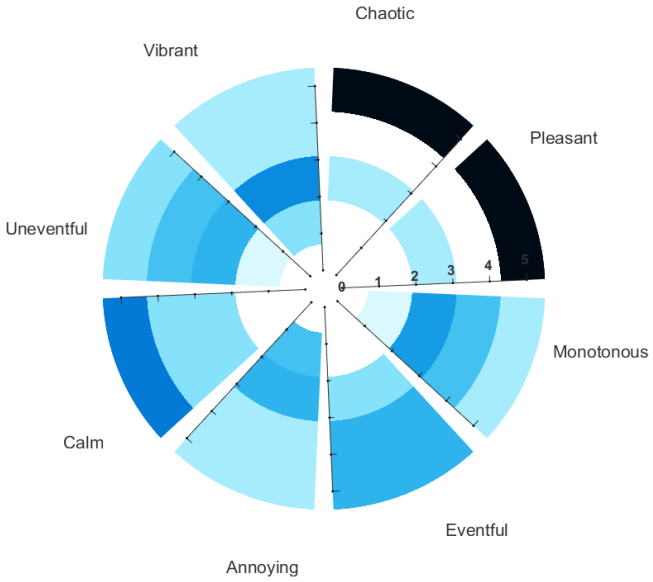


Figure 31. Rose-pie graph for adjective scales regarding KPM cloud with colour density indicating the amount of people answering: darker colours indicate a higher number of people.

4.1.5 Location 5 Kungsparken Roaside (KPR)

Figure 32. Measurement location Kungsparken near the road

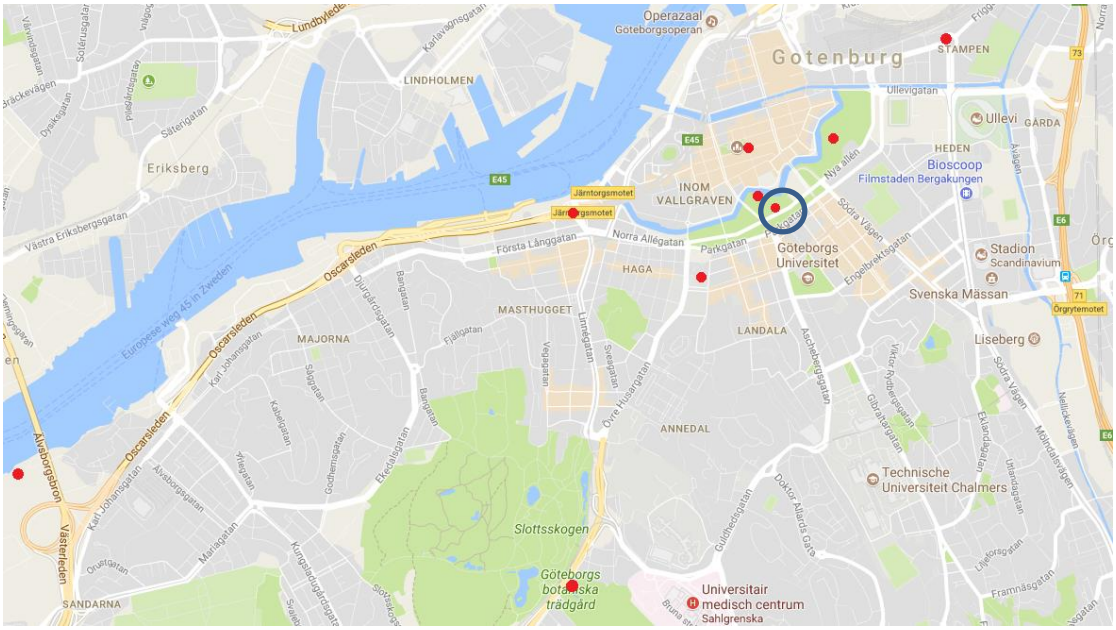


Figure 33. Measurement location KPR on map indicated with a blue circle

The last measurements in Kungsparken were performed on a sunny day at the roadside of the park. This part provides a large open space with trees located only alongside the road. In Figure 34 a summary is given of the "rating questions" of the questionnaire.

The average rating for acoustic quality is lower (0.58) compared to the waterside location in Kungsparken (0.71), the perceived loudness in this location is higher (0.63) than in the waterside location (0.44). This due to the presence of the road so nearby increasing the level of traffic noise. The rating for the appropriateness is also lower (0.43) than in the waterside location (0.71). This is because parks are mostly associated with tranquiluty and natural sounds and the sound environment here is dominated by traffic sound.

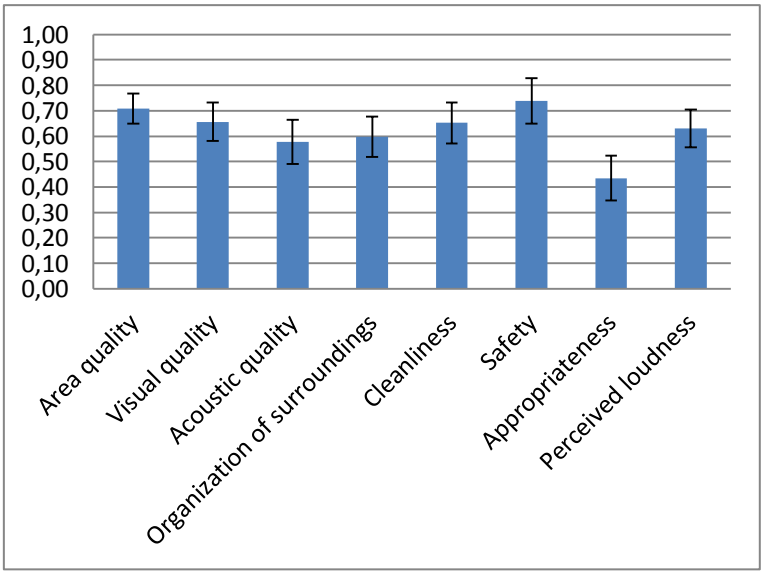


Figure 34. Summary of rating questions, KPR, normalized values

Table 6. Summary of municipality and measurement data, KPR

Noise level indicated on noise map municipality:	60-65 dBA
Noise level measured in a single number of LAeq:	61 dBA
Sociotop indicators:	Green Walking

In Table 6 it can be seen that the measured level agrees well with that indicated by the municipality. However, the sociotops do not seem to match well with the purpose of the users coming to the location. The main purpose was "meeting friends and eating and drinking" (see Figure 35), while the municipality sees the location as a place to walk and not to sit down. This is partly because no benches are provided to sit on at the location. But the users of the space bring blankets and sit on the grass. Also the activity "travel/passing through" gets a medium rating. The highest rated activities are "hanging out", "meeting friends" and "appreciation of parks and trees", which coincides with the sociotop green (see Figure 36).

In Figure 37 the sound spectrum can be seen. A wide range of frequencies is visible, although the most energy is contained in the lower frequencies. This can be connected to the top 3 sound sources chosen by the users: 1) Traffic, 2) Music, 2) Birds. The traffic noise can be seen very clearly here forming one continues band over time. The birds cause the fluctuations in the higher frequencies.

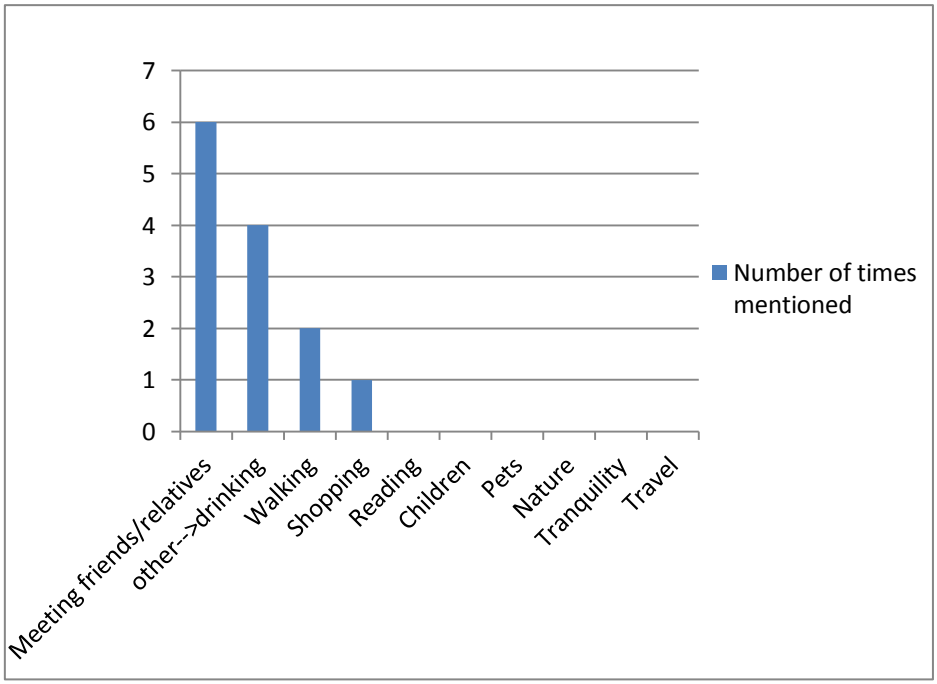


Figure 35. Purpose of users coming to KPR

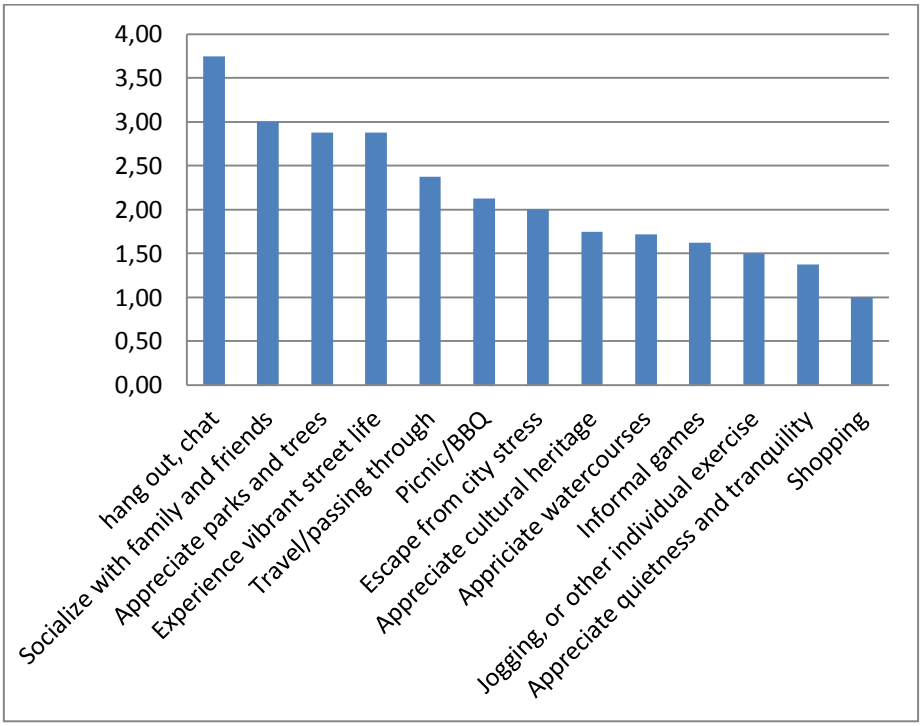


Figure 36. Rating for applicability of activities to KPR, on a scale from 0-4

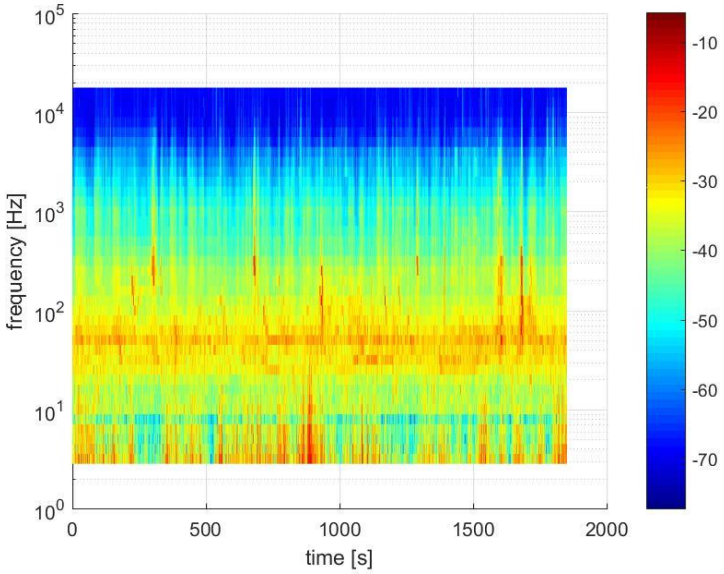


Figure 37. Sound spectrum of recording made in KPR

In Figure 38 the results for the adjective scales shows a high number of people ranking the place as very "pleasant". Also "vibrant" has a significant amount of people giving a high rating. "Monotonous", "annoying" and "uneventful" have a many people answering a low rating. With this information and the use of Equation 1 and 2 (Sottek, 2017), the soundscape can be placed in the quadrant of "exciting" (pleasant and eventful) according to Axelsson (2010).

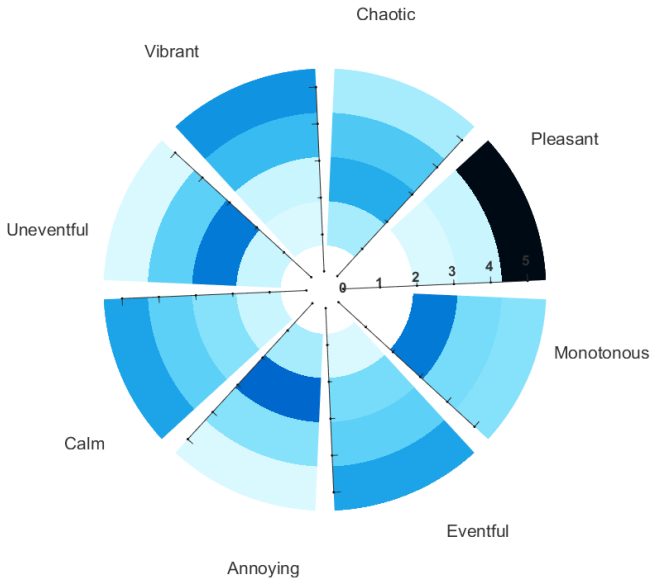


Figure 38. Rose-pie graph for adjective scales regarding KPR with colour density indicating the amount of people answering: darker colours indicate a higher number of people.

4.1.6 Location 6 Hagakyrkan (HK)

Figure 39. Measurement location near Hagakyrkan

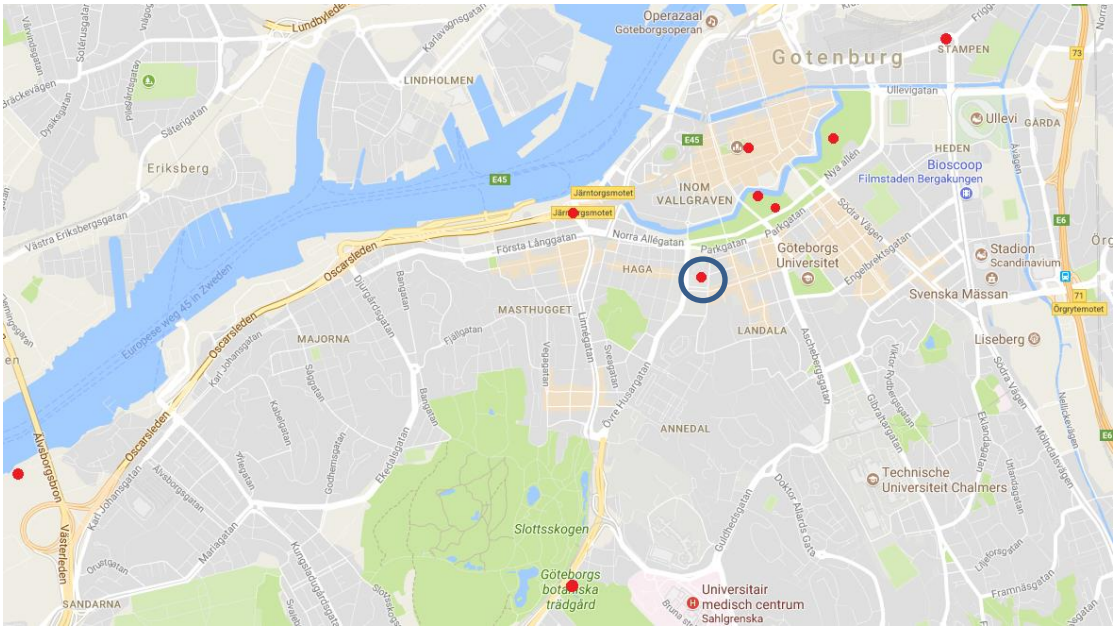


Figure 40. Measurement location HK on map indicated with a blue circle

This measurement location is a square in front of the church in the centrical area of Haga in Gothenburg. It is situated between two roads. The square has various kinds of vegetation: trees and potted plats. In the corner of the square a playground is situated. In Figure 41 a summary is given of the "rating questions" of the questionnaire.

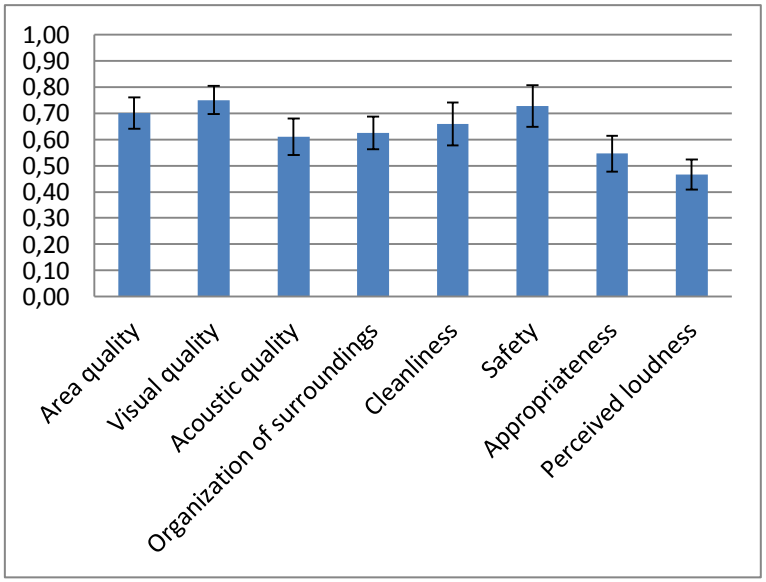


Figure 41. Summary of rating questions, HK, normalized values

The location has a high visual quality rating (0.75) and a low acoustic quality rating (0.61) compared to the other quality ratings, altough the perceived loudness rating is not high compared to the other variables (0.47). This is because the approriateness of the sound is rated as 0.55, decreasing the acoustic quality of the area.

Table 7. Summary of municipality and measurement data, HK

Noise level indicated on noise map municipality:	55-60 dBA
Noise level measured in a single number of LAeq:	56 dBA
Sociotop indicators:	Green Meeting people Picnic Group games Rest

In Table 7 it can be seen that the measured level agrees well with that indicated by the municipality. The sociotop indicators do not seem to agree very well with the purpose and activity rating of the users of the space. The main purpose of coming to this location is "walking", which is not indicated in the sociotop activities (see Figure 42). The top 3 rated activities suitable for the location are "passing through", "hang out" and "appreciate parks and trees" (see Figure 43). This could correspond with "green" and meeting people, however picnic, group games and rest do not get high ratings.

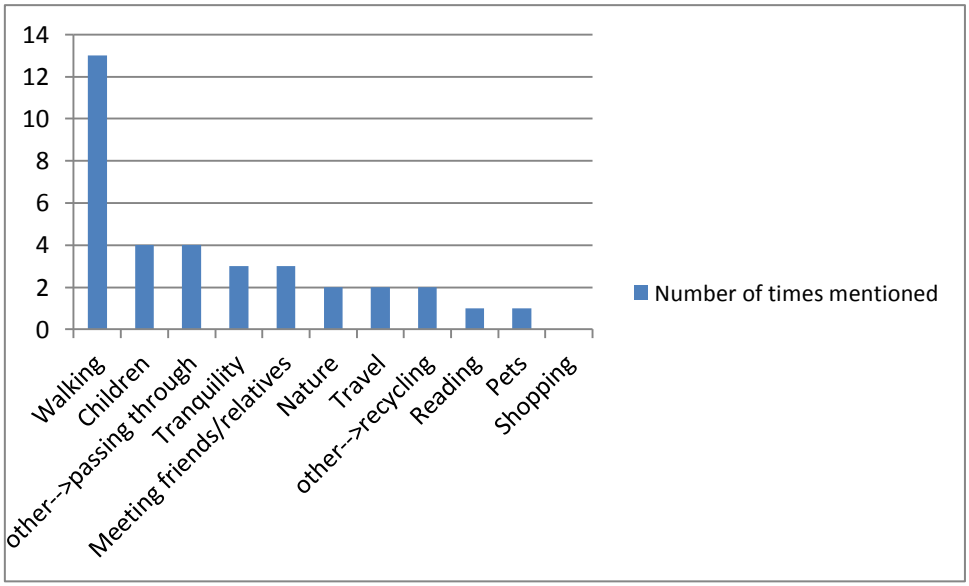


Figure 42. Purpose of users coming to HK

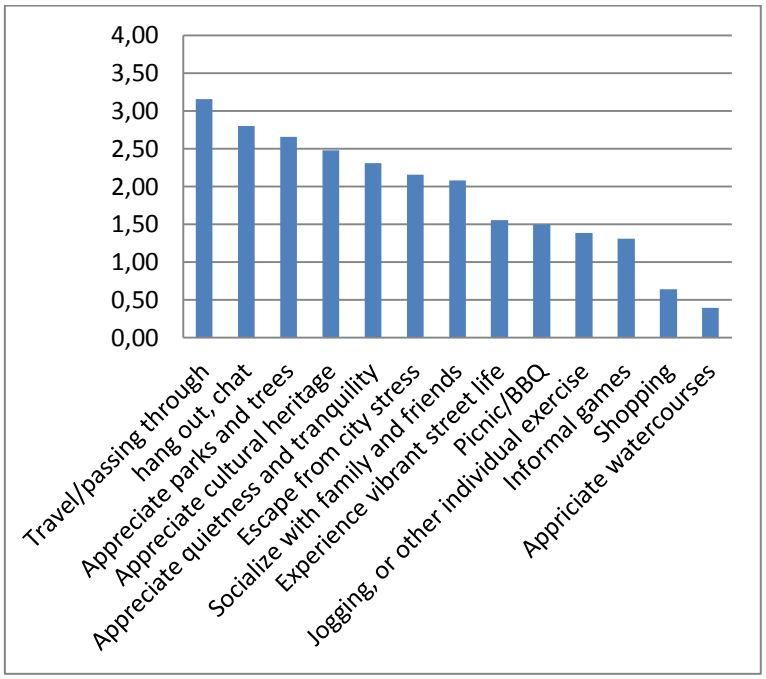


Figure 43. Rating for applicability of activities to HK, on a scale from 0-4

The top 3 sound sources indicated by the users of the space are 1) Birds, 2) Traffic, 3) Church bells. Church bells are a very iconic sound and are directly associated to a type of location and can even be connected to a specific church if the bells are unique. A location with a church is directly identified by the sound of church bells and eventhough the level of these bells can be high, they are accepted because it is part of the location (sound mark). The combination of birdsong and traffic can be seen in Figure 44 by the wide varity in frequencies and the high energy content in the low-mid frequency range.

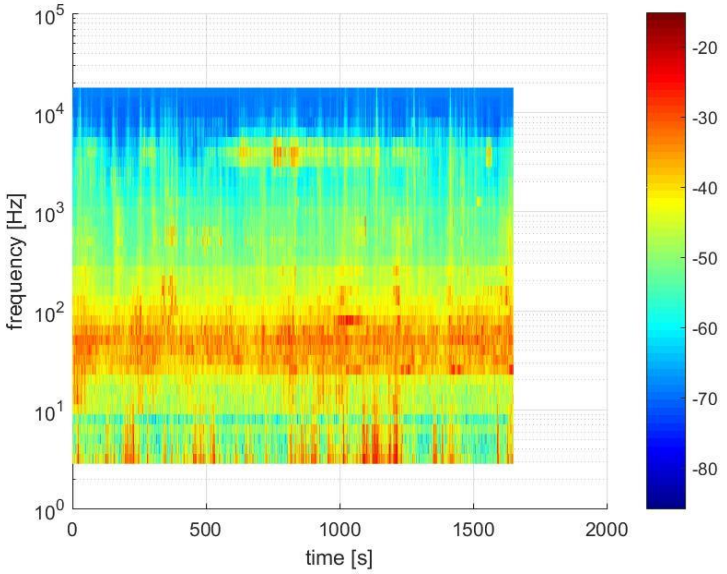


Figure 44. Sound spectrum of recording made in HK

In Figure 45 the results for the adjective scales can be seen. The adjective "pleasant" has the highest number of people rating the place as very pleasant. Also "calm" has a significant amount of people giving it a high rating. "Chaotic", "vibrant" and "annoying" are given a moderate rating. With this information and the use of Equation 1 and 2 (Sottek, 2017), the soundscape can be placed in the quadrant of "calm" (pleasant and uneventful) according to Axelsson (2010).

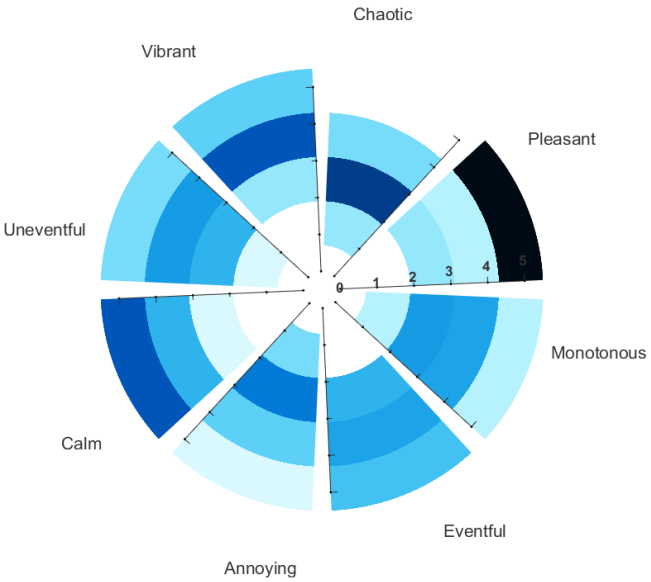


Figure 45. Rose-pie graph for adjective scales regarding HK with colour density indicating the amount of people answering: darker colours indicate a higher number of people.

4.1.7 Location 7 Botanical garden (BT)

Figure 46. Measurement location botanical garden near the entrance

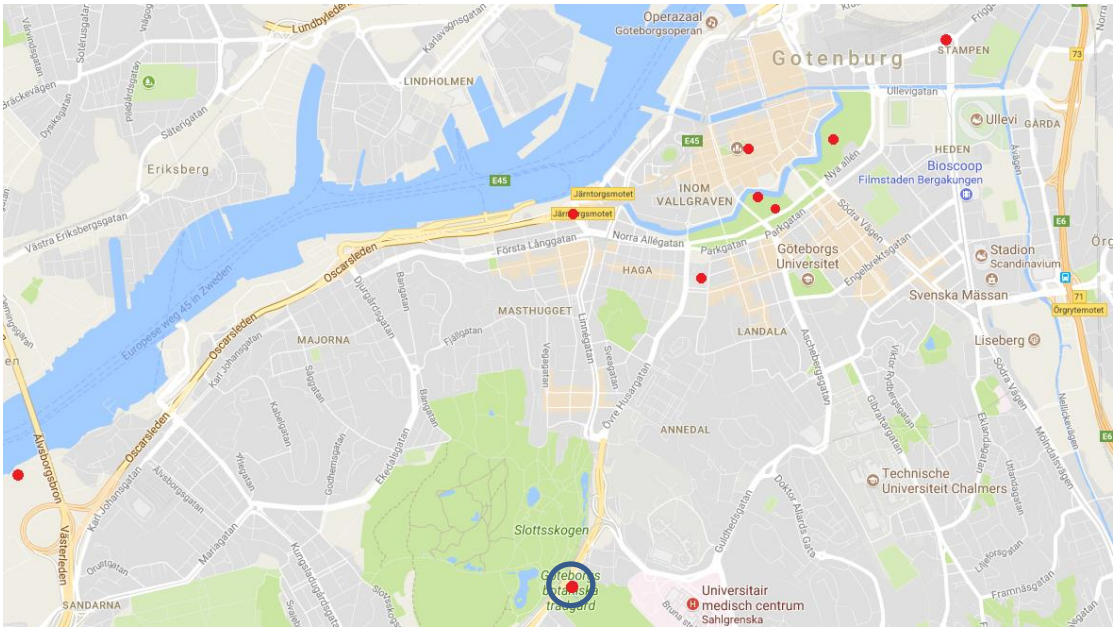


Figure 47. Measurement location BT on map indicated with a blue circle

The Botanical Garden in Gothenburg is located along a major road leading to the city. Not only cars but also trams pass close by the entrance of the park. The entrance has several facilities to sit, a small shop and a large pond with fishes. In Figure 48 a summary is given of the "rating questions" of the questionnaire.

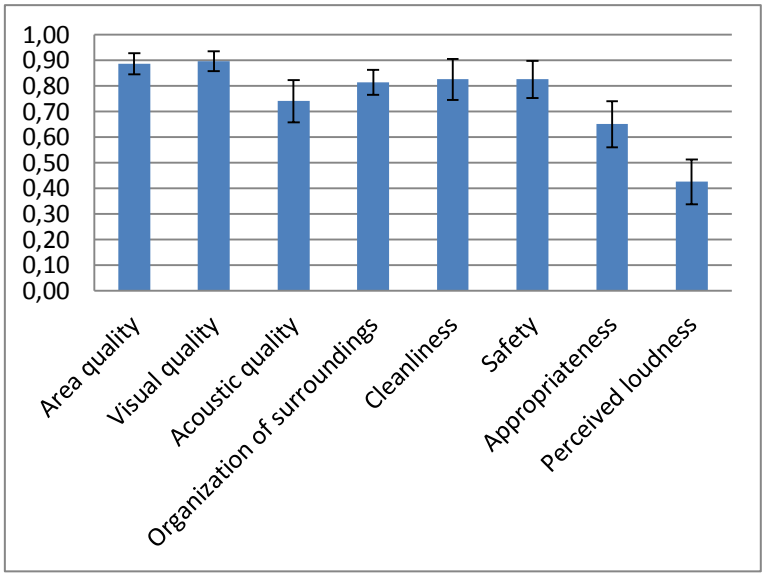


Figure 48. Summary of rating questions, BT, normalized values

The area and visual quality of the location is rated 0.90, the acoustic quality has a lower, but still a good rating of 0.74. The perceived loudness is low (0.43), but the appropriateness is mediocre (0.65). There is quite some difference between the visual and acoustic quality rating, however the location is rated very good overall (quality ratings all above 0.6). This can be explained by the fact that there are a lot of visual elements that need to be assessed by the brain first upon entering the park. Adding to this is the fact that the pond is shaped in such a way (broader in the front than in the back) that it optically elongates this part of the park and redirects your attention to the back of the pond. Users' focus on the visual instead on the noise might increase tolerance and overall quality. Another aspect could be that users visiting the park often filled in the questionnaire based partly on their memories. Deeper in the park the sound level is lower and one could probably experience tranquility and escape city stress.

In Table 8 it can be seen that the measured level agrees well with that indicated by the municipality. The sociotop activities indicated by the municipality match the answers given by the users of the space. The main purpose for going to the location is "nature", "walking" and "tranquility" which matches with the sociotops "flowering"/"nature reserve", "walking" and "rest ", see Figure 49. The highest rated activities applicable to the location are "appreciation of parks and trees", "escaping city stress" and "socializing", see Figure 50, which adds the sociotop activity "meeting people" to the previous list.

Table 8. Summary of municipality and measurement data, BT

Noise level indicated on noise map municipality:	55-60 dBA
Noise level measured in a single number of LAeq:	60 dBA
Sociotop indicators:	Flowering Events Cultural history Meeting people Nature reserve Cultivation Picnic Walk Rest

In Figure 51 the sound spectrum can be seen. A continues band in one particular frequency, as in previous spectra, cannot be seen here. There is more energy in the lower frequencies, which can be contributed to the traffic passing by. However the passing of vehicles seems to be infrequent. The top 3 sound sources indicated by the users of the space are: 1) Traffic, 2) Birds, 3) Wind. Indeed traffic is the most prominent sound source, explaining the higher energies is the lower frequencies. The sound of birds can be identified by the short periods of high energy in the higher frequencies. The effect of the wind cannot be seen in the sound spectrum.

The main sound source, traffic, can be connected to the lower ratings for appropriateness (0.65) and acoustic quality (0.74). The presence of mechanical sounds in a natural environment decreases the appropriateness, which also influences the overall acoustic quality rating. However, comparing to other locations there is no clear connection between the main sound source and acoustic quality rating. For example DK and HK both have natural sound sources (birds) as their main sound source, but have a lower acoustic quality rating (DK 0.65 and HK 0.61) than BT.

In Figure 52 the results for the adjective scales can be seen. The adjective with a high rating is “pleasant“ and “calm“. Also “vibrant“ has a significant amount of people giving it a high rating. “Chaotic“ and “uneventful“ are given a moderate rating. With this information and the use of Equation 1 and 2 (Sottek, 2017), the soundscape can be placed in the quadrant of “calm” (pleasant and uneventful) according to Axelsson (2010).

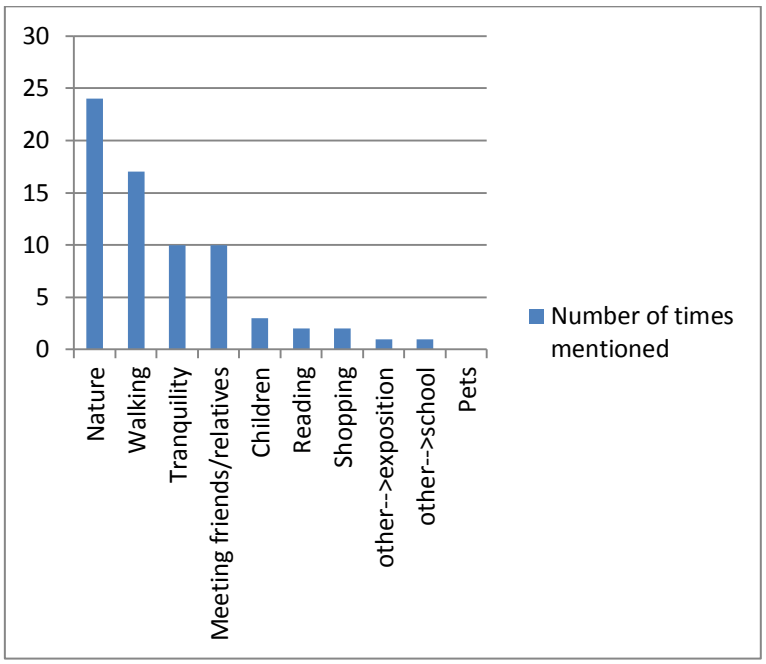


Figure 49. Purpose of users coming to BT

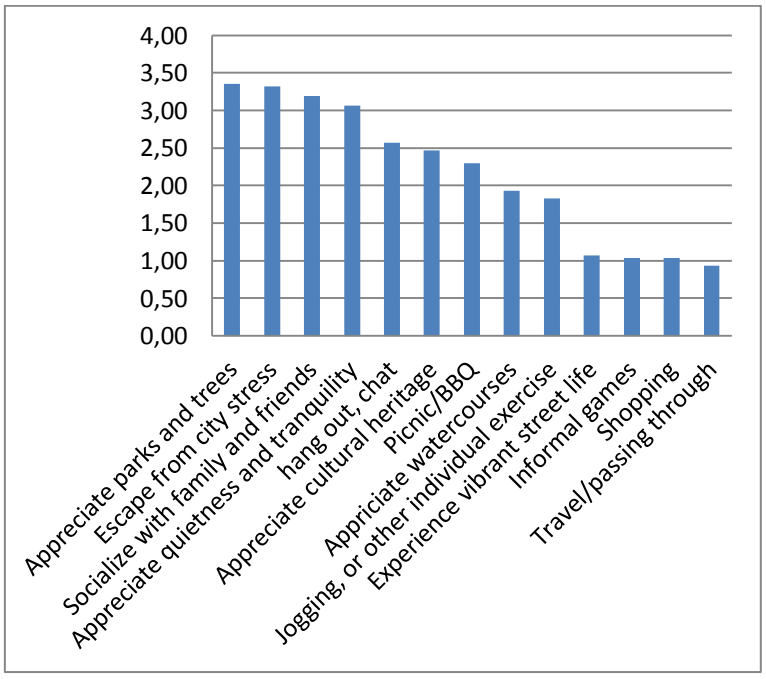


Figure 50. Rating for applicability of activities to BT, on a scale from 0-4

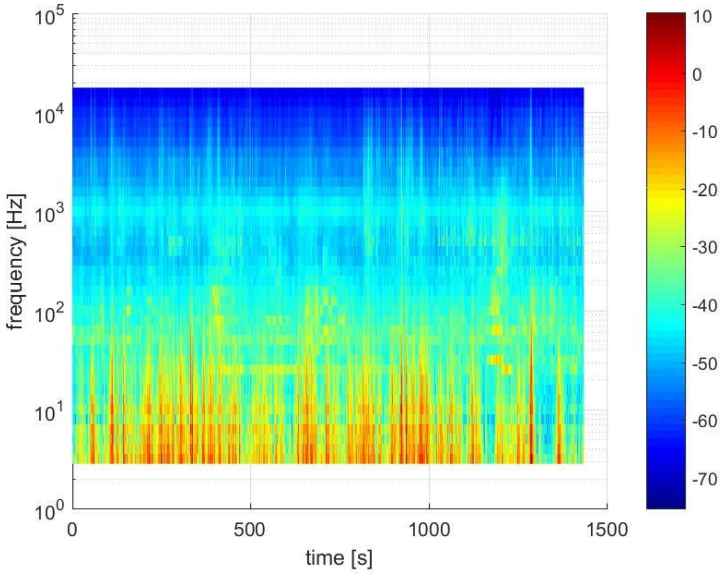


Figure 51. Sound spectrum of recording made in BT

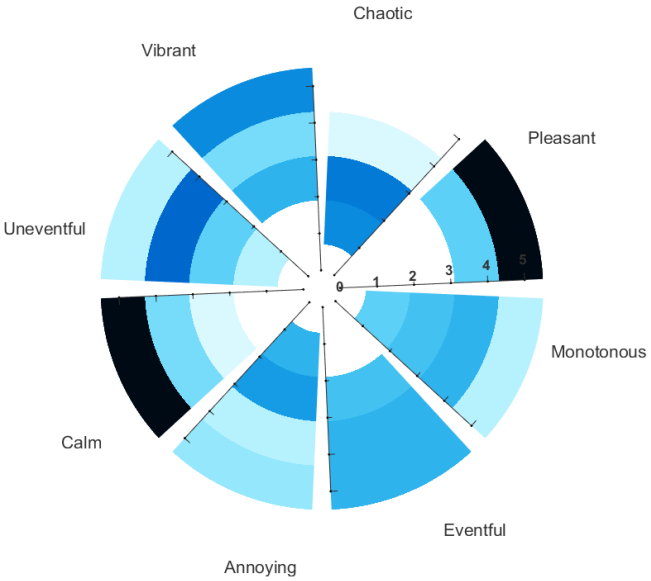


Figure 52. Rose-pie graph for adjective scales regarding BT with colour density indicating the amount of people answering: darker colours indicate a higher number of people.

4.1.8 Location 8 Rodasten

Figure 53. Measurement location Rodasten, near the river

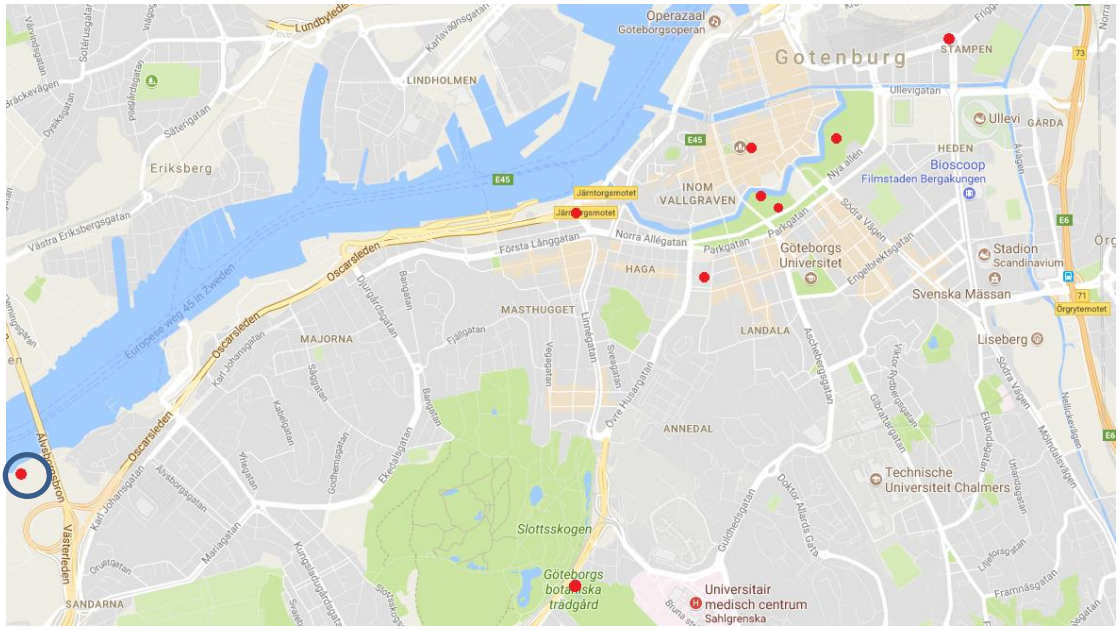


Figure 54. Measurement location RS on map indicated with a blue circle

Rodasten is a modern art museum located outside the city center of Gothenburg. The measurements took place outside the museum, along the river. Above the river, a traffic bridge is located, joining the two parts of the city, allowing the boats to pass under the bridge. In Figure 55 a summary is given of the "rating questions" of the questionnaire.

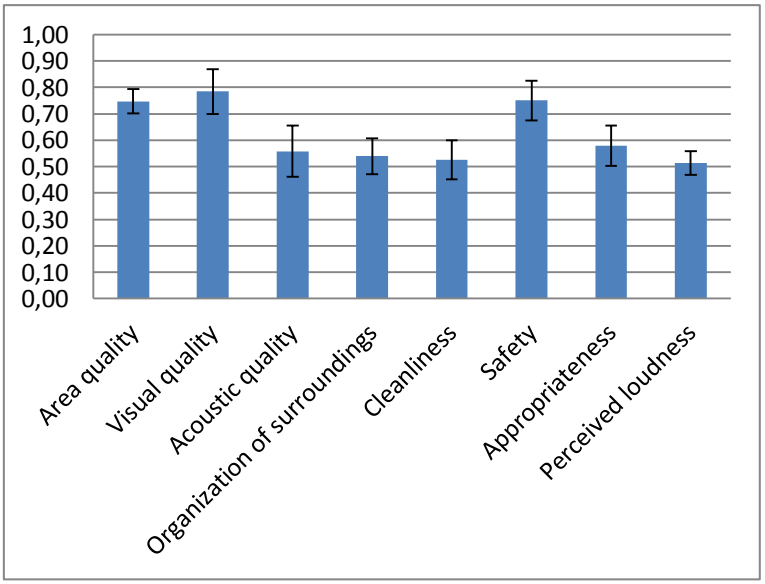


Figure 55. Summary of rating questions, RS, normalized values

This location has one of the lowest ratings for acoustic quality (0.56), organization of surroundings (0.54) and cleanliness (0.53). However, it still has a good overall and visual quality rating (0.75 and 0.78). The perceived loudness is rated 0.51 and the appropriateness is rated 0.58, eventhough there is a large road located above the location. The road itself is not visible and therefore no cars are visible, this may also contribute to the increase in visual quality and a decrease in perceived loudness.

Table 9. Summary of municipality and measurement data, RS

Noise level indicated on noise map municipality:	55-60 dBA
Noise level measured in a single number of LAeq:	60 dBA
Sociotop indicators:	Swimming Events Fishing Street sports Cultural history Picnic Walking Outlook Water adventure Rest

In Table 9 it can be seen that the measured sound level is at the maximum of the indicated sound level by the municipality. The sound level may be higher if there is more boat traffic or events take place at the museum. The main purpose of the users of the space is "walking", see Figure 56, which matches with the sociotop activity. Other high rated activities applicable to the location are "socializing", "hanging out", "appreciation of watercourses" and "escaping city stress", see Figure 57. The sociotops "swimming"/"fishing"/"water adventure" could correspond to "appreciation of water courses" and "escaping city stress" to rest. However socializing/hanging out is not represented in the sociotop activities.

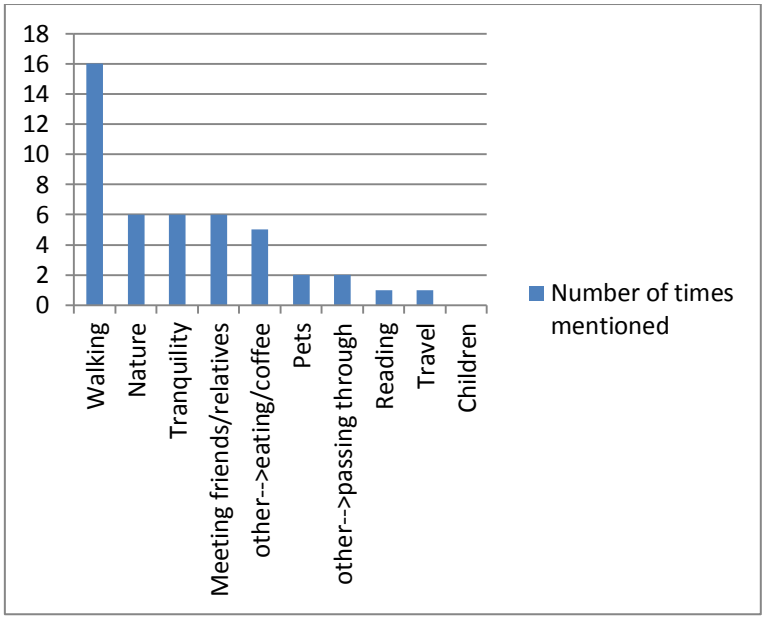


Figure 56. Purpose of users coming to RS

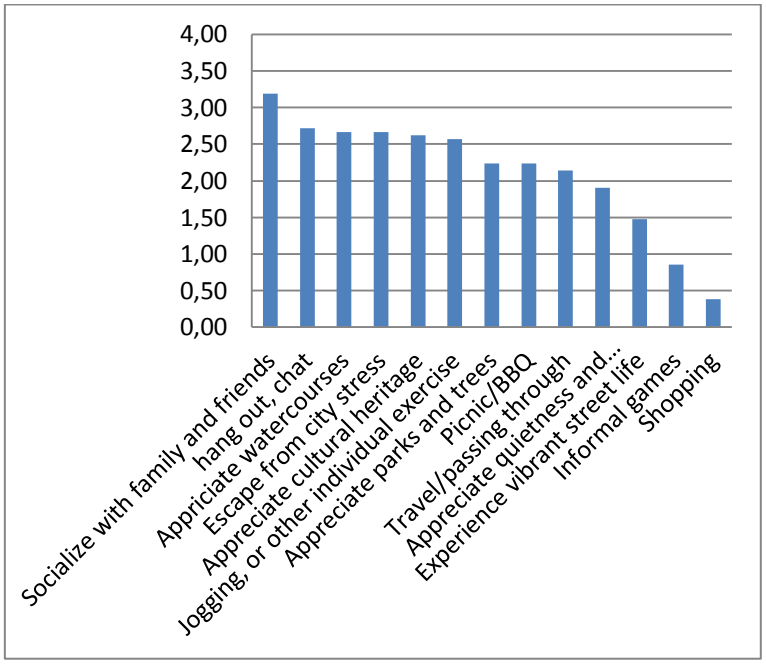


Figure 57. Rating for applicability of activities to RS, on a scale from 0-4

The top three sound sources chosen by the users of the space is: 1) Traffic, 2) Boats, 3) Talking/birds. The steady noise of the traffic on the bridge can be recognized in the spectrum (Figure 58).

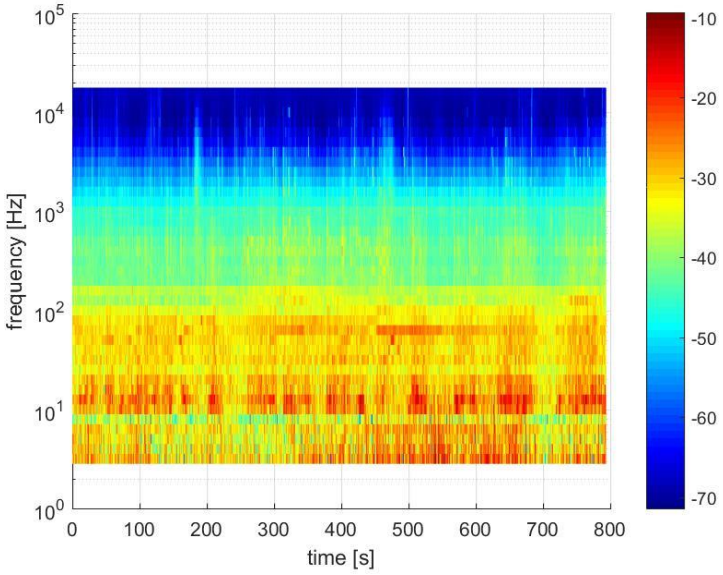


Figure 58. Sound spectrum of recording made in RS

In Figure 59 the results for the adjective scales can be seen. The adjectives with the largest number of people giving the highest rating were "vibrant" and "eventful". Also, "pleasant" has a significant amount of people giving it a high rating. "Calm" and "chaotic" are given a moderate rating. With this information and the use of Equation 1 and 2 (Sottek, 2017), the soundscape can be placed in the quadrant of "exciting" (pleasant and eventful) according to Axelsson (2010).

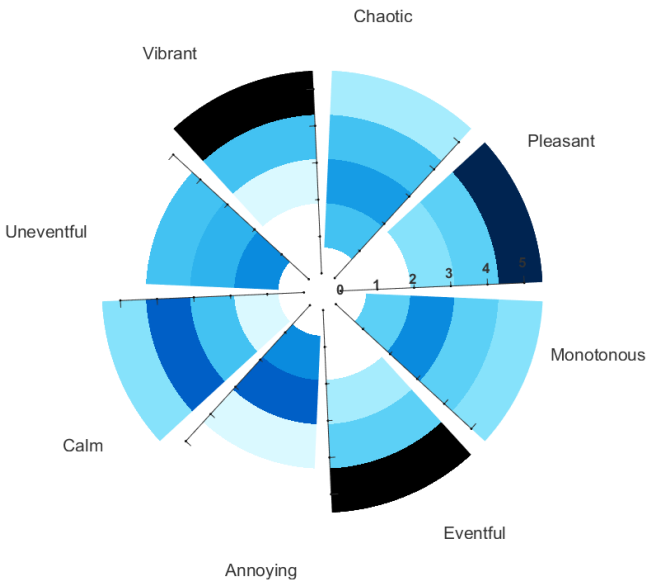


Figure 59. Rose-pie graph for adjective scales regarding RS with colour density indicating the amount of people answering: darker colours indicate a higher number of people.

4.1.9 Location 9 Järntorget (JT)

Figure 60. Measurement location järntorget near the fountain

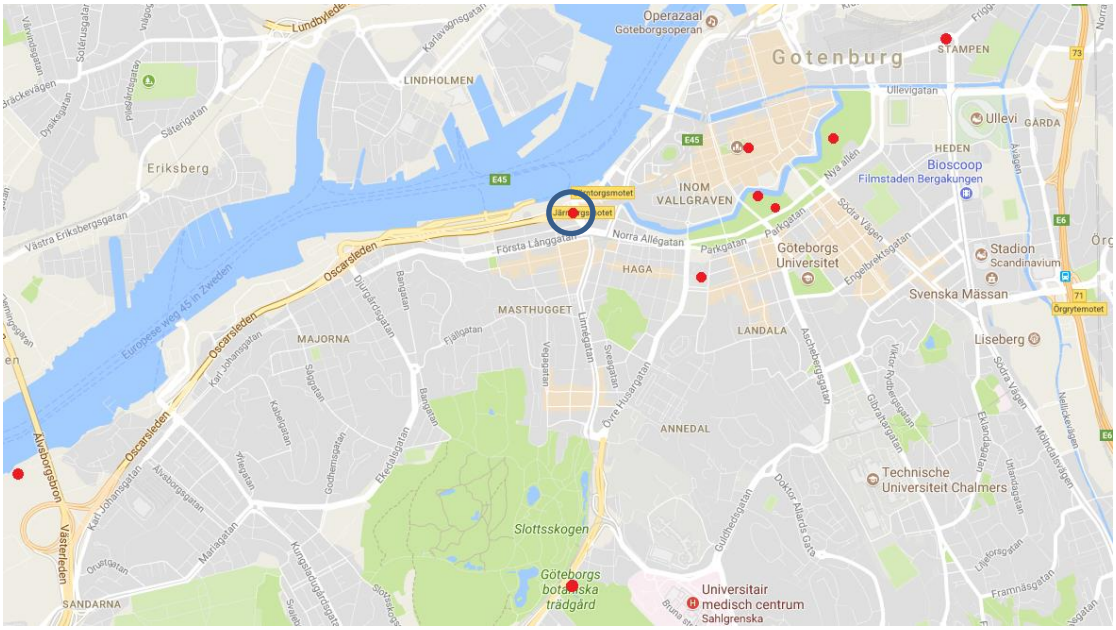


Figure 61. Measurement location JT on map indicated with a blue circle

Järntorget is a square in the center of Gothenburg surrounded by shops and cafes. One of the main bar-streets is located adjacent to it and it is also a traffic junction for trams. A fountain is situated in the middle of the square. In Figure 62 a summary is given of the "rating questions" of the questionnaire.

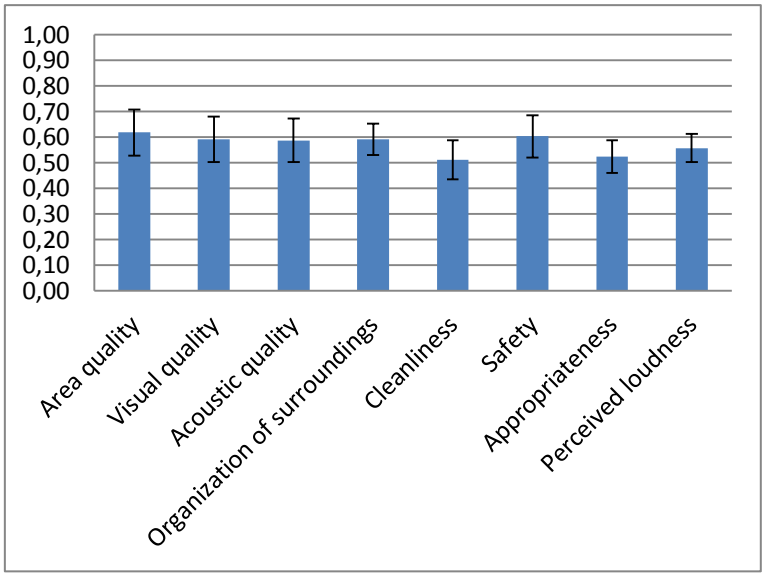


Figure 62. Summary of rating questions, JT, normalized values

This location has one of the lowest overall, visual and acoustic quality ratings (0.62, 0.59, 0.59, respectively). It is an urban environment without vegetation, with the exception of a few trees along the street. The fountain does make an interesting visual element, but the location does not seem to please the users as much as a location with vegetation. The preceived loudness is rather high (0.56) and this is also reflected in the measured level.

Table 10. Summary of municipality and measurement data, JT

Noise level indicated on noise map municipality:	>65 dBA
Noise level measured in a single number of LAeq:	63 dBA
Sociotop indicators:	Flowering Events Cultural history Meeting people Rest

In Table 10 it can be seen that the measured level is lower than the one indicated by the municipality. This can be explained by the fact that the measurements were performed on a Sunday, when tram traffic is less dense than during week days.

The sociotop activities indicated by the municipality only partly agree with the purpose and activity ratings given by the users of the space, see Figure 63 and 64. The main purpose of people coming to the location is “meeting people“, “travel“ and “walking“. “Meeting people“ is indicated as a sociotop

activity, however "travel" or "walking" is not. "Experiencing vibrant street life" could be coupled to the sociotop "events".

The municipality also indicated the location as a resting place, however the rating for "escaping city stress" is rather low and "tranquility" was the purpose of only one person visiting the location.

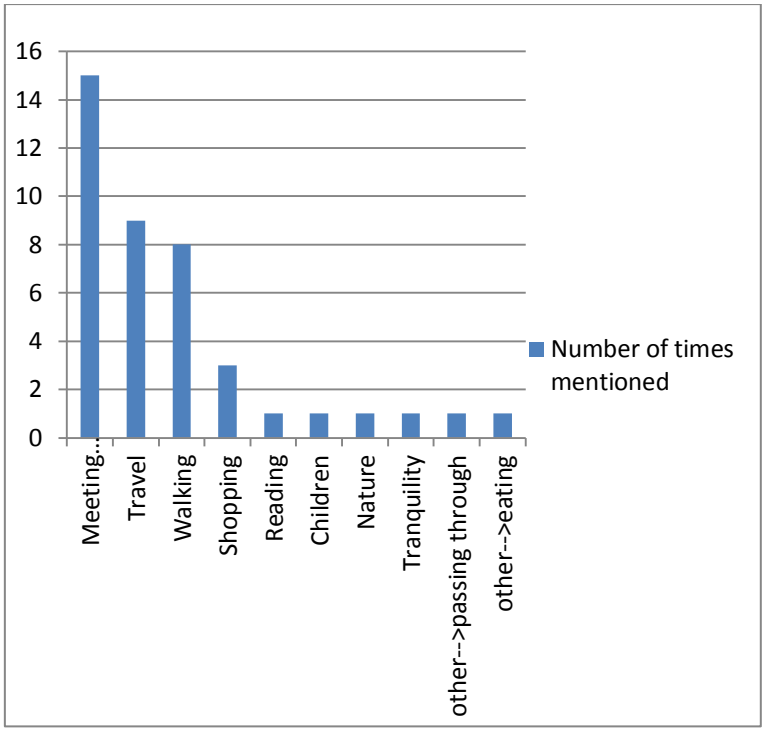


Figure 63. Purpose of users coming to JT

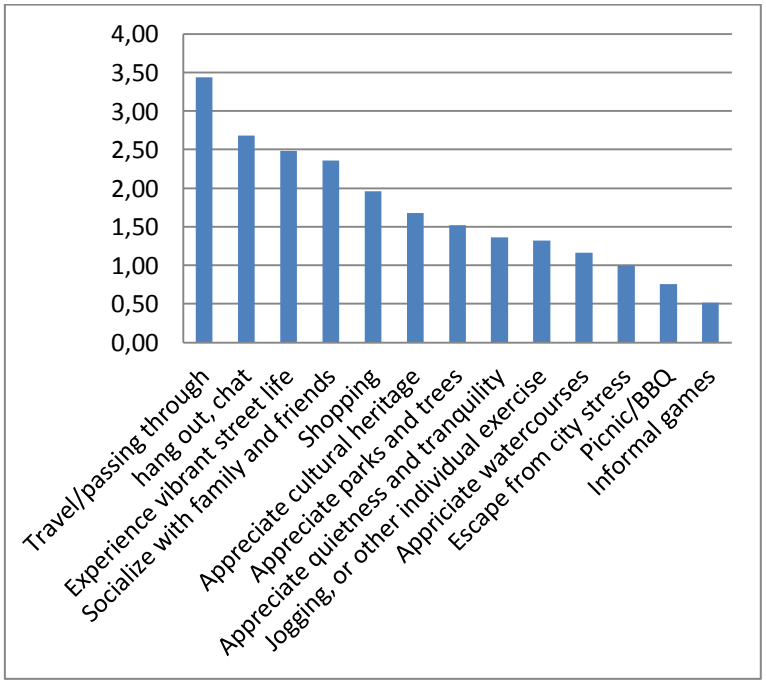


Figure 64. Rating for applicability of activities to JT, on a scale from 0-4

The top 3 sound sources as chosen by the users of the space is: 1) Water, 2) Traffic, 3) Talking. Traffic is not the main sound source that users of the space hear, which is to be expected, the measurements and questionnaires were conducted around the fountain, not close to the road. The steady sound of the water flowing in the fountain and trams passing by constantly can be recognized in the sound spectrum (Figure 65). The fountain, however, does not seem to influence the judgment on visual or sound quality. Comparing the site to TG, where the first sound source was also the fountain, it can be seen that the ratings are different. In TG the visual quality was rated 0.8 and the sound quality 0.69. In JT the ratings are 0.59 for both qualities. The ratings for sound quality at both places are closer than for the visual quality. But nevertheless, the differences in ratings indicate that other factors such as the presence of vegetation and the second and third sound sources might also influence the quality rating.

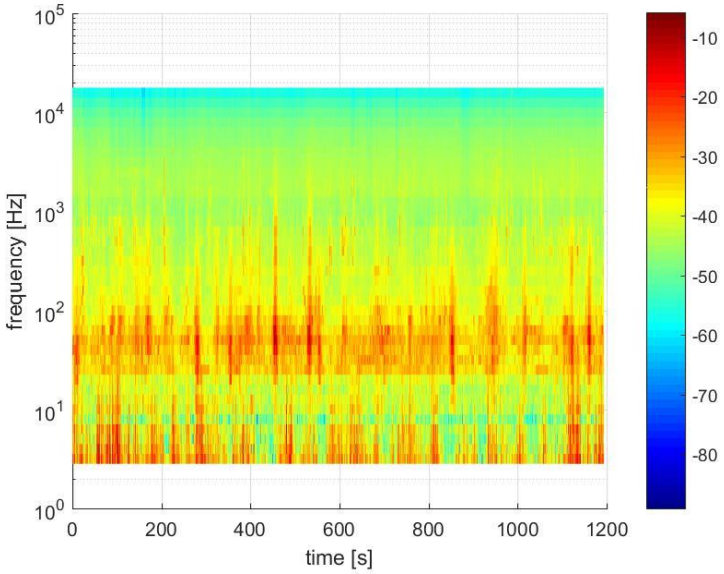


Figure 65. Sound spectrum of recording made in JT

In Figure 66 the results for the adjective scales can be seen. A large number of people rate the site as very "vibrant" (12 people, 55%) and "eventful" (9 people, 41%). Also "pleasant" has a significant amount of people giving it a high rating (11 people, 50%). "Calm" (12 people, 55%) has a high amount of people giving it a low rating. With this information and the use of Equation 1 and 2 (Sottek, 2017), the soundscape can be placed in the quadrant of "exciting" (pleasant and eventful) according to Axelsson (2010).

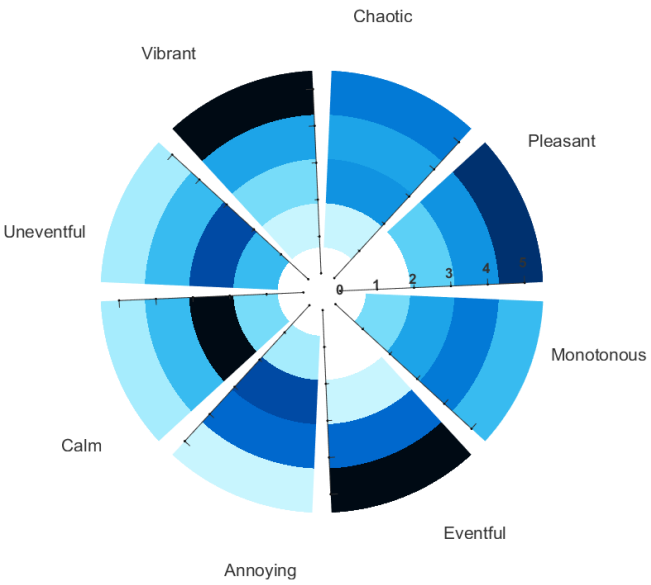


Figure 66. Rose-pie graph for adjective scales regarding JT with colour density indicating the amount of people answering: darker colours indicate a higher number of people.

4.1.10 Location 10 Odinsplats (OP)

Figure 67. Measurement location Odinsplats

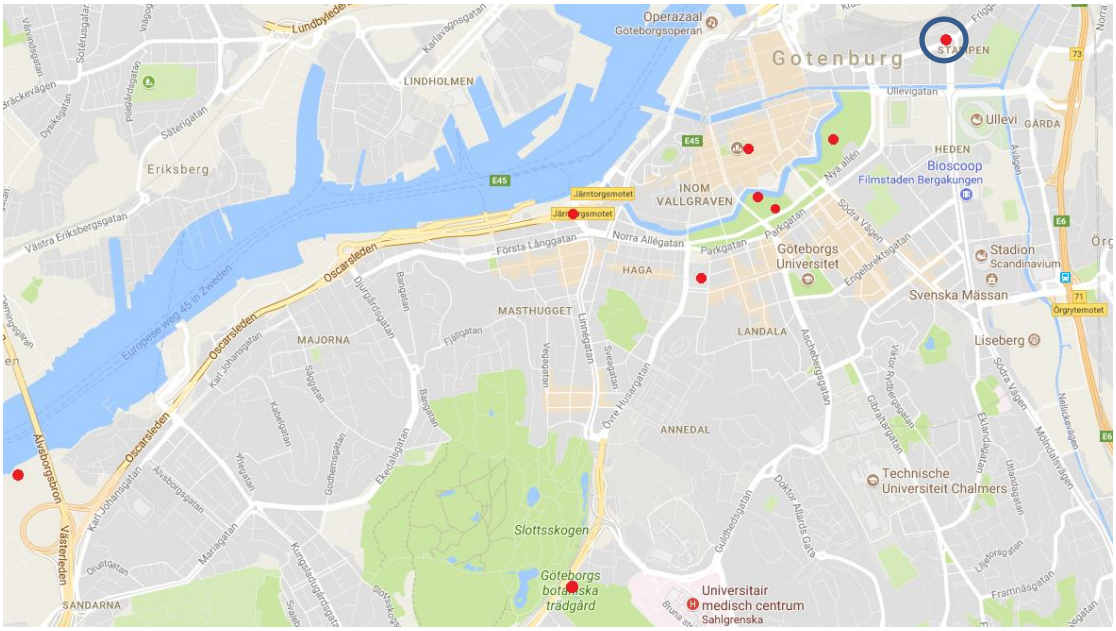


Figure 68. Measurement location OP on map indicated with a blue circle

Odinspaltsen is located at the edge of the city center, between the central station and a residential area. The square is essentially a roundabout, thus surrounded by traffic. At the center of the square, a fountain is located, which children also play in. There is also a small kiosk where food and drinks can be bought. In Figure 69 a summary is given of the "rating questions" of the questionnaire.

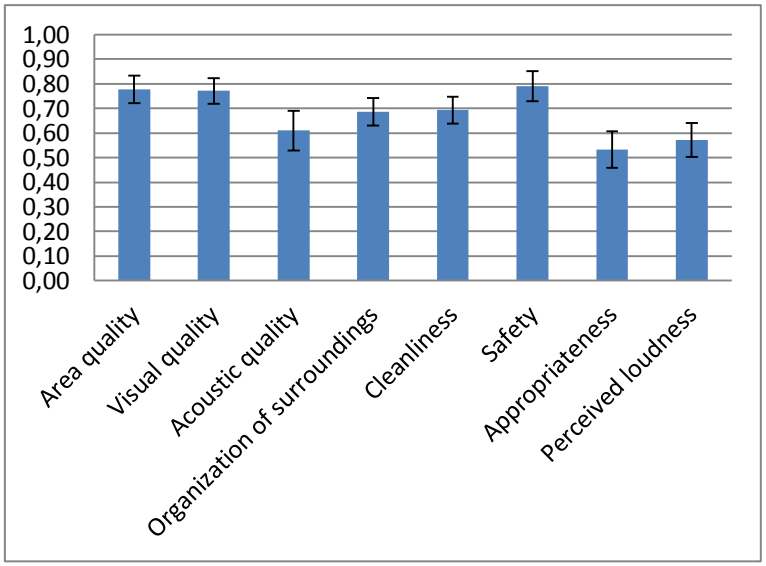


Figure 69. Summary of rating questions, OP, normalized values

The area has a high overall and visual quality (0.78 and 0.77 respectively). The acoustic quality is lower (0.61), most likely due to the presence of traffic noise.

Table 11. Summary of municipality and measurement data, OP

Noise level indicated on noise map municipality:	60-65 dBA
Noise level measured in a single number of LAeq:	65 dBA
Sociotop indicators:	Not available

In Table 11 it can be seen that the noise level measured is in line with the one indicated by the municipality. No sociotop activities were provided by the municipality.

The main purposes of the people at this location are "meeting friends", "walking" and "tranquility" (see Figure 70). Also many parents were present playing with children in the fountain. However they were unable to fill in the questionnaire since they had to keep an eye on their children. The top rated activities are social activities; "hanging out" and "socializing", see Figure 71.

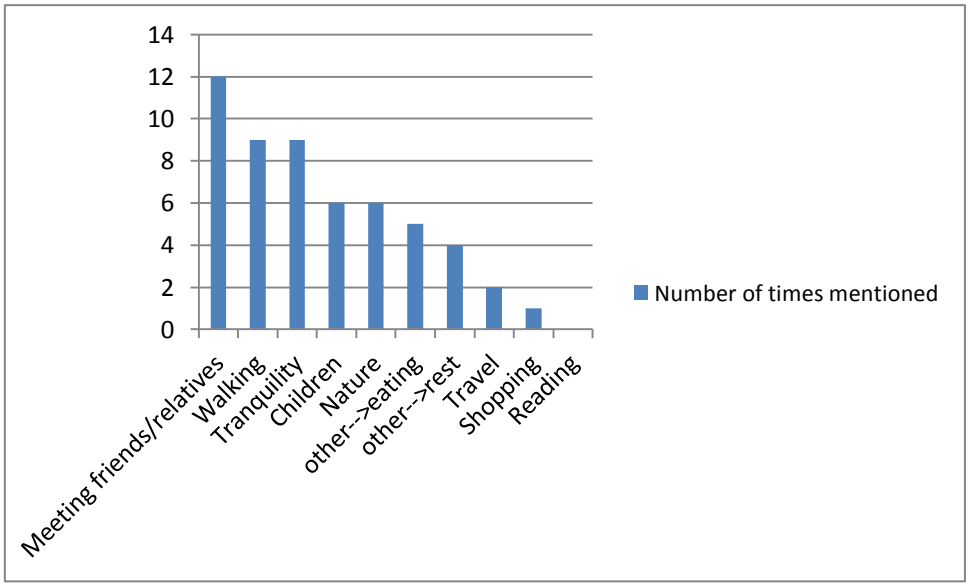


Figure 70. Purpose of users coming to OP

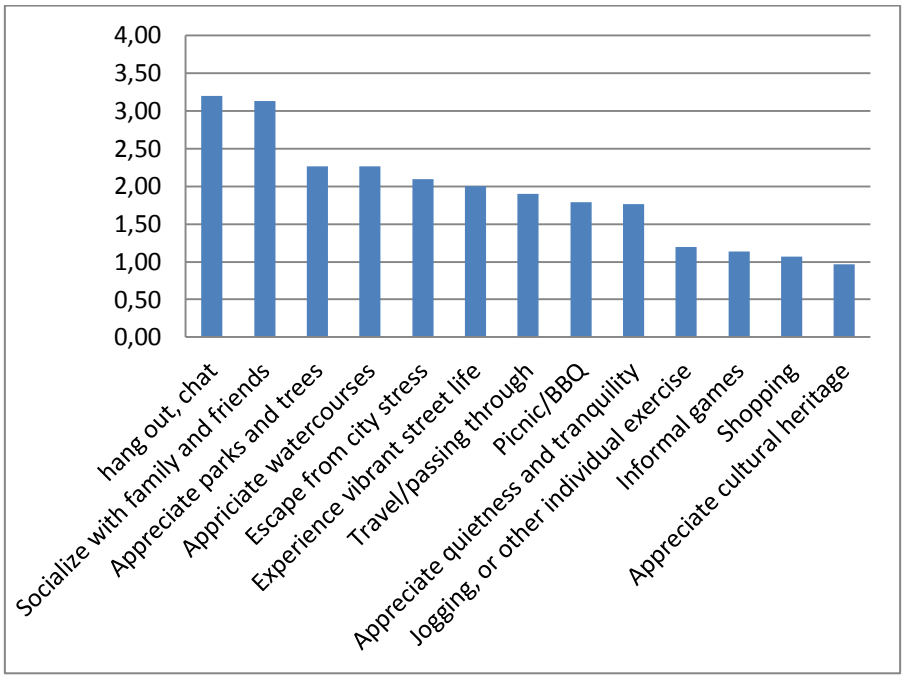


Figure 71. Rating for applicability of activities to OP, on a scale from 0-4

In Figure 72 the sound spectrum can be seen. The top 3 sound sources as chosen by the users of the space are: 1) Traffic, 2) Water, 3) Children. The steady water and traffic sound can be recognized in the sound spectrum.

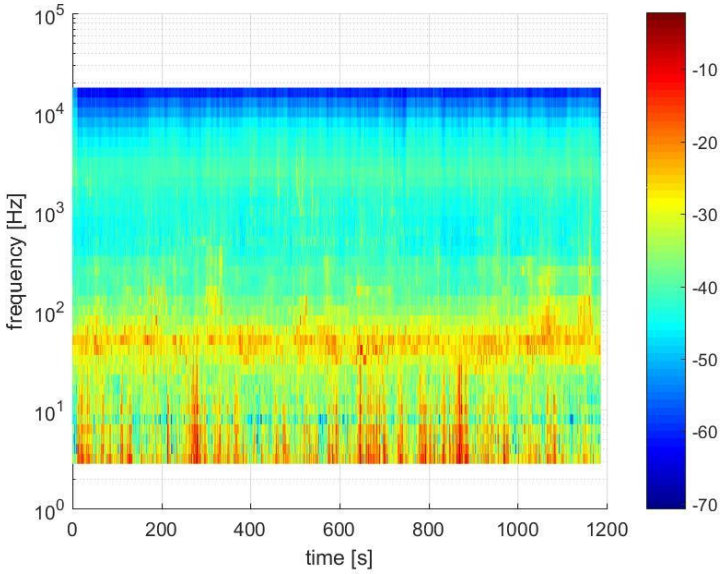


Figure 72. Sound spectrum of recording made in OP

In Figure 73 the results for the adjective scales can be seen. The adjective with a high rating is "vibrant". Also "pleasant", "calm" and "eventful" have a significant amount of people giving it a high rating. With this information and the use of Equation 1 and 2 (Sottek, 2017), the soundscape can be placed in the quadrant of "exciting" (pleasant and eventful) according to Axelsson (2010).

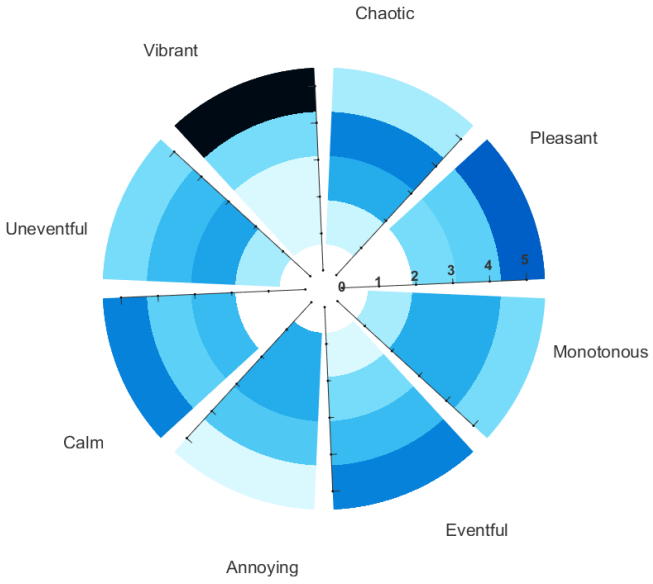


Figure 73. Rose-pie graph for adjective scales regarding OP with colour density indicating the amount of people answering: darker colours indicate a higher number of people.

4.2 The Relationship between Overall Area Quality, Visual Quality and Sound Quality

In this chapter, locations will be compared to each other to try and find relationships between overall, visual and sound quality. At first, the quality ratings for all locations will be assessed separately to see if similar locations are clustered and have the same quality rating. Here the relationship with the other rating variables (organization of the surroundings, cleanliness, safety, appropriateness of the sound and perceived loudness) will also be assessed. After that the relation between the quality ratings will be analyzed using correlation coefficients and the mean values of each variable on each location.

4.2.1 Quality Rating Assessment

In Figure 74 the average value of the overall area quality can be seen per location, ranked from the location with the lowest to the highest overall quality. Within the graph, three clusters can be identified, see Table 12.

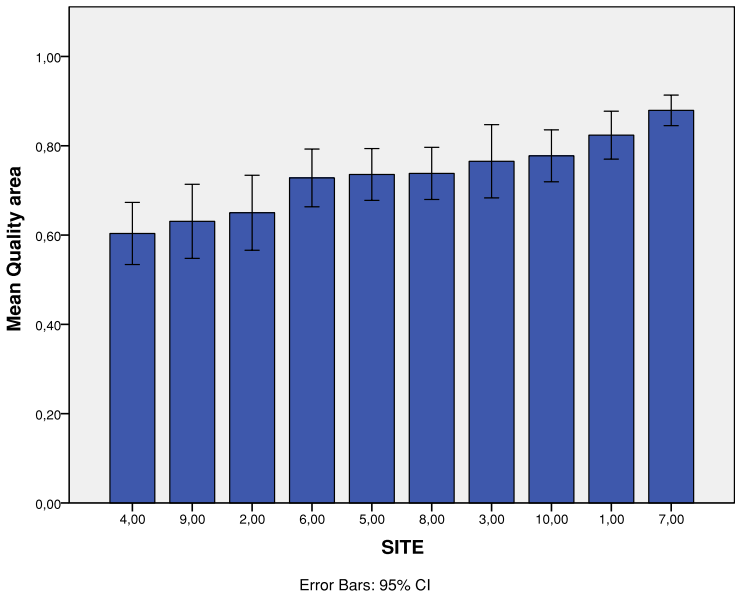


Figure 74. Ranking of overall area quality

Table 12. Clusters which can be identified based on the ranking of overall area quality and their visual category and facilities

	Location	**Visual category**	**Facilities**
Cluster 1	4 KPM cloud	Near water and vegetation	Benches, large open space
	9 JT	Urban	Benches, fountain, shops, travel
	2 DK	Urban	Benches, shops, church

Cluster 2	6 HK	Urban vegetation	Benches, church
	5 KPR	Non-urban vegetation	Large open space
	8 RS	Urban/near water	Benches, museum, restaurant
Cluster 3	3 KPM sun	Near water and vegetation	Benches, large open space
	10 OP	Urban/Near water and vegetation	Benches, fountain, shops, restaurants
	1 TG	Near water and vegetation	Benches, fountain, restaurant, playground, large open space
	7 BT	Near water and vegetation	Benches, shop

The first cluster contains the locations that were categorized as having an urban visual character and the location in Kungsparken on a cloudy day. The second cluster has locations which are close to roads but contain some form of natural elements like water or vegetation. The thirds cluster contains locations with water elements, either fountains or natural water elements and vegetation. Location 10, Odinsplats, was at first categorized as urban due to the location at the center of a roundabout. However the presence of the fountain and some vegetation seems to significantly increase the overall quality of the location. Location 3 and 4 are in different clusters, while the only difference between them is weather. The presence of sun also significantly increases the overall quality.

Another factor that could influence overall quality of an area is the safety. From prehistoric times our ancestors looked for safe place to escape predators. Farina (2014) stated that this still remains in the human system, therefore safe places are favorable to others (Farina, 2014). The feeling of safety can therefore increases comfort and may increase overall quality judgement. In Figure 75 the overall area quality is compared to the mean safety ratings of each area. Ranked from the location with the lowest area quality to the highest.

It can be seen that the rating for safety increases when the area quality increases, meaning that safety has some influence on the judgement of overall area quality. In the first cluster there are areas with a lower safety rating. In

the second and third cluster there is a small increase in safety rating but the last two clusters do not differ much from each other in this case.

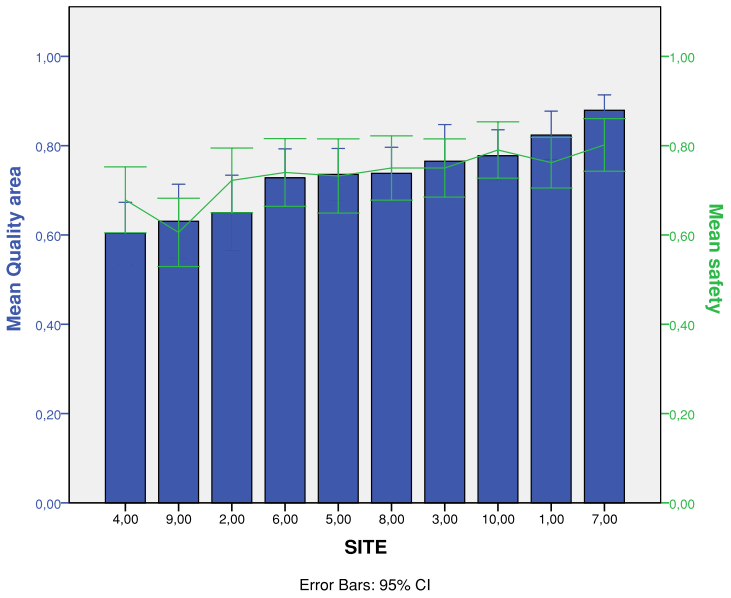


Figure 75. Mean overall area quality compared to the mean safety rating

In Figure 76 the average value of the visual area quality can be seen per location, ranked from the location with the lowest to the highest visual quality. Within the graph two clusters can be identified, see Table 13.

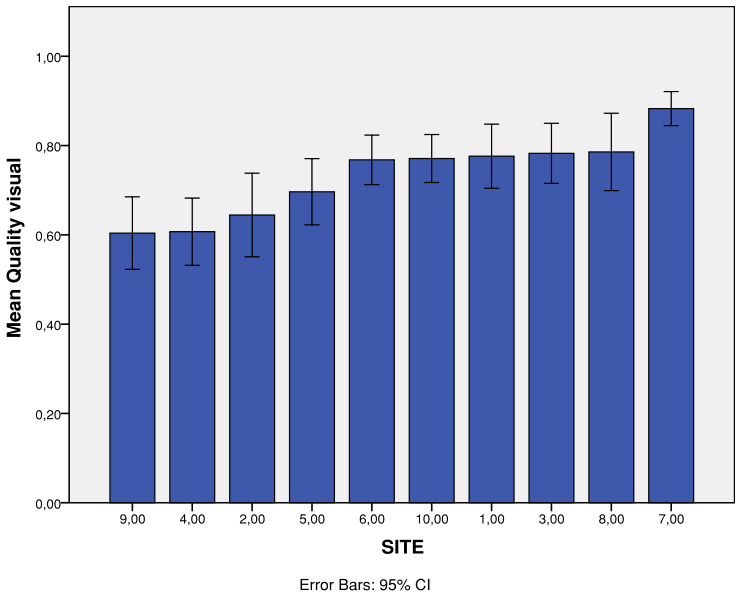


Figure 76. Ranking of visual quality

Table 13. Clusters which can be identified based on the ranking of visual quality and their visual category

	Location	Visual category
Cluster 1	9 JT	Urban
	4 KPM cloud	Near water and vegetation
	2 DK	Urban
	5 KPR	Non-urban vegetation
Cluster 2	6 HK	Urban vegetation
	10 OP	Urban/Near water and vegetation
	1 TG	Near water and vegetation
	3 KPM sun	Near water and vegetation
	8 RS	Urban/near water
	7 BT	Near water and vegetation

The first cluster contains urban locations and Kungsparken on a cloudy day and near the road. The second cluster contains locations with vegetation and water, with one exception being location 6 Hagakyrkan. The clustering here is not as clear as in the overall quality clusters; a different approach is needed to find the common factor for the locations within a cluster.

Hong et al (2015) stated that a location is judged on its attractiveness, simplicity, enclosure, harmony and the fact of being interesting or not. The organization of the surroundings could be linked to harmony or attractiveness. Cleanliness could be linked to attractiveness, making attractiveness a combination of different factors, most likely containing more than cleanliness and the organization of the surroundings. To find the relation between the clusters of visual quality, the ratings for the organization of the surroundings and the cleanliness are analyzed. In Figure 77 and 78 the mean visual quality is compared to the mean organization of the surroundings and the mean cleanliness to see if they follow the same trend. Again the mean visual quality is ranked from lowest to highest visual quality.

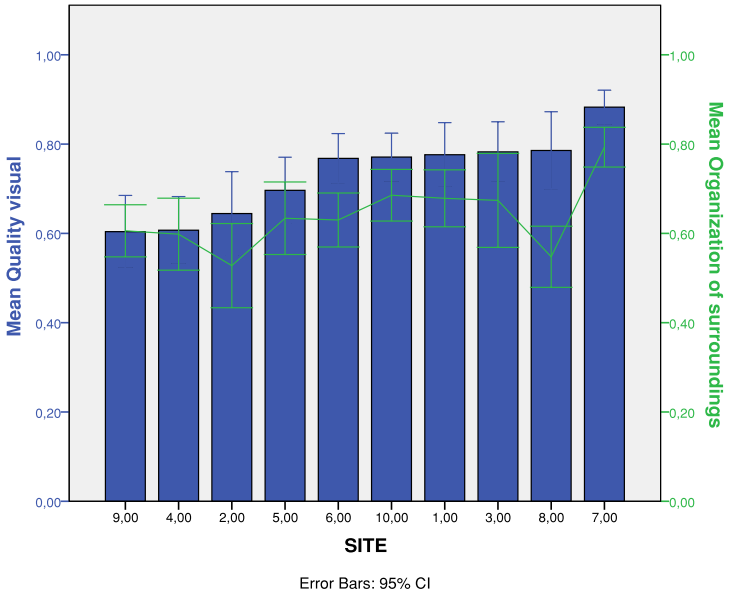


Figure 77. Mean visual quality compared to the mean rating of the organization of surroundings

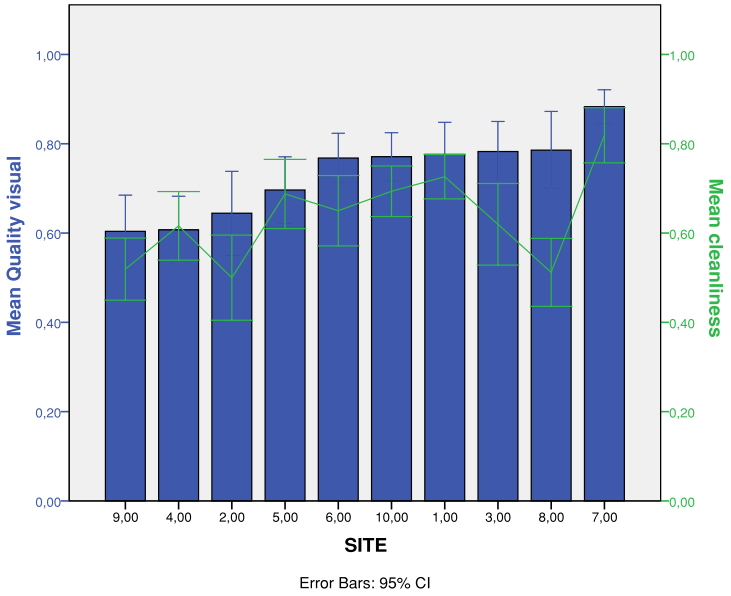


Figure 78. Mean visual quality compared to the mean rating of cleanliness

Similarities can be seen between the increasing trend of the visual quality and the organization of the surroundings and cleanliness. However location 8 Rodasten has low ratings for both variables but a high rating for visual quality. This could be because the location is visually more interesting and therefore gets a higher rating for visual quality. But in general it could be said that the locations in the first cluster have a lower organization of the surroundings and cleanliness than those in the second cluster. Again locations 3 and 4 have large differences in rating for all variables discussed above.

In Figure 79 the average value of the sound area quality can be seen per location, ranked from the location with the lowest to the highest sound quality. Within the graph, three clusters can be identified, see Table 14.

Traffic is the most common number 1 sound source in almost all locations. The second sound source is not of a specific type within each cluster. Remarkable is that TG is the location without any mechanical sound sources present in the top 3, however it is not the location with the highest sound quality rating. BT has the highest sound quality rating, 0.71 compared to 0.67 in TG). BT also has the highest visual and overall area quality rating. Here, TG gets the third and the second place. This can be an indication that visual and overall quality influence the sound quality judgement. The acoustic environment in TG contains no mechanical sources and according to Brown (2011) and Nilsson (2007) this should increase the quality of the acoustic environment (also see Section 2.9). So, even though, in theory, the acoustic environment is better in TG (no mechanical sources), it is not judged as such.

There are also two other variables regarding sound: the perceived loudness and the appropriateness. These are analyzed to find a relationship between the clusters, see Figure 80 and 81.

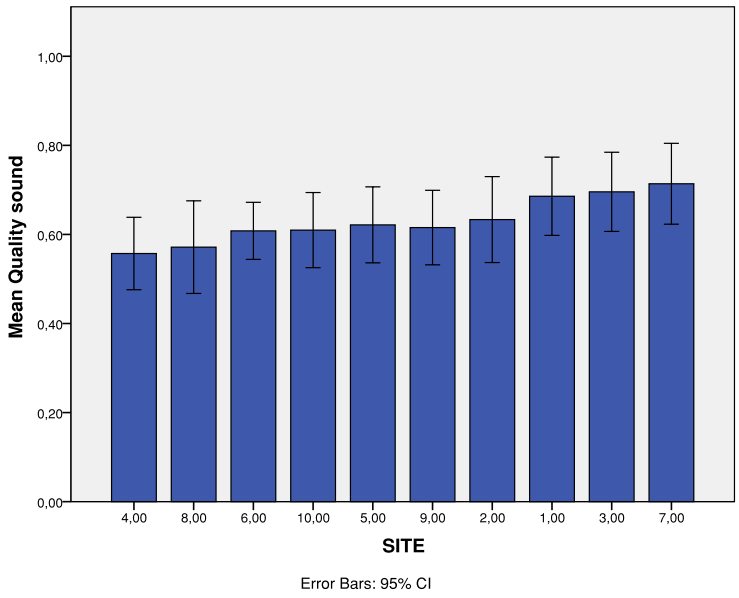


Figure 79. Ranking of sound quality

Table 14. Clusters which can be identified based on the ranking of sound quality and their top sound sources. Similar sound sources marked.

	Location	Sound source 1	Sound source 2	Sound source 3
Cluster 1	4 KPM cloud	traffic	birds	people
	8 RS	traffic	boats	talking/birds

Cluster 2	6 HK	birds	traffic	church bells
	10 OP	traffic	water	children
	5 KPR	traffic	music	birds
	9 JT	water	traffic	talking
	2 DK	birds	people	traffic
Cluster 3	1 TG	water	children	talking/birds
	3 KPM sun	traffic	people	birds
	7 BT	traffic	birds	wind

The mean appropriateness has an increasing trend with increasing sound quality. The trend is visible for locations with a mean sound quality of 0.6 and higher. Below this rating there is no clear relationship. Outliers here are location 8, Rodasten, where the appropriateness is quite high (0.58) compared to the mean sound quality rating given (0.56). Also, the perceived loudness is not high (0.51). The fact that it has a low sound quality despite the higher ratings for other variables may be explained by the top two sound sources. The first one being traffic and the second boats, they are both mechanical sounds, which are the least preferred (Liu et al., 2014). Location 8 is the only location where both the first and second sound sources are mechanical sound sources. The other outlier is location 5, Kungsparken roadside, where the mean perceived loudness suddenly increases and the appropriateness decreases. This is most likely due to the close presence of a busy road. It can also be seen in the sound sources that the most prominent sound source is traffic. However, the second and the third sound sources can be catalogued as pleasant sources: music and birds, human and natural sounds. The presence of these pleasant sounds may compensate for the traffic, where the overall sound quality has a good rating despite the high-perceived loudness.

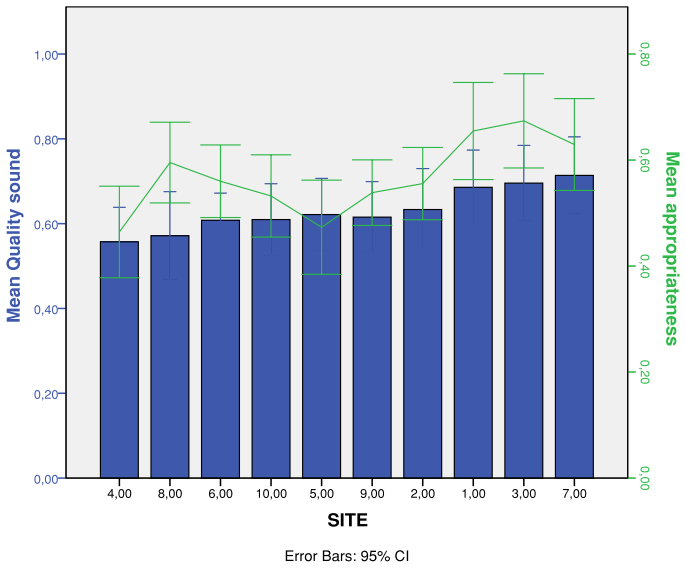


Figure 80. Mean sound quality compared to the mean rating of appropriateness of the sound to the surrounding

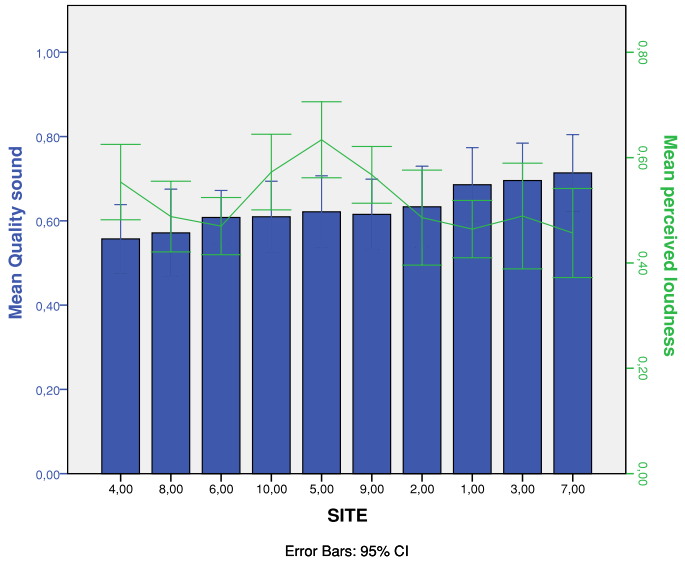


Figure 81. Mean sound quality compared to the mean rating of perceived loudness

Within the first cluster is also location 4, Kungsparken on a cloudy day. While location 3, Kungsparken on a sunny day is in the third cluster. This proves again that weather conditions change the whole perception of a location and can increase perceived loudness and decrease appropriateness.

For the perceived loudness there seems to be a threshold. When the mean quality of sound is above 0.65, the perceived loudness becomes a more steady value. To check if the information on the perceived loudness is meaningful the mean perceived loudness is compared to the measured diffuse field loudness in Figure 82. It can be seen that the perception of loudness is in line with the measured loudness. With increasing perceived loudness also the measured loudness increases. Although, there are some fluctuations,

especially between location 10 (OP) and 5 (KPR), where the measured loudness significantly decreases, but the perceived loudness increases. This can be due to the fact that in Kungsparken roadside traffic is the most dominant sound source, however the appropriateness was rated low (0) as an answer to the fact that the sound does not match to the location, the perceived loudness can be increased.

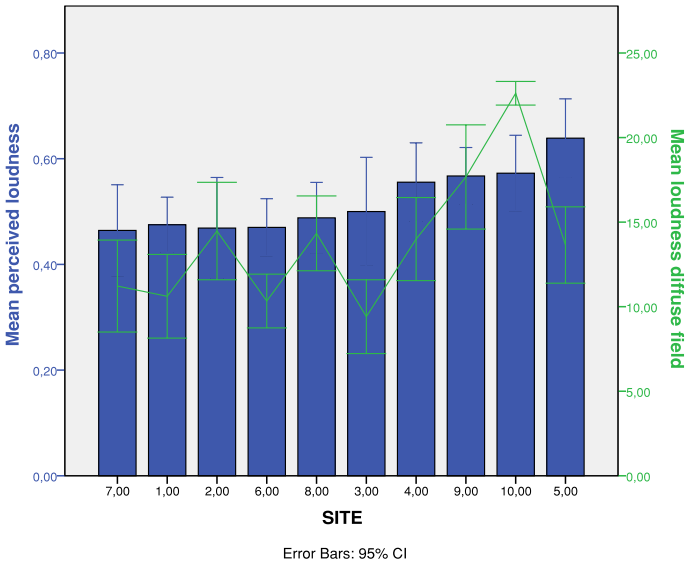


Figure 82. Mean perceived loudness compared to mean diffuse field loudness

In general it can be said that the overall sound quality is related to the perceived loudness and appropriateness. When the appropriateness is high and the perceived loudness is low, the sound quality gets the highest rating (third cluster). When the perceived loudness is high and the appropriateness is low, the types of sound sources may play a role in the rating of the overall sound quality (first and second cluster).

4.2.2 Interrelationships Quality Ratings

The relation between qualities and other variables have been assessed; however the qualities themselves are also depended on each other. As can be read in the literature study, sound and visual elements are in a constant battle for attention. If the location is visually attractive or interesting, these factors may have the upper hand in determining the rating for the overall quality.

It can be seen in the clusters that were formed in the paragraph above that the ratings are not perfectly correlated with each other. If the correlation were perfect the location clustering would have been the same. However, an overall trend is visible. The visually attractive, well-organized, least loud locations are always placed in the third cluster with the highest ranking.

The relationship between overall, visual and sound quality can be displayed using correlation coefficients or with graphs. In Table 15 the correlation coefficients can be seen. This is the correlation between the total raw data, in the graphs the mean values of each location is used.

In Figure 83 the mean area quality and the mean visual quality can be seen. Ranked from low to high area quality. The visual quality follows the same trend as the area quality and looking at the 95% confidence intervals, there is a chance that the rating for the overall area quality will be the same as the visual quality. This is not the case looking at the comparison to sound quality in Figure 84. Although the same trend is visible, the ratings for sound quality are lower than that of the overall area quality. The increasing trend is visible in the sound quality, however it is not as pronounced as the trend in visual quality, also see Figure 83. From this it can be said that the visual quality has a higher influence on the overall quality than sound quality does. This is also confirmed in the higher correlation coefficient between area quality and visual quality, see Table 15.

Table 15. Correlation coefficients between quality ratings

	QA	QV	QS
QA	1		
QV	0,77	1	
QS	0,56	0,51	1

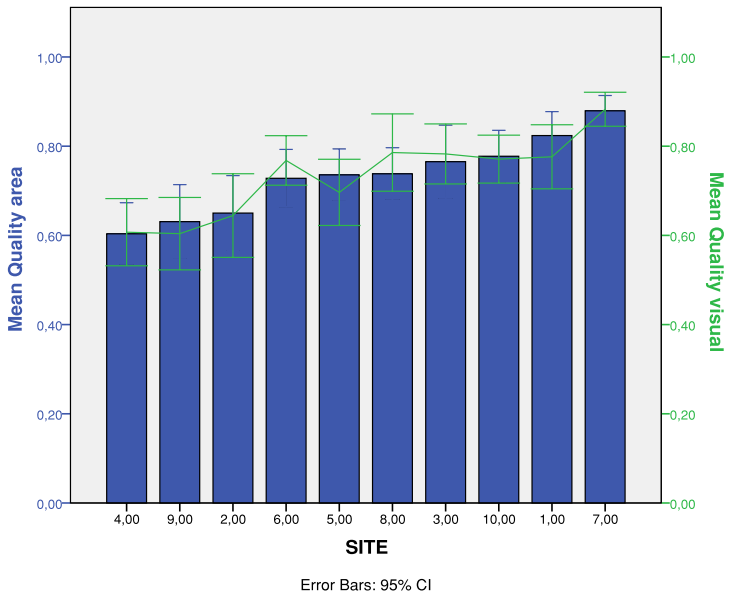


Figure 83. Mean overall area quality compared to the mean visual quality

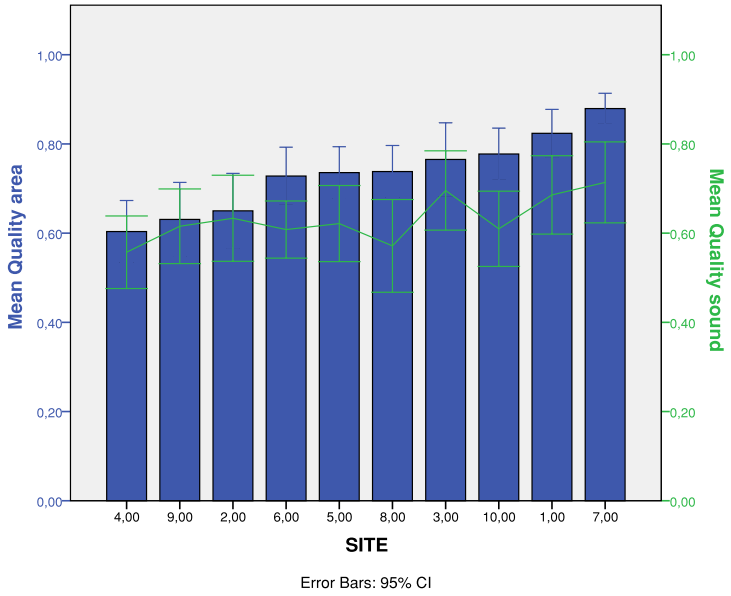


Figure 84. Mean overall area quality compared to the mean sound quality

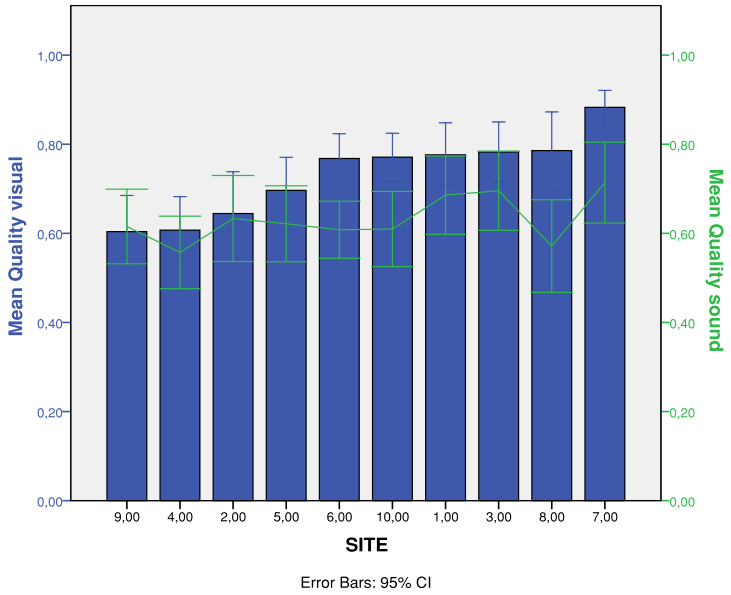


Figure 85. Mean visual quality compared to the mean sound quality

Until now, only the average values for each location have been assessed. Now the correlation between the total data, for all locations combined will be discussed. In Table 16 the correlation coefficients can be seen.

Table 16. Correlation coefficients between quality ratings and other rating variables

	QA	QV	QS	OS	CL	SA	AP	PL
QA	1							
QV	0,77	1						
QS	0,56	0,51	1					
OS	0,55	0,46	0,42	1				
CL	0,44	0,40	0,36	0,51	1			
SA	0,26	0,20	0,13	0,32	0,44	1		
AP	0,19	0,21	0,43	0,35	0,28	0,36	1	
PL	-0,08	-0,11	-0,19	-0,09	-0,16	-0,19	-0,26	1

In the previous chapter it was stated that the safety might have a relationship with the overall area quality. However, the correlation coefficient between the two is rather small, only 0.26. This indicates that although the means of all locations may correlate, the answers given by the individual users of the space do not. Table 16 does confirm the relation between overall area quality and visual and sound quality. The overall quality of the area has the highest correlation with the visual quality of the area, but also has high correlations with sound quality and the organization of the surroundings. The visual quality is also correlated to the sound quality, but with a lower coefficient.

Table 16 also confirms the relationship between visual quality and the organization of the surroundings and cleanliness.

The sound quality rating has no correlation with perceived loudness; it does have a correlation with appropriateness, to a certain extent. In the previous chapter, a slight similarity could be seen between these variables, but there were a few outliers. This makes it hard to draw definite conclusions on the relationship between sound quality, perceived loudness and appropriateness. Also the difference in sound quality rating between the locations is too small to see clear differences. The difference between the lowest and highest rating is 0.15. Nevertheless it is surprising that the sound quality has no correlation with other rating variables regarding sound.

4.3 The Relationship between Quality Ratings and Measurement Values

Ideally the quality of a space could be defined by measurable values. So that without a need of conduction questionnaires a space could be analyzed. In Table 17 the correlation between the average values of the quality ratings of each location and the measured values per location can be seen.

Table 17. Correlation coefficients between quality ratings and measurement values

	QA	QV	QS	LDF	P5	P10	P50	P90	P95	LAeq
QA	1									
QV	0,94	1								
QS	0,72	0,58	1							
LDF	-0,24	-0,33	-0,33	1						
P5	-0,23	-0,29	-0,33	0,95	1					
P10	-0,13	-0,20	-0,30	0,96	0,99	1				
P50	-0,03	-0,10	-0,24	0,95	0,93	0,98	1			
P90	-0,01	-0,07	-0,20	0,95	0,90	0,95	0,99	1		
P95	0,00	-0,07	-0,19	0,94	0,88	0,94	0,98	1,00	1	
LAeq	-0,24	-0,33	-0,36	0,97	0,99	0,98	0,94	0,91	0,90	1

Any quality rating has a strong correlation with a measured value. The overall area quality and visual quality are not related to most of the measurement values. There is a small correlation with loudness, LA95 and LAeq. Also, the sound quality has no strong correlation with any of the measurement values, however the single value for LAeq is almost 0.4 which is reasonable correlation. To analyze further, in Figure 86 the relation between sound quality and LAeq can be seen. No clear relation can be seen between the sound quality and LAeq. This is partly caused by the fact that the LAeq does not vary much between the locations.

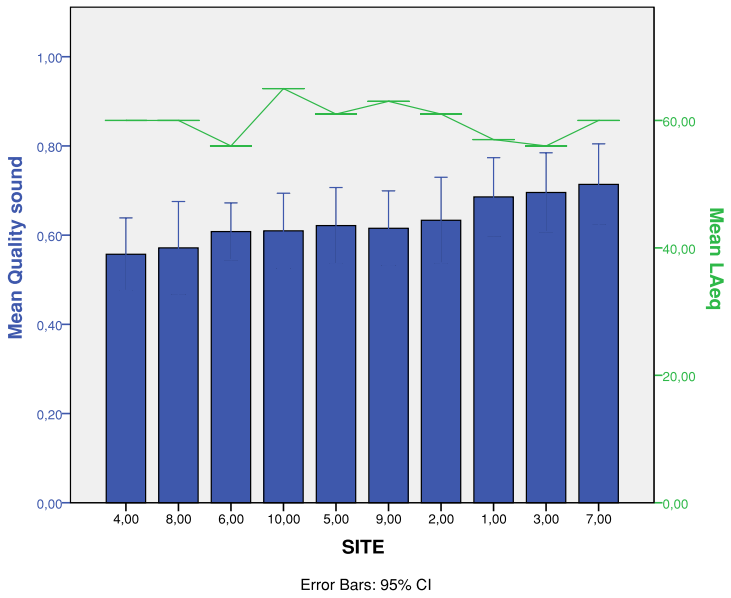


Figure 86. Mean sound quality compared to the mean L_{Aeq}

It seems that there is no single measurement value that can predict accurately what the quality of a certain area will be. In the principle component chapter we analyze if it is possible to relate measurement values to principle components.

With the measured data, one calculation was made, known as the center of gravity of the spectrum (see equation 3, Chapter 3, Section 3.3.2). The results of this are in Figure 87. The amount of pollution by traffic noise can be estimated. The threshold log(G)>2.8 has been appointed as a good indicator for a quiet rural environment (Brambilla et al., 2013).

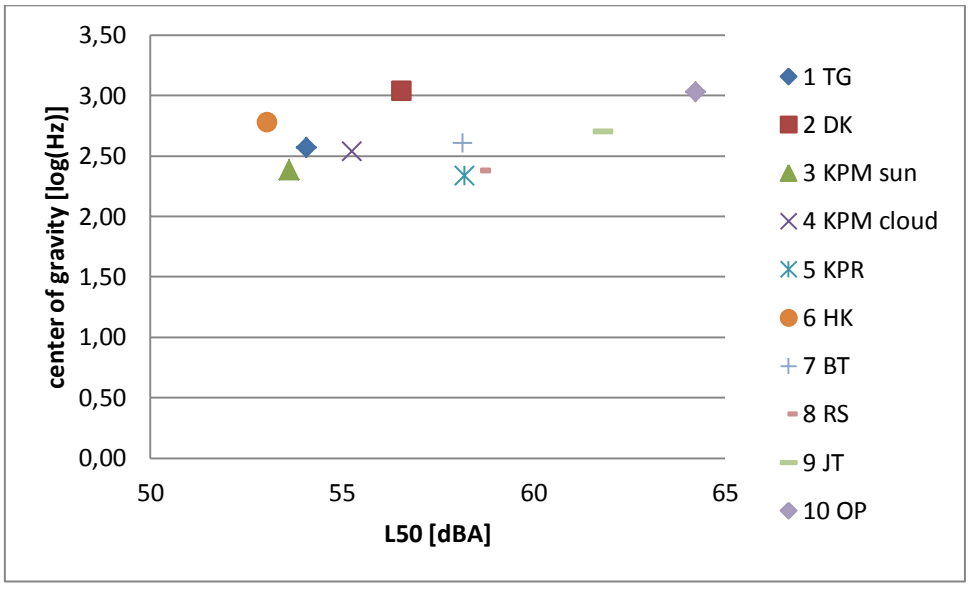


Figure 87. Center of gravity log (G) plotted with the A-weighted L_{50} level per location

Comparing the locations with the minimum and maximum values for log(G) it can be seen that they contain different sound sources. The maximum value

is for location 2, Domkyrkan (DK). The minimum value is for location 5 Kungsparken at the roadside, with location 8 Rodasten quite close. The main sound sources in DK are birds, people and traffic. In Kungsparken roadside traffic, music and birds. Rodasten also has traffic and boat sound as its top sound sources. In the lower range of the centre of gravity, locations with more mechanical sounds can be found and in the higher range natural and human sounds, which is in line with literature (Brambilla et al., 2013). However, a clear relationship between log(G) and sound quality rating cannot be seen.

4.4 The Relationship between Quality Ratings and Activity Ratings

Previously clusters of locations have been identified with the same overall, visual or sound quality rating. In this chapter the relationship between these clusters and activity choice will be investigated. In the questionnaire, the users were asked to give to a set of activities, a rating of applicability to the location. These activities can roughly be separated into three categories: appreciation, socializing and passing. Below, the three categories will be discussed and their relation to the clusters of overall quality. This is done through the locations' ranking on the x-axis from low to highest overall quality. The 95% confidence intervals have not been displayed to improve readability.

1. Appreciation (can be done alone, supportive soundscape needed)
    - Appreciation of cultural heritage
    - Appreciation of parks and trees
    - Appreciate water courses
    - Experiencing quietness and tranquility
    - Escaping city stress

An increasing trend can be seen in the rating for the activities when the overall area quality increases, see Figure 88. Meaning that locations with a high overall area quality are more suitable for "escaping city stress", "experience quietness" and "experience the space" (cultural heritage, parks and trees, water courses). The increase is especially strong for the "appreciation of parks and trees", "escaping city stress" and "experience quietness/tranquility". This can be explained by the fact that the locations with a high overall area quality have more parks, trees or vegetation and therefore appreciation of it also increases. Regarding "escaping stress" and "tranquility", it is known that the presence of vegetation lowers stress levels (Beute & de Kort, 2014), therefore, locations with vegetation are more likely to be used for stress relieving activities.

Because for these activities a supportive soundscape is needed, they were also compared to the sound quality of the area by ranking the locations on the x-axis from low to highest sound quality, see Figure 89.

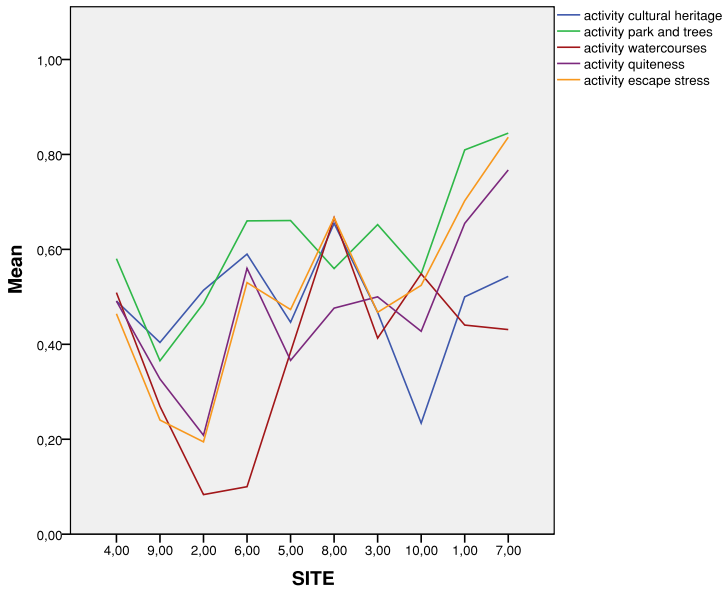


Figure 88. Ratings for appreciation activities ranked according to increasing overall area quality

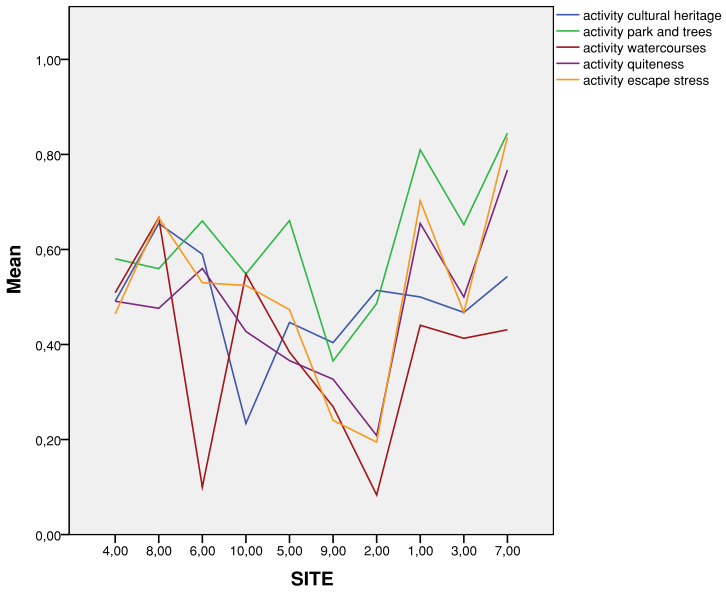


Figure 89. Ratings for appreciation activities ranked according to increasing sound quality

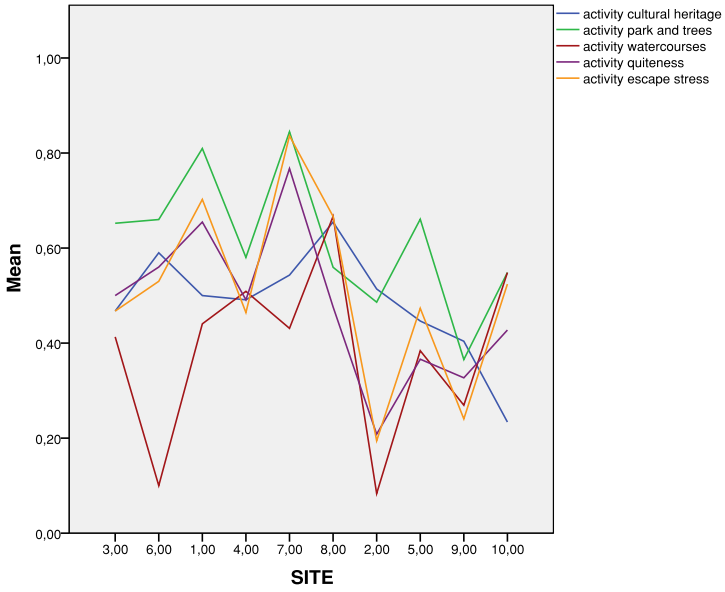


Figure 90. Ratings for appreciation activities ranked according to increasing sound level

Here, a similar increasing trend is visible. In the previous chapter it was shown that the sound quality has a relationship with the perceived loudness and measured loudness, although not strong. So it could be said that for the appreciation activities a low (perceived) loudness is needed, otherwise, "escaping city stress" and "experiencing quietness/tranquility" is not possible. Thus an increase in sound quality and decrease in (perceived) loudness should increase the rating for the applicability of the appreciation activities.

To find a measurable threshold the relation between the activity ratings and sound level is also assessed in figure 90. A breakpoint can be seen at location 8 where the sound level goes up and the ratings go down. Location 8, Rodasten, has an average level of 60dBA. So from this it can be said that to get a good rating for the appreciation activities, the sound level must be below 60dBA. Above 60dBA, the ratings go down. This is especially true for the activities "experiencing quietness" and "escaping city stress".

2. Socializing (more than one person required, involves producing sound)
    - Group exercise or games
    - Experiencing vibrant street life
    - Hang out/chat
    - Socializing with family or friends
    - Picnic/BBQ

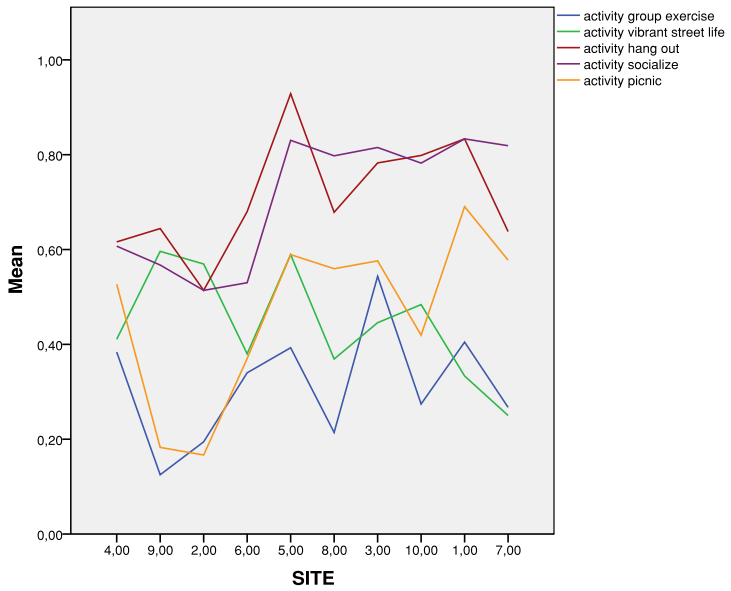


Figure 91. Ratings for socializing activities ranked according to increasing overall area quality

A slight increasing trend can be seen in the rating for the activities "hanging out", "socializing" and "picnic/BBQ" when the overall area quality increases, see Figure 91. However, the rating for "hanging out" and "socializing" follows almost a continues line after location 6. For the activities "group exercise" and "experiencing vibrant street life" a slight decrease can be seen as the overall area quality increases. This indicates that social activities involving a longer stay in a location, like "socializing" or "picnic", are more applicable to locations with a higher area quality. On the other hand "experiencing vibrant street life" is more applicable to locations with a lower area quality. In the previous chapter it can be seen that the locations with lower area quality are the more urban locations. "Experiencing vibrant street life" is more likely in an urban area than in a park area. The park areas mostly lack of the dynamic and vibrant environment that contributes to this activity.

3. Passing (fast paced, no intention on staying in a location)
    - Individual exercise
    - Shopping
    - Travel/passing trough

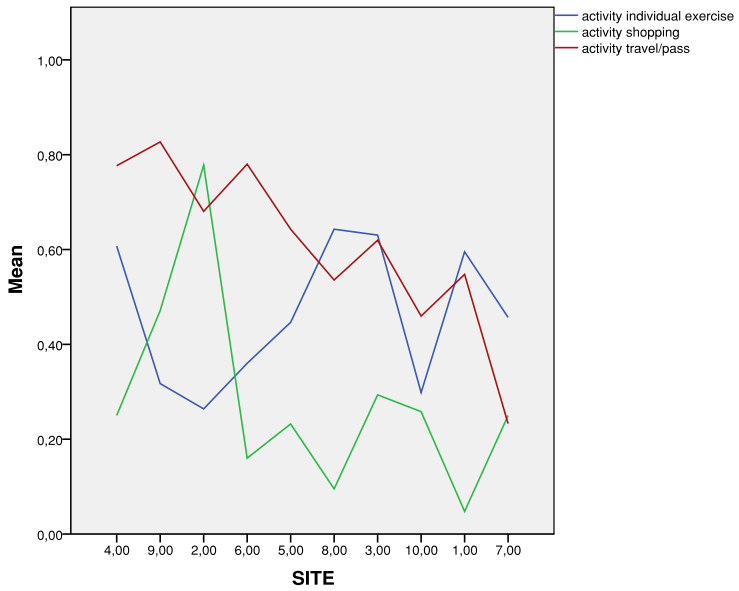


Figure 92. Ratings for passing activities ranked according to increasing overall area quality

A decreasing trend can be seen in the rating for the activities when the overall area quality increases, see Figure 92. Although the activity "shopping" and "individual exercise" have large fluctuations, the decreasing trend is clearly visible in the activity "travel/passing through". Indicating that locations with a higher overall quality are less applicable to just pas through and more applicable for a longer stay. This is confirmed by the fact that the rating for "hanging out" and "socializing" increases with increasing overall area quality, see figure 92.

Overall the trends were more clear with the appreciation activities than with the other activity categories.

4.5 Principle Component Analysis

Various elements have been assessed separately. However, to get a view of which component or components influence the way users perceive and use a space the most, principle component analysis has been performed. A principle component analysis or PCA provides the elements that explain the most variance in the data. The first component explaining the largest variance, the second one explains the second largest, and so on. A component may consist of a number of variables each contributing to the component more or less than the other. In the PCA, the measurement data is not taken into account. Instead the principle components or PCs that are given by the PCA are correlated to the measurement data to see if one component can be related to a physical value.

4.5.1 Defining the Principle Components

In total three PCs were found explaining 79% of the variance in total. In Table 18 the PCs and their variables can be seen. The contribution of a variable to the PC is given in the form of a score. The higher the score the more influence this variable has on the PC. The score is given in the form of a number between -1 and 1. Only variables with a score larger in magnitude than 0.2 are taken into account.

Table 18. Principle components and their variable scores

PC1 (56%)		PC2 (69%)		PC3 (79%)	
Variable	Score	Variable	Score	Variable	Score
Appreciate parks and trees	0,258	Appreciate parks and trees	-0,244	Group exercise	0,366
Appreciate watercourses	0,242	Hang out	0,203	Appreciate cultural heritage	0,207
Socialize	0,228	Appreciate watercourses	**0,521**	Appreciate watercourses	-0,262
Experience quietness/tranquility	0,296	Experience quietness/tranquility	-0,226	Individual exercise	0,302
Escape stress	0,392	Individual exercise	0,263	Shopping	-0,251
Picnic/BBQ	0,341	Shopping	-0,265	Travel/passing through	**0,576**
Individual exercise	0,203	Uneventful	-0,225		
Shopping	-0,362				
Travel/passing trough	-0,257				

All PCs are mainly influenced by activities (scores above 0.2). The first PC is mainly influenced by activities involving tranquility. The "appreciation of

parks and trees“, “appreciation of water courses“, “socializing“, “experiencing quietness/tranquility“, “escaping city stress“, “picnic/BBQ“ and “individual exercise“ having moderately high positive scores. The activities “shopping“ and “travel/passing through“ have moderately high negative scores.

The second PC is mainly influenced by the activity “appreciation of watercourses“, which has a rather high variable score. It is also positive influenced by the activities “hanging out“ and “individual exercise“. The activities “appreciation of parks and trees“, “experiencing quietness/tranquility“, “shopping“, and the adjective “uneventful“ have moderately high negative scores.

The third PC is mainly influenced by the activity “travel/passing through“. Also the activities “group and individual exercise“ have moderately high scores. Indicating that this component is mainly influenced by the passing activities mentioned in Chapter 4.4.

In Figure 93 the principle components PC1 and PC2 can be seen as the x and y-axis of the graphs, with the red dots indicating the measurement sites.

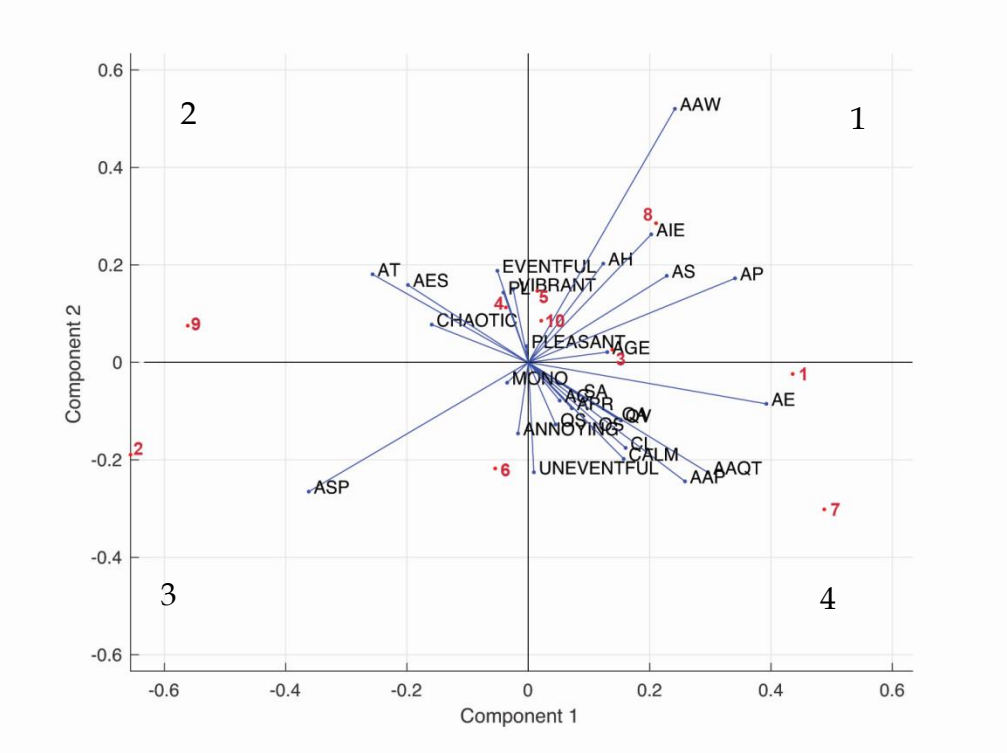


Figure 93. Principle component 1 and 2 and their variables, red dots indicating the measurement sites

Components 1 and 2 in Figure 93 show resemblance with the research performed by Axelsson (2010). “Eventful“ and “uneventful“ have a vertical orientation along the y-axis, the second quadrant contains the variable “chaotic“, the third “monotonous“ and the fourth “calm“ (also see Figure 1).

In Figure 94 the principle components PC2 and PC3 can be seen as the x and y-axis of the graphs, with the red dots indicating the measurement sites.

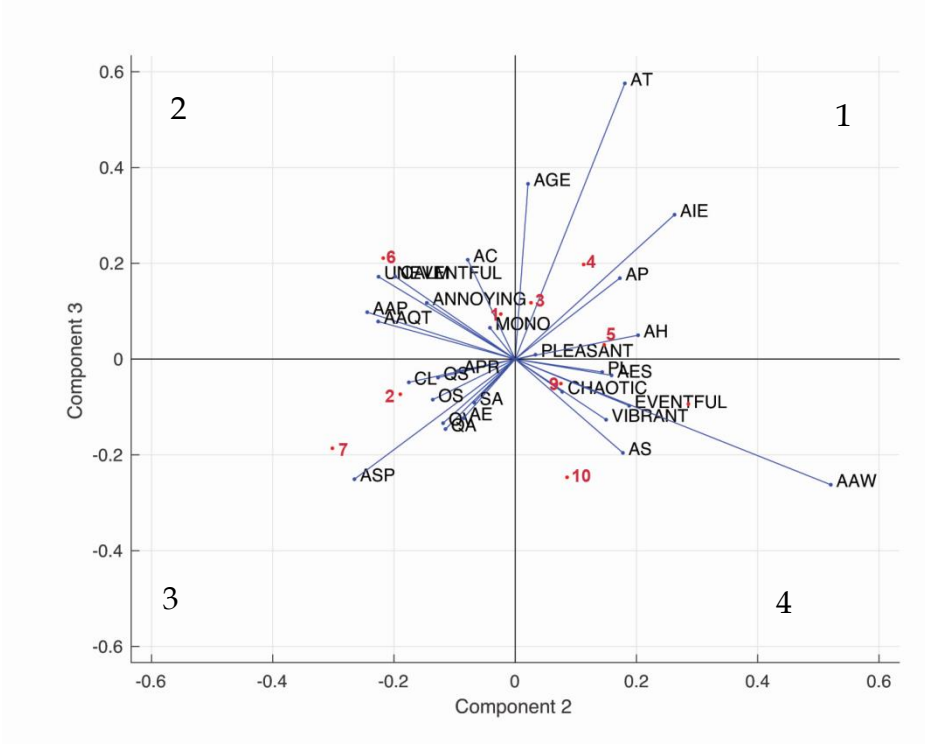


Figure 94. Principle component 2 and 3 and their variables, red dots indicating the measurement sites

4.5.2 Placement of the Locations within the Principle Components

Each of the locations can be placed within the frame of the PC's. The placement is determined by the scores of the variables within the PC and their values given by the users. In Figure 95, a 3D representation of the locations placement can be seen.

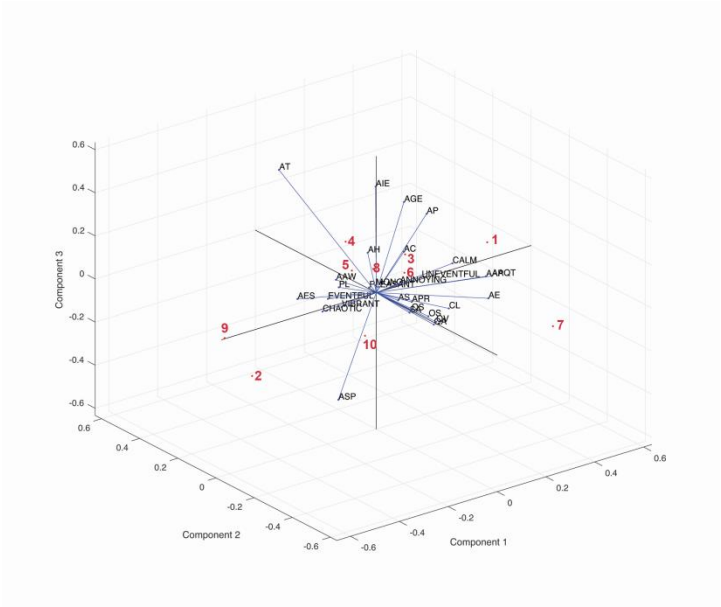


Figure 95. Placement of the locations within the three principle components

Table 19. Location number and label per quadrant

	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
PC 1-2	3 KPM sun	4 KPM cloud	2 DK	1 TG
	5 KPR	9 JT	6 HK	7 BT
	8 RS			
	10 OP			
PC 2-3	3 KPM sun	6 HK	2 DK	9 JT
	4 KPM cloud	1 TG	7 BT	10 OP
	5 KPR			
	8 RS			

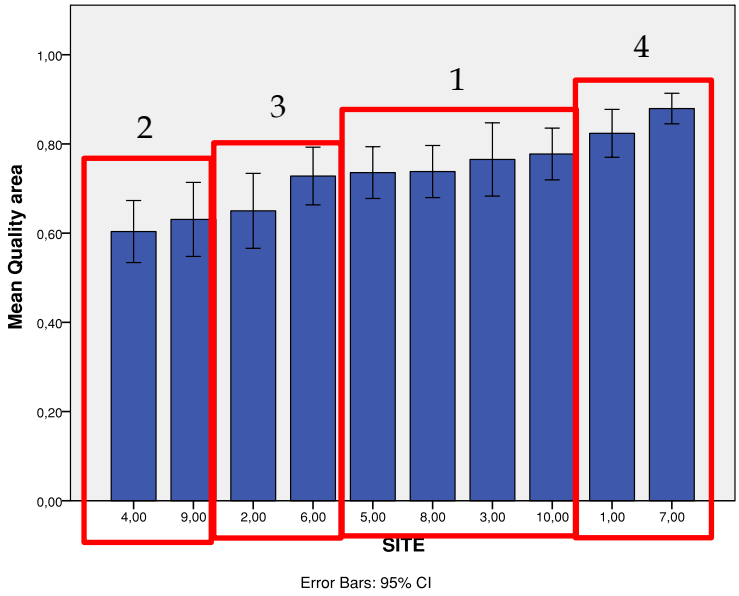


Figure 96. Comparison of mean overall quality ranking to placement in the PC space

Comparing the placement of the locations within the first and second component, a relation with the overall quality can be seen. In Figure 96, the ranking of the overall area quality is shown, marking the locations per quadrant. It can be seen that sites with a positive score in PC1 (positive or negative score in PC2) have a higher overall quality rating compared to the sites with a negative score in PC1 (positive or negative score in PC2). Comparing this to the ranking of sound quality no clear relationship can be seen. However two out of the top 3 locations with the highest sound quality ranking can be found in quadrant 4 (PC1 positive score, PC2 negative score).

The location on the outer sides (high negative or high positive values) of PC1 can clearly be distinguished by the amount of green and the amount of buildings in the location. On the negative side of PC1, the locations are dominated by buildings with a small amount of green (JT and DK). On the positive side there are parks (TG and BT) dominated by green and there are only few buildings with a maximum of two stories height. There is a cluster around 0 for PC1 containing HK, KPM cloud, OP and KPR. Here, natural elements are present but negative influence on the environment is close, like a major road or bad weather. The final two locations on the positive side of PC1 are KPM sun and RS. These two locations have in common that they are dominated by a natural water element. For Kungsparken this is the canal and for Rodasten the river.

A similar type of relation with component 2 and 3 and the quality ratings was not found.

4.5.3 Relation between the principle components and measurement values

In practice, a relation between the principle components and measurement values is convenient. When assessing a location, measurements could be easily performed and the use of questionnaires could be omitted.

In Figure 97 and 98, the values of PC3 of each location are displayed against the values for L50 (dBA) and loudness to see if there is a correlation between these factors. The relationship between PC1, PC2, L50 (dBA) and loudness (sone) was not clear (also see Table 20), therefore, only the results of PC3 are discussed.

A decreasing trend can be seen in L50 (dBA) and loudness (sone) when the score of PC3 increases. PC3 and L50 (dBA) show a strong negative correlation (R^2=-0.80), being smaller for PC3 and loudness (R^2 = -0.60).

To investigate the relations, a correlation coefficient table is made, see Table 20. Also, the correlation coefficients with other percentile values are given. PC3 also has a strong correlation with the other percentile values, among which values of 0.8. Because of this strong correlation if may be assumed that the principle component can be defined as "*sound level*".

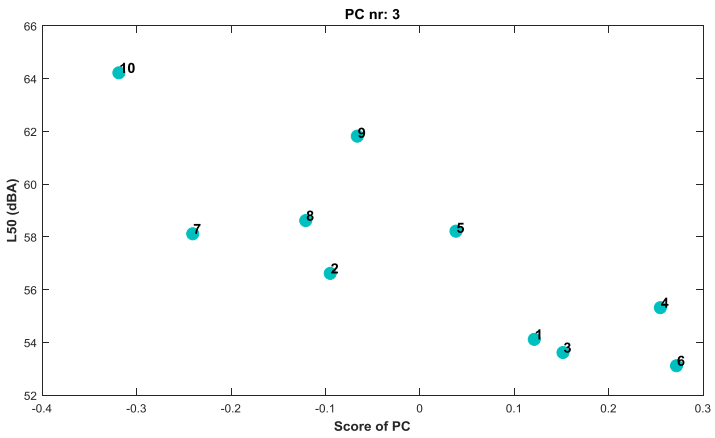


Figure 97. Principle component 3 score with L_{50} in dBA per location

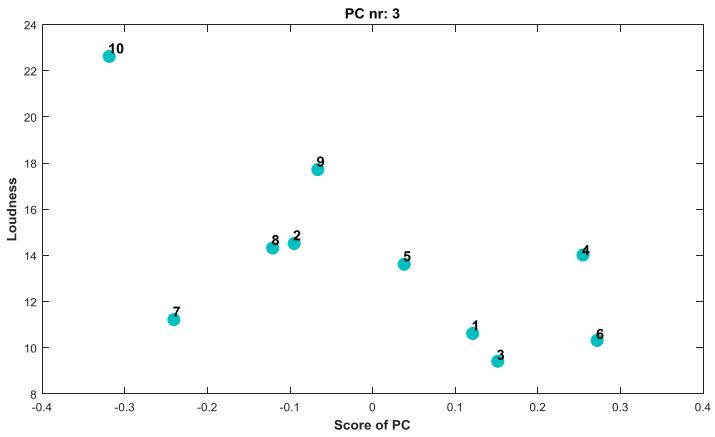


Figure 98. Principle component 3 score with loudness per location

Table 20 Correlation coefficients PC's and measurement values

	PC1	**PC2**	**PC3**
Loudness [sone]	-0.410	0.388	-0.628
L50 [dBA]	-0.236	0.333	-0.817
L5 [dBA]	-0.402	0.222	-0.751
L10 [dBA]	-0.320	0.271	-0.787
L90 [dBA]	-0.181	0.349	-0.813
L95 [dBA]	-0.172	0.352	-0.810

5 Remarks

In this research only a relatively small number of locations have been investigated (10 locations). To get more accurate results, a larger number of locations are needed, as well as a higher variety within the type of location. For example, locations closer to highways or situated far away from major roads, however, theses spaces are generally not used as public space or have very few activities, e.g. passing by, making it very difficult to use them for this type of study. Moreover, the target of the study was to ask current users of the space, and the chances to find people in such places are limited. In this way, the spread in the noise levels would have been wider and extremes could have been present. The current spread in noise level is not large (LAeq values ranging from 56dBA to 65dBA) and it is difficult to predict what would happen if the noise level increases or decreases.

The lack of variation in the type of location can also be seen in the soundscape placement in the framework according to Axelsson (2010). The coordinates are determined by Equation 1 and 2 (Sottek, 2017). There is a clustering of the locations with two outliers: JT and RS. The outliers are judged as more "eventful" as the others. Looking at the individual adjectives, these locations are also more "vibrant". The explanation for this can be found in the frequency spectrum. JT and RS have a larger frequency content than the other locations. Meaning that more frequency bands contain higher levels of energy compared to the other sites. The locations in the quadrant "calm" have a higher rating for the adjective "pleasant" and have a neutral rating for "eventfulness" (around 0), however there is no clear relation with frequency content, besides the fact that these locations have a narrower range of frequencies. To define clearer relations between frequency content and location type a wider variety of locations is needed. In the cases investigated now no extreme rating was found for pleasantness or eventfulness and there is not a large spread within the framework (see, Figure 99).

For more accurate results, a larger number of conducted questionnaires are also needed to reduce the confidence intervals, as the spread within the answers of the users is large. The current number of respondents per site can be seen in Table 21. Not all questionnaires were entirely answered by the participants; however, the percentage of participants covering the full questionnaire was between 74% and 90%, varying at each site.

To further investigate the connection between the principle components and sound variables, an investigation regarding the sound spectra and types of sound sources could bring more answers.

Another thing that has not gotten much attention in this research is the urban form. Due to the lack of resources and time it was not possible to classify each

location according to their urban form as discussed in Chapter 2, Section 2.5. The urban form may also have relations with the principle components.

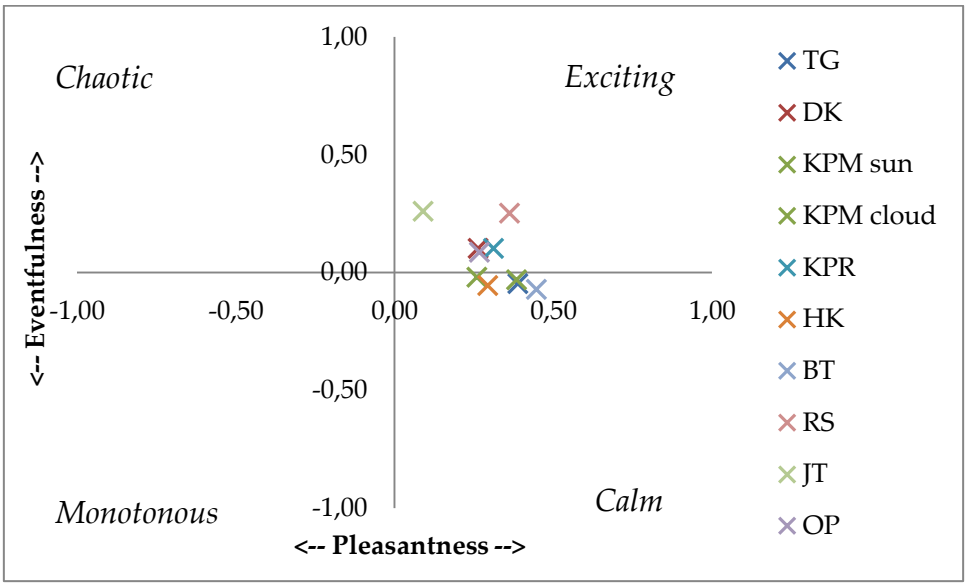


Figure 99. Summary of the placement in soundscape classification framework (Axelsson, 2010)

Table 21. Number of respondents and complete questionnaires per location

	Number of respondents (normal hearing)
Trädgårdsföreningen	21
Domkyrkan	18
Kungsparken sun	23
Kungsparken cloudy	28
Kungsparken road	28
Hagakyrkan	25
Botanical garden	29
Rodasten	21
Järntorget	26
Odinsplats	31

6 Conclusion

In this research the relation between the soundscape and the perception and use of the urban environment is investigated. Measurements were performed at 10 sites in central Gothenburg, Sweden. The measurements contained sound recordings and conducting questionnaires. The questionnaire addressed the purpose of coming to the location, the use of the space and perception of it. Actual users of the space filled in the questionnaires.

Several forms of perception (overall, visual and sound) were related to each other in the form of quality ratings. It was found that the visual quality rating has a strong connection with the overall quality rating (corr 0.77). The sound quality has a relation with both the overall and visual quality. However, the relation is less strong (corr 0.56/0.51).

It could be seen that locations with similar ratings for overall quality and sound quality shared similar attributes (e.g. vegetation type or similar ratings for appropriateness). The relation within the clusters of visual quality was less clear. Between these clusters and measured values, no clear relationship can be found. For example, the perceived loudness seems only to have a minor influence on the quality of sound (in the highest rated locations). However there is a relation between perceived loudness and measured loudness.

Regarding the activities, a trend can be seen of the increased rating of applicability of *appreciation activities* ("appreciation of parks and trees", "water courses", "escaping city stress", etc.) when the overall or the sound quality increases. For the less tranquil activities ("shopping", "travel", "sports", "vibrant street life", etc.) a decrease in rating can be seen when the overall area quality increases.

To investigate more complex relation between the quality ratings and activity choices a principle component analysis was made. It was found that the perception and use of a space can be defined by three components explaining 79% of the variance. The first component (56% of total variance explained) contains tranquil, stress relieving activities. However, it has no strong variable score for a specific one. It also has a strong relation with the overall quality perception of the location and the amount of green space. Therefore, this component will be named *tranquil green*. The second component (69% of total variance explained together with the first component) has a strong score for the variable appreciation of watercourses. It has a negative score for experiencing tranquility and the appreciation for parks and trees, giving the impression that it is determined by active, more social activities. Therefore this component will be named *socially active*. The third component (79% total variance explained together with the first and second components) has a high variable score for the activity "travel/passing through". It is also strongly

correlated with measurement values regarding sound level (corr >0.8). Due to this strong correlation this component will be named *sound level*. With this it is seen that sound does have an influence on our perception and use of a location. However, it explains only 10% of the variation in the answers of the questionnaires. Compared to PC1 ("tranquil green") and PC2 ("socially active"), which explain 56% and 13% of the variance, sound level is of a third order importance.

7 References

Aletta, F., Kang, J., & Axelsson, Nilsson. (2016). Soundscape descriptors and a conceptual framework for developing predictive soundscape models. *Landscape and Urban Planning*, *149* (February), 65–74. https://doi.org/10.1016/j.landurbplan.2016.02.001

Aletta F., Filipan, K., Puyana Romero, V. (2016). Urban Soundscape . In: W. Kropp, J. Forssén, L. Estévez-Mauriz (Eds.) *Urban sound planning – the SONORUS project*. ISBN 978-91-639-1859-9. Chalmers University of Technology. Gothenburg, Sweden.

Axelsson, Ö., Nilsson, M. E., Berglund, B. (2010). A principal components model of soundscape perceptiona. *The Journal of the Acoustical Society of America*, *2836*(128), 555–560. https://doi.org/10.1121/1.3493436

Beute, F., & de Kort, Y. a. W. (2014). Salutogenic Effects of the Environment: Review of Health Protective Effects of Nature and Daylight. *Applied Psychology: Health and Well-Being*, *6*(1), 67–95. https://doi.org/10.1111/aphw.12019

Brambilla, G., Gallo, V., & Zambon, G. (2013). The soundscape quality in some urban parks in Milan, Italy. *International Journal of Environmental Research and Public Health*, *10*(6), 2348–2369. https://doi.org/10.3390/ijerph10062348

Brown, A. L. (2011). Advancing The Concepts of Soundscapes and Soundscape Planning. *Proceedings of ACOUSTICS 2011*, (115), 1–9.

Bruce, N. S., & Davies, W. J. (2014). The effects of expectation on the perception of soundscapes. *Applied Acoustics*, *85*, 1–11. https://doi.org/10.1016/j.apacoust.2014.03.016

Can, A., Aumond, P., Michel, S., Coensel, B. D. E., Ribeiro, C., & Lavandier, C. (2016). Comparison of noise indicators in an urban context. In: Proceedings of the 45th inter-noise, Hamburg, Germany, 2016 August 21–34.

Carles, J. L., Barrio, I. L., Lucio, J. V. (1999). Sound infuence on landscape values, *Landscape and Urban planning 43, 191-200*.

Davies, W. J., Adams, M. D., Bruce, N. S., Cain, R., Carlyle, A., Cusack, P., … Poxon, J. (2013). Perception of soundscapes: An interdisciplinary approach. *Applied Acoustics*, *74*(2), 224–231. https://doi.org/10.1016/j.apacoust.2012.05.010

De Coensel, B., & Botteldooren, D. (2006). The Quiet Rural Soundscape and How to Characterize it, *Acta Acustica united with Acustica 92* (August), 887–897.

Echevarria Sanchez, G. M., Van Renterghem, T., Thomas, P., & Botteldooren, D. (2016). The effect of street canyon design on traffic noise exposure along roads. *Building and Environment*, *97*, 96–110. https://doi.org/10.1016/j.buildenv.2015.11.033

Estévez-Mauriz, L., Zachos, G., Forssén, J., Kropp, W. (2016). "Soundwalks in Gothenburg" Report 2016:12. ISSN 1652-9162. Chalmers University of Technology.

Farina, A. (2014). *Soundscape ecology: Principles, patterns, methods and applications*. *Soundscape Ecology: Principles, Patterns, Methods and Applications* (Vol. 9789400773). https://doi.org/10.1007/978-94-007-7374-5

Göteborgs Stad Miljö (2006). *Sociotopkartor.* Retrieved from: http://goteborg.se/wps/portal/start/byggande--lantmateri-och-planarbete/kommunens-planarbete/verktyg-for-stadsplanering-2/overgripande-stadsbyggnad/sociotopkartor/!ut/p/z1/hY5BC4JAFIR_jdd9T9fk2W07GKmkQZDtJTQ2FdSVdUvo12fHoGhuw3zDDEgoQA7lo61L2-qh7BZ_lsEld-MDbVyB2TaMcHdM8mifpBmFHpz-AXKJ8YcEQgyyrXo2X3uGjHwiDzm5wYoT9-k9L4aKUw3SqJsyyrC7WV411o7T2kEH53lmtdZ1p9ikHPzWaPRkofgAYeyLZ6pO4gUho3lr/dz/d5/L2dBISEvZ0FBIS9nQSEh/

Göteborgs Stad Miljö (2013). *Buller och ljud.* Retrieved from: http://goteborg.se/wps/portal/start/miljo/miljolaget-i-goteborg/buller-och-ljud/!ut/p/z1/hY7BCoJAGISfxuv-6KpddsII5U0CrS9hMa2CurKurXQ02fHoGhuw3zDDHAogQ_Vo5WVadVQdbM_c_-S0_gQrinDbLuMcHdK8mifpNlxE0DxD-BzjD_EEGLgbd0Te-0JEoqUuui7C_QC9NAP3vtsqN1QAtfiJrTQ5K7nW40x47Ry0EFrLZFKyU6QSTj4rdGoyUD5AcLYl89UFOwFKP-Fog!!/dz/d5/L2dBISEvZ0FBIS9nQSEh/

Hao, Y. (2014). *Effects of Urban Morphology on Urban Sound Environment from the Perspective of Masking Effects*. Thesis PhD in architecture, School of Architecture, The University of Sheffield

Hong, J. Y., & Jeon, J. Y. (2015). Influence of urban contexts on soundscape perceptions: A structural equation modeling approach. *Landscape and Urban Planning*, *141*, 78–87. https://doi.org/10.1016/j.landurbplan.2015.05.004

Hong, J. Y., & Jeon, J. Y. (2016). Relationship between soundscapes and landscape factors in urban commercial spaces. In: Proceedings of the 45th inter-noise, Hamburg, Germany, 2016 August 21–34.

Jeon, J. Y., & Hong, J. Y. (2015). Classification of urban park soundscapes through perceptions of the acoustical environments. *Landscape and Urban*

Planning, *141*(May 2015), 100–111. https://doi.org/10.1016/j.landurbplan.2015.05.005

Kang, J., & Zhang, M. (2010). Semantic differential analysis of the soundscape in urban open public spaces. *Building and Environment*, *45*(1), 150–157. https://doi.org/10.1016/j.buildenv.2009.05.014

Kogan, P., Turra, B., Arenas, J. P., & Hinalaf, M. (2016). A comprehensive methodology for the multidimensional and synchronic data collecting in soundscape. *Science of The Total Environment*, *580*, 1068–1077. https://doi.org/10.1016/j.scitotenv.2016.12.061

Lavia, L., Easteal, M., Close, D., Witchel, H., Axelsson, Ö., Ware, M., & Dixon, M. (2012). Sounding Brighton : practical approaches towards better soundscapes. *Inter-Noise 2012*, 12.

Lee, P. J., & Kang, J. (2015). Effect of height-to-width ratio on the sound propagation in urban streets. *Acta Acustica United with Acustica*, *101*(1), 73–87. https://doi.org/10.3813/AAA.918806

Liu, J., Kang, J., Behm, H., & Luo, T. (2014). Landscape spatial pattern indices and soundscape perception in a multi-functional urban area, Germany. *Journal of Environmental Engineering and Landscape Management*, *22*(February), 208–218. https://doi.org/10.3846/16486897.2014.911181

Meng, Q., & Kang, J. (2013). Influence of Social and Behavioural Characteristics of Users on Their Evaluation of Subjective Loudness and Acoustic Comfort in Shopping Malls. *PLoS ONE*, *8*(1). https://doi.org/10.1371/journal.pone.0054497

Meng, Q., Kang, J., & Jin, H. (2013). Field study on the influence of spatial and environmental characteristics on the evaluation of subjective loudness and acoustic comfort in underground shopping streets. *Applied Acoustics*, *74*(8), 1001–1009. https://doi.org/10.1016/j.apacoust.2013.02.003

Nilsson, M. E. (2007). Soundscape quality in urban open spaces. In: Proceedings of the 36th inter-noise, Istanbul, Turkey, 2007 August 28–31. https://doi.org/10.1260/135101007781447993

Berghauser-Pont, M., & Haupt, P. (2010). *Spacematrix: space, density and urban form*. Rotterdam: NAi publishers. Retrieved from: https://doi.org/9789052693750

Rehan, R. M. (2015). The phonic identity of the city urban soundscape for sustainable spaces. *HBRC Journal*, *12*(3), 337–349. https://doi.org/10.1016/j.hbrcj.2014.12.005

Rohrmann, B. (1978). Emprische Studien zur Entwicklung von Antwortskalen für die sozialwissenschaftliche Forschung. *Zeitschrift Für Sozialpsychologie*. Retrieved from http://people.f3.htw-

berlin.de/Professoren/Pruemper/pdf/Antwortskalen.pdf

Sottek, R. (2017). Human Response to Sound and Vibration. Course material. Gothenburg: Chalmers University of Technology.

Viollon, S., Lavandier, C., & Drake, C. (2002). Influence of visual settings on sound ratings in an urban environment. *Applied Acoustics*, *63*, 493-511.

Wang, B., & Kang, J. (2011). Effects of urban morphology on the traffic noise distribution through noise mapping: A comparative study between UK and China. *Applied Acoustics*, *72*(8), 556–568. https://doi.org/10.1016/j.apacoust.2011.01.011

Yang, W., & Kang, J. (2005). Acoustic comfort evaluation in urban open public spaces. *Applied Acoustics*, *66*(2), 211–229. https://doi.org/10.1016/j.apacoust.2004.07.011

Yu, L., & Kang, J. (2010). Factors influencing the sound preference in urban open spaces. *Applied Acoustics*, *71*(7), 622–633. https://doi.org/10.1016/j.apacoust.2010.02.005

Appendix A

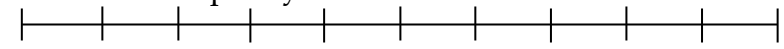
0. Current Time: _____

1. How often do you visit the location?
□ Every day
□ 2-4 times per week
□ 1 time per week
□ 2-4 times per month
□ 1 time per month
□ Less than 10 times per year

2. What is the average duration of the visit?
_____ minutes or _____ hours

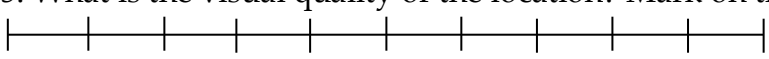
3. What is the purpose of the visit? mark your main purpose with 1, your second purpose with 2, etc.
□ Reading
□ Children
□Pets
□ walking
□ Sports
□ Nature
□ Tranquility
□ Meeting friends/relatives
□ Shopping
□ Travel
□ Other _____

4. What is the quality of the area as a whole? Mark on the stripes



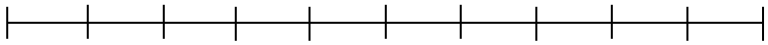
0-bad 10-very good

5. What is the visual quality of the location? Mark on the stripes



0-bad 10-very good

6. What is the acoustic quality of the location? Mark on the stripes



0-bad 10-very good

7. How close is the location to your house (choose the mode of transportation you most often use to get to this location)?

□ < 5 min □ by foot
□ 5-10 min □ by bike
□ 10-15 min □ by tram
□ > 15min □ by car

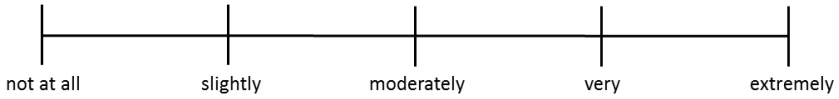
8. Are the following activities applicable to the location ?

	don't know/not applicable	**slightly**	**moderately**	**very**	**perfectly**
Play informal games Group exercise/collective sports like soccer or group fitness	□	□	□	□	□
Appreciate cultural heritage	□	□	□	□	□
Appreciate parks and trees	□	□	□	□	□
Experience vibrant street life	□	□	□	□	□
Hang out, chat, talk	□	□	□	□	□
Appreciate watercourses	□	□	□	□	□
Socialize with family and friends	□	□	□	□	□
Appreciate quietness and tranquility	□	□	□	□	□
Escape from city stress	□	□	□	□	□
Picnic/barbeque	□	□	□	□	□
Jogging, running or other individual exercise	□	□	□	□	□
Shopping	□	□	□	□	□
Travel, passing through	□	□	□	□	□

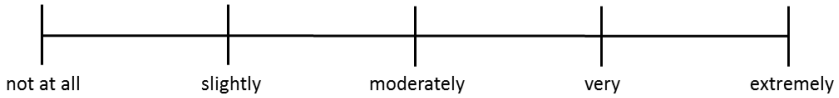
Other:*	□	□	□	□	□

*_____

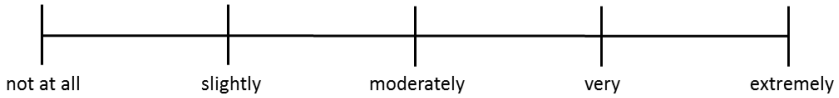
9. Do you find your surroundings well organized ? Mark on the stripes



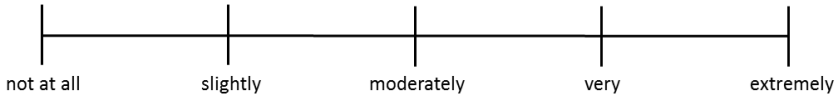
10. How clean do you find the surroundings? Mark on the stripes



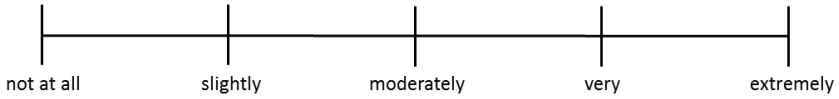
11. How safe do you feel? Mark on the stripes



12. How appropriate is the sound to the surrounding? Mark on the stripes



13. How loud is it here? Mark on the stripes



14. For each of the 8 scales below, to what extend do you agree or disagree that the present surrounding sound environment is … (Please tick off one response alternative per scale)

	Strongly agree	**Agree**	**Neither agree, nor disagree**	**Disagree**	**Strongly disagree**
Pleasant	□	□	□	□	□
Chaotic	□	□	□	□	□
Vibrant	□	□	□	□	□
Uneventful	□	□	□	□	□
Calm	□	□	□	□	□
Annoying	□	□	□	□	□
Eventful	□	□	□	□	□
Monotonous	□	□	□	□	□

15. Please list sound sources you noticed in descending order starting with the most noticeable sound source. Any number of listed sound sources is possible, but limited to 5.

_____
_____
_____
_____
_____

General information

Age:_____

Gender: Male/Female/Other/Don't want to say

Occupation: _____ _____

Do you have normal hearing? Yes/No

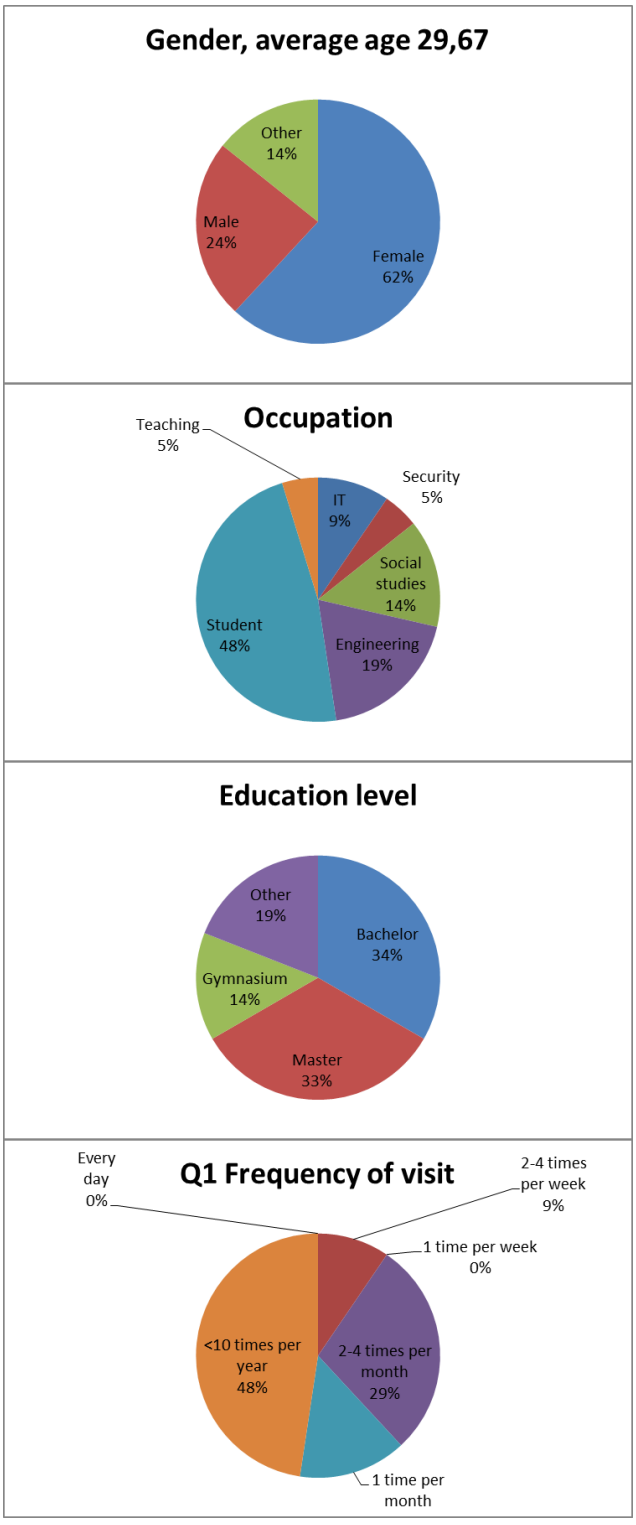
Highest completed level of education:_____

Optional: Comments (length of questionnaire/clarity of questions/etc.)

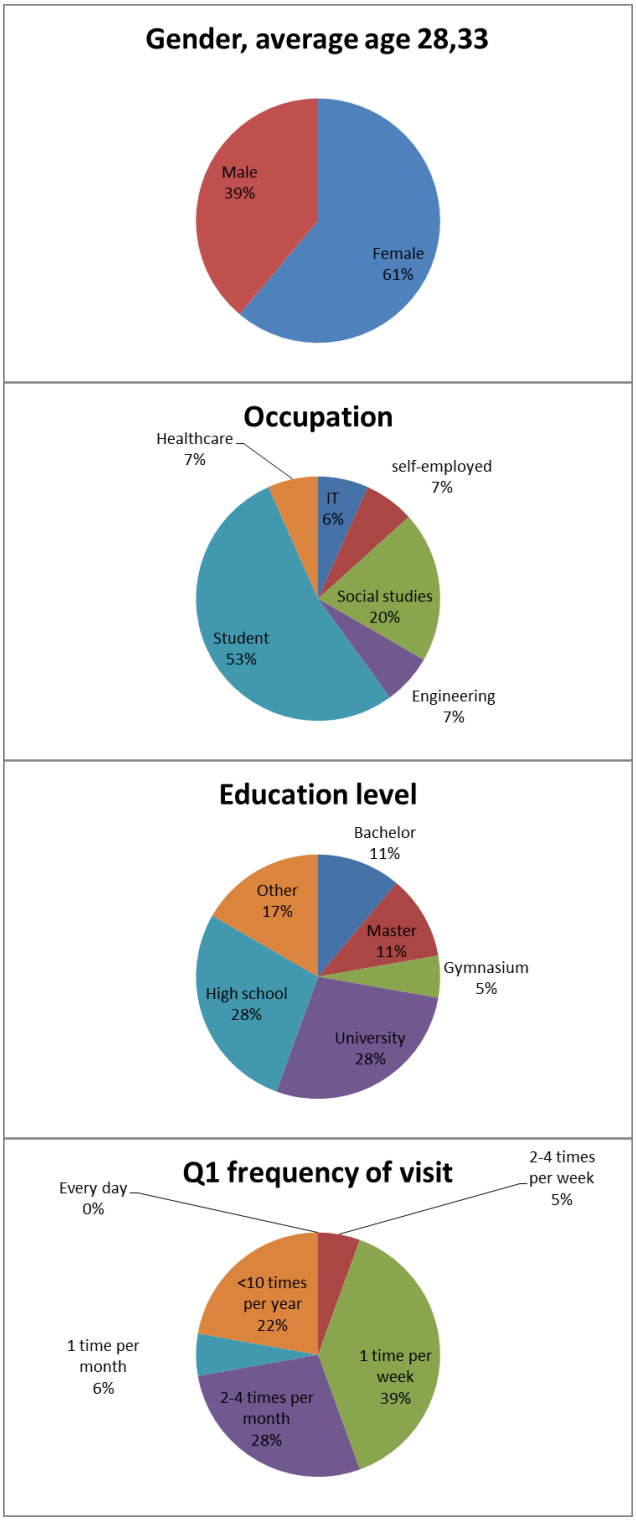
Appendix B

General information per location

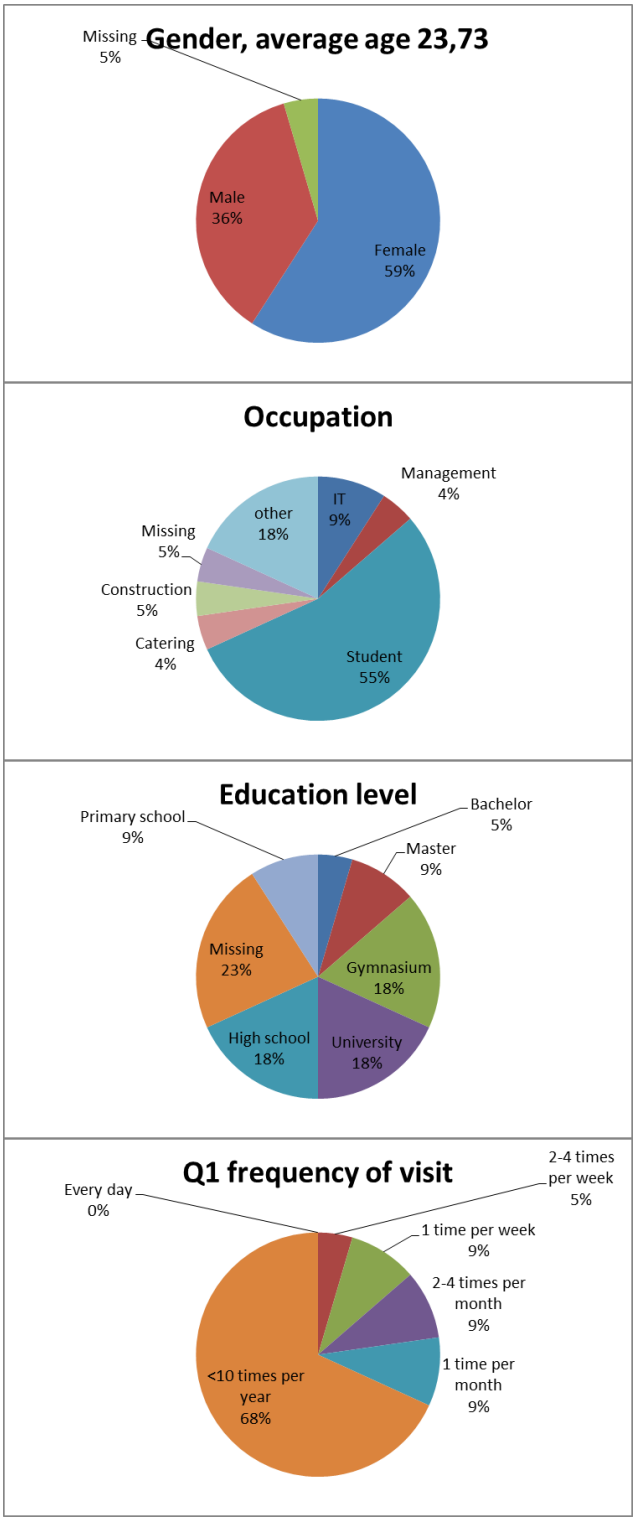
Trädgårdsföreningen



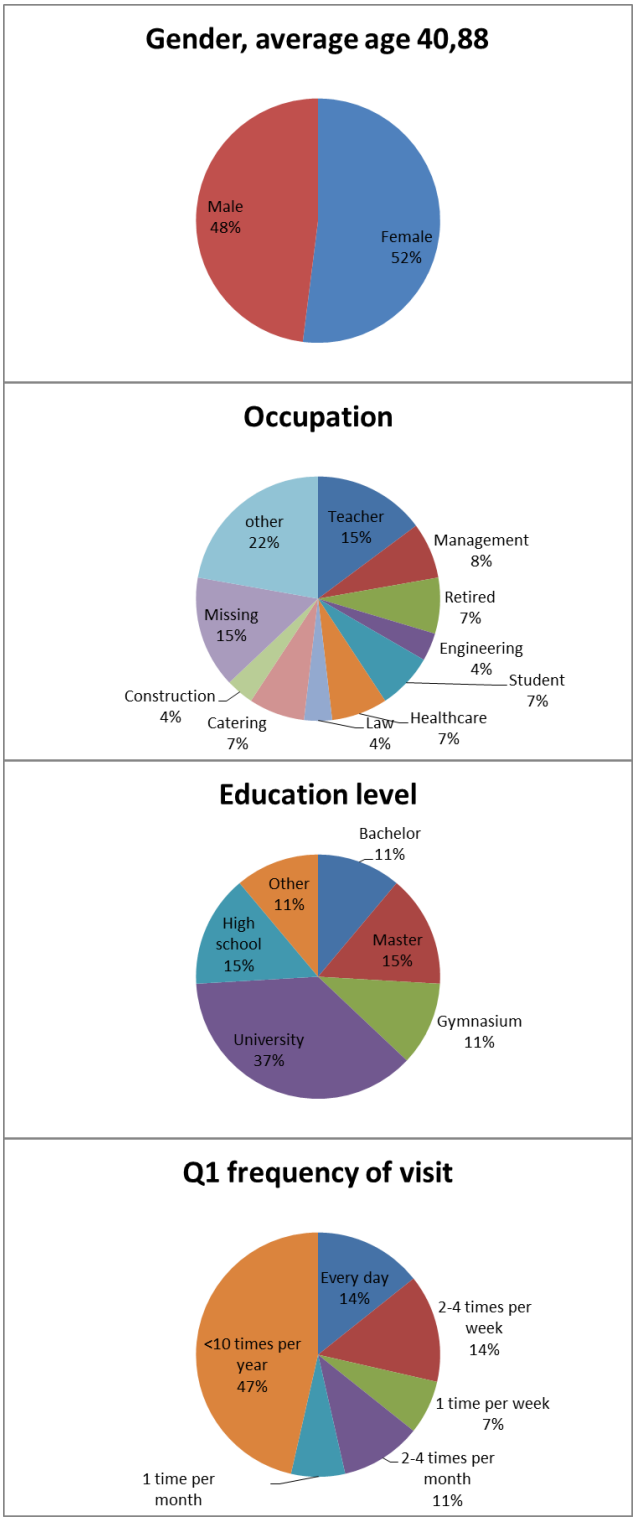
Domkyrkan


Gender, average age 28,33
Male 39%
Female 61%
Occupation
Healthcare 7%
self-employed 7%
IT 6%
Social studies 20%
Student 53%
Engineering 7%
Education level
Bachelor 11%
Other 17%
Master 11%
Gymnasium 5%
High school 28%
University 28%
Q1 frequency of visit
Every day 0%
2-4 times per week 5%
<10 times per year 22%
1 time per month 6%
1 time per week 39%
2-4 times per month 28%

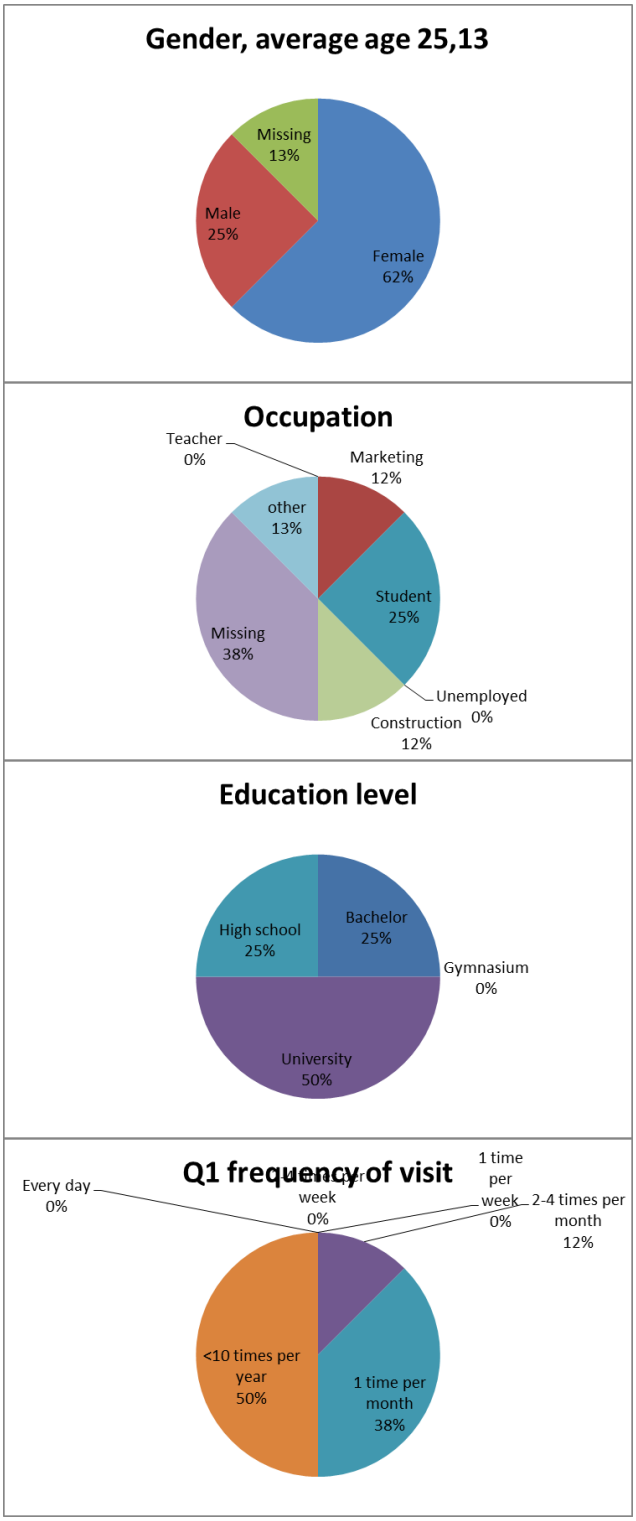
Kungsparken waterside sunny day



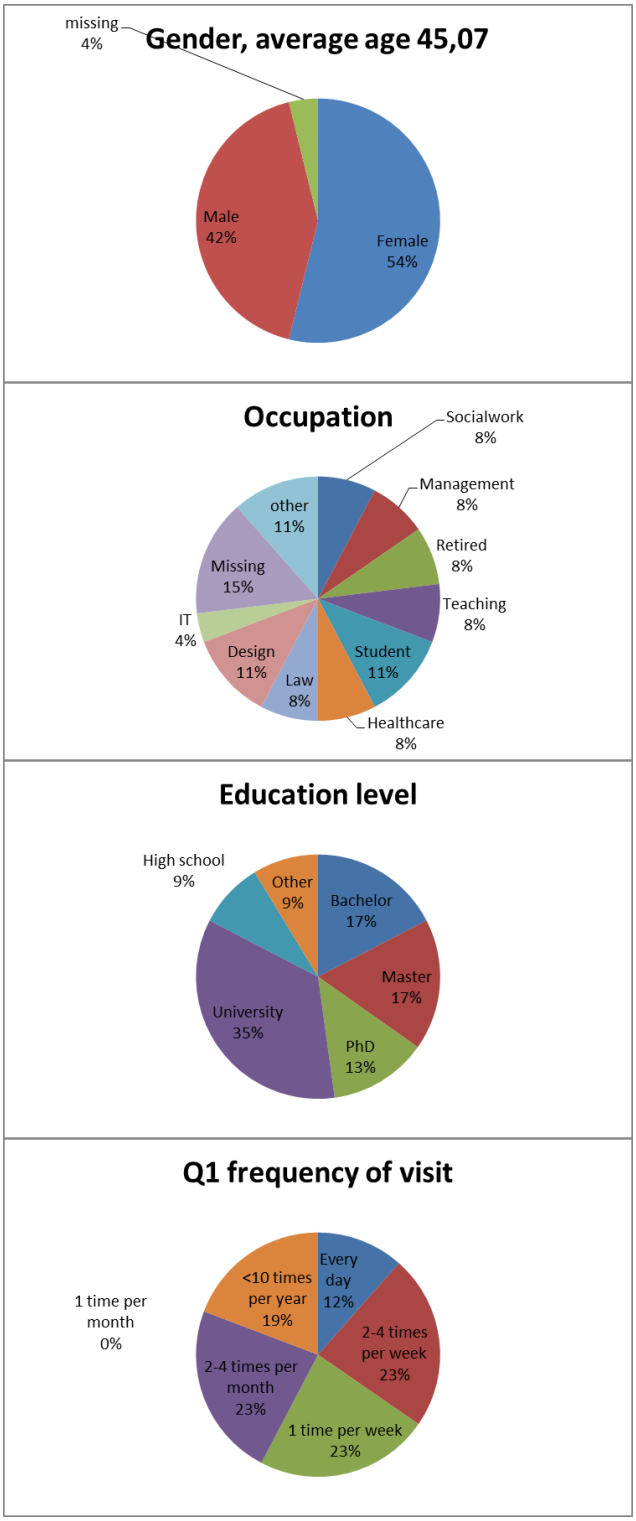
Kungsparken waterside cloudy day



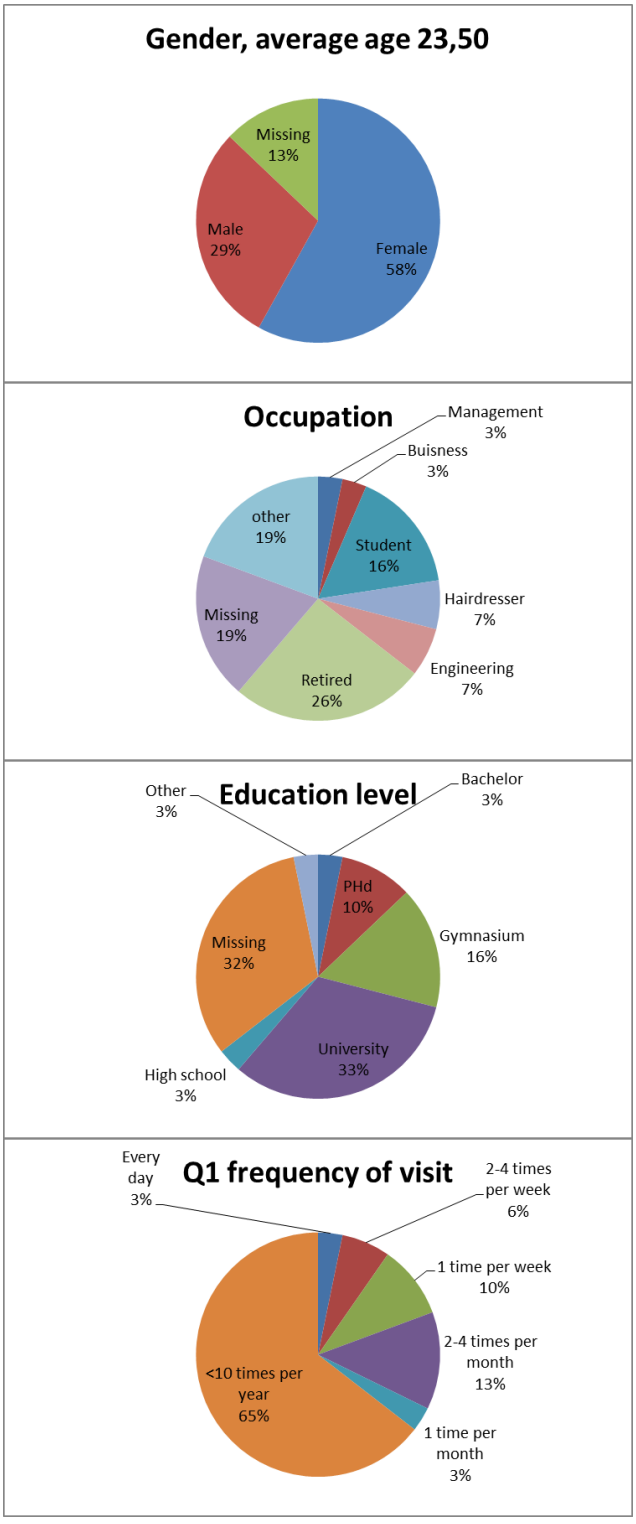
Kungsparken roadside



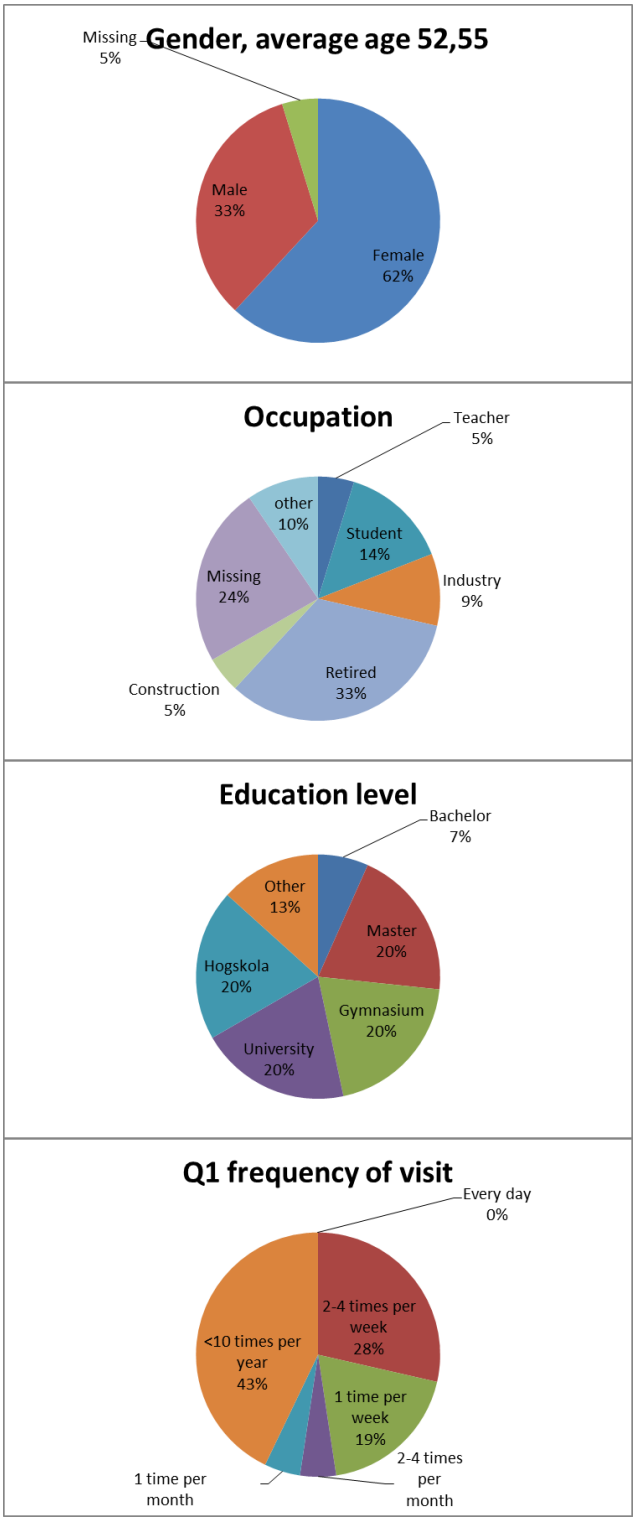
Hagakyrkan


Gender, average age 45,07
missing 4%
Male 42%
Female 54%
Occupation
Socialwork 8%
Management 8%
Retired 8%
Teaching 8%
Student 11%
Healthcare 8%
Law 8%
Design 11%
IT 4%
Missing 15%
other 11%
Education level
High school 9%
Other 9%
Bachelor 17%
Master 17%
PhD 13%
University 35%
Q1 frequency of visit
Every day 12%
2-4 times per week 23%
1 time per week 23%
2-4 times per month 23%
<10 times per year 19%
1 time per month 0%

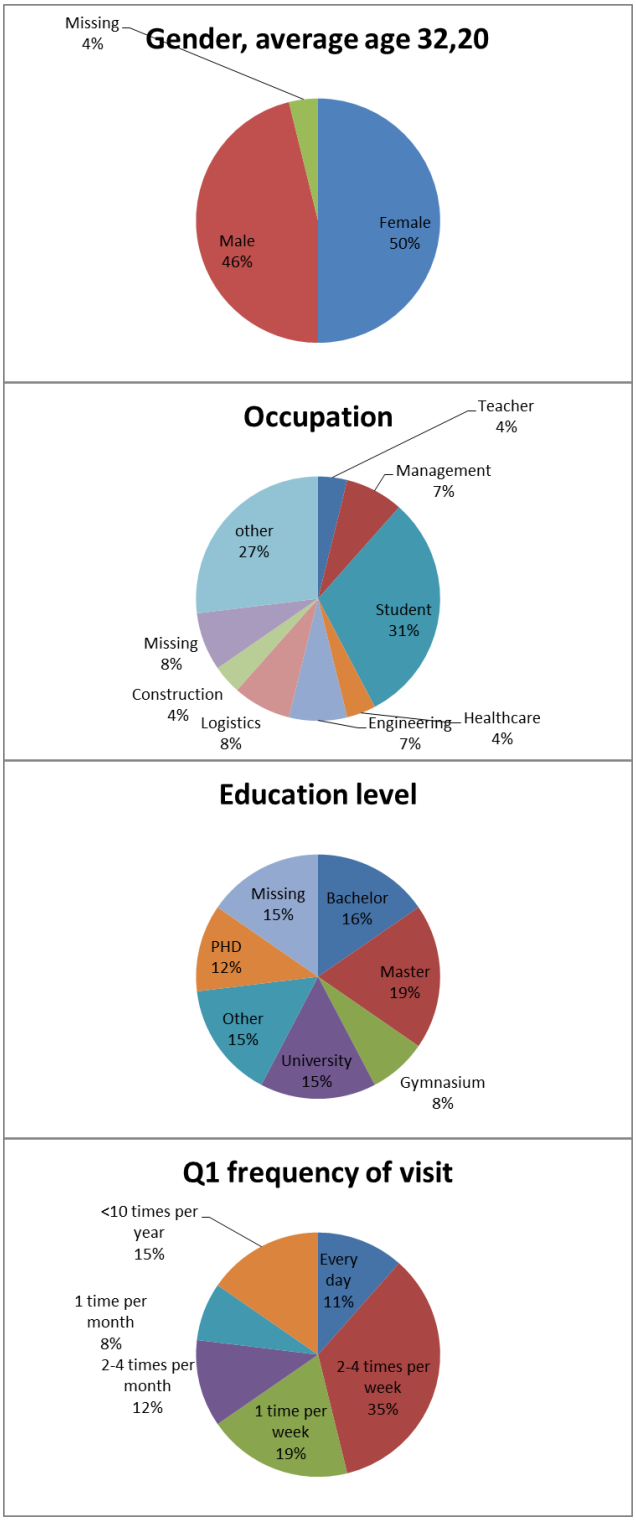
Botanical garden



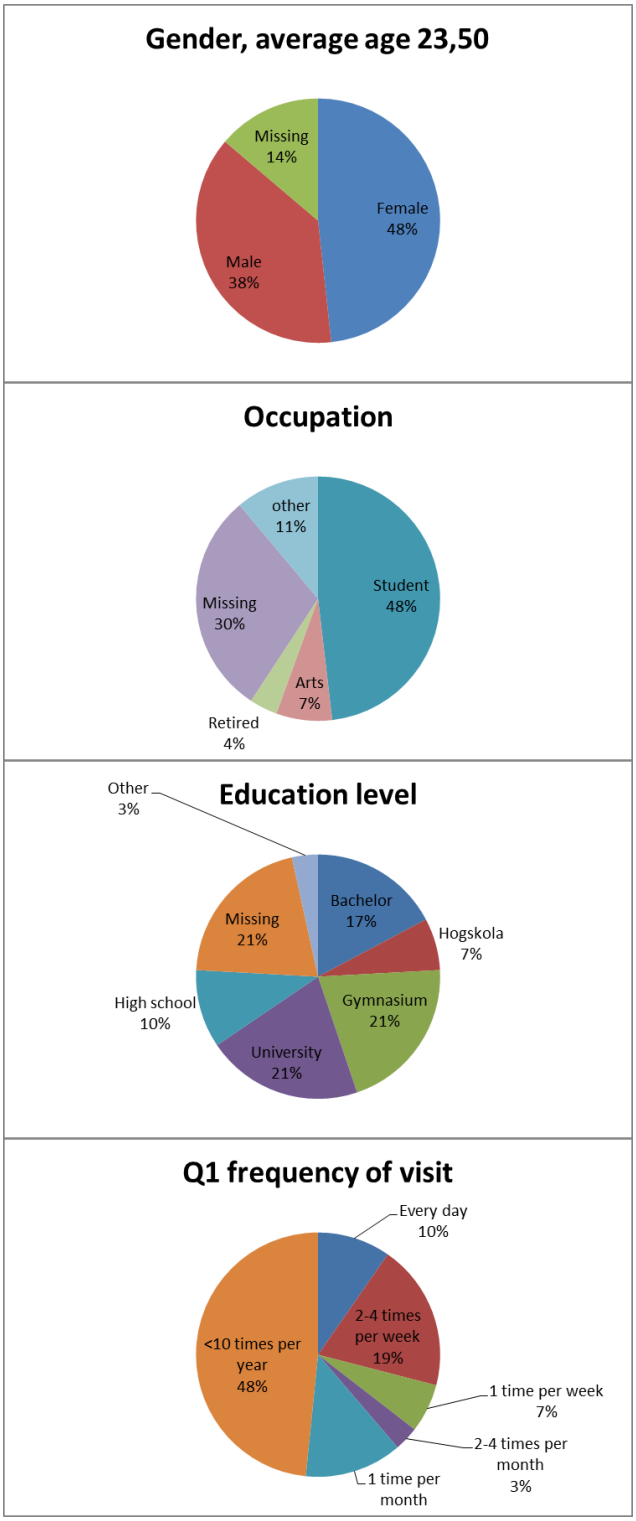
Rodasten


Gender, average age 52,55
Missing 5%
Male 33%
Female 62%
Occupation
Teacher 5%
other 10%
Student 14%
Industry 9%
Missing 24%
Retired 33%
Construction 5%
Education level
Bachelor 7%
Other 13%
Master 20%
Hogskola 20%
Gymnasium 20%
University 20%
Q1 frequency of visit
Every day 0%
2-4 times per week 28%
<10 times per year 43%
1 time per week 19%
2-4 times per month
1 time per month

Järntorget


Gender, average age 32,20
Missing 4%
Female 50%
Male 46%
Occupation
Teacher 4%
Management 7%
Student 31%
Healthcare 4%
Engineering 7%
Logistics 8%
Construction 4%
Missing 8%
other 27%
Education level
Bachelor 16%
Master 19%
Gymnasium 8%
University 15%
Other 15%
PHD 12%
Missing 15%
Q1 frequency of visit
Every day 11%
2-4 times per week 35%
1 time per week 19%
2-4 times per month 12%
1 time per month 8%
<10 times per year 15%

Odinsplats


Gender, average age 23,50
Missing 14%
Female 48%
Male 38%
Occupation
other 11%
Student 48%
Missing 30%
Arts 7%
Retired 4%
Education level
Other 3%
Bachelor 17%
Hogskola 7%
Missing 21%
High school 10%
Gymnasium 21%
University 21%
Q1 frequency of visit
Every day 10%
2-4 times per week 19%
<10 times per year 48%
1 time per week 7%
2-4 times per month 3%
1 time per month