Noise abatement from buskers at Mauerpark on Sundays.

Master Thesis

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01. Declaration

I declare that this is my own work

“Eidesstattliche Erklärung

Hiermit versichere ich, dass ich die vorliegende Arbeit selbstständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe. Alle Ausführungen, die anderen veröffentlichten oder nicht veröffentlichten Schriften wörtlich oder sinngemäß entnommen wurden, habe ich kenntlich gemacht. Die Arbeit hat in gleicher oder ähnlicher Fassung noch keener anderen Prüfungsbehörde vorgelegen.”

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02. Abstract

Mauerpark is an internationally renowned public park in Berlin, Germany with up to 40,000 visitors during the weekends, (Hönicke, 2019). The visitors come for the eventful Sundays which include a flea market, a karaoke event, and buskers from all over the world sharing their music and art with the public.

Noise pollution from park on Sundays has been a problem for many years, but during the summer of 2018 the noise complaints from the neighbours reached record levels, (Löser, 2018). The noise complaints started several discussions regarding the future of the park. The neighbours stated that the main source of noise pollution derived from the buskers' electric amplifiers and drums, especially when several buskers would perform at the same time and increase their volume to be heard, (Schmitz, 2018).

The results from discussions were demands for new park rules regarding the use of music and physical structures to reduce the noise pollution, (Löser, 2019; Grün Berlin Stiftung, 2019; Schmitz, 2018; SPD Linksfraktionen, 2018).

Grün Berlin Stiftung which operates and develops the park stated that there is need for further research regarding noise pollution and how to abate it in their feasibility study of Mauerpark. The purpose of this research is to recommend specific new rules and physical structures to reduce the noise pollution from the park on Sundays.

There are no scientific studies regarding noise abatement from buskers in public parks, and this is a demanded topic due to increase of small festivals and musical events in urban parks, (Zaldua, 2019).

The thesis concludes that there is a need for permanent acoustic shells for small groups of buskers, sound barriers for larger groups of buskers, noise abating pavilions to reduce the noise from drums, and additional rules regarding for cooperation between the buskers.

03. key words and key organisations

Table 1 Key words and explanations

Key word	Explanation
Acoustic (musical instrument)	Not having electrical amplification
Band Gap	Total loss of a certain frequency.
Busker	A person who is entertaining with music in public spaces in exchange for monetary donations.
Busking	The activity of playing music in public spaces in exchange for monetary donations.
Decibel (dB)	measure of intensity and degree of loudness of a sound
Decibel A-filter (dB(A))	a measurement of decibel which corresponds with equal-loudness curve of the human ear.
Frequency	Total Number of reoccurring events per unit of time. A presentation of how many vibrations build up a soundwave for a certain sound or noise.
fundamental frequency	All instruments have an individual fundamental frequency which is the frequency which is perceived as the loudest by human hearing, (Zytrax, 2019.
Hertz (Hz)	Used when describing a specific amount of cycles per second in a frequency spectre. Commonly used when describing the specific frequencies of musical tones.
Kilohertz (kHz)	Refers to one thousand hertz
Sonic	Source of sound and frequencies within the audible range for humans.
Soundscape	Describes the acoustic environment of a place.
Transmission Loss	The amount of sound lost when travelling through a material.

Table 2 Key groups and explanations

Key Groups	Explanation
Berlin Street Music	Berlin Street Music s an advocacy group fighting for street musicians and performers rights in Berlin.
Fruende des Mauerpark	The non-profit organization Fruende des Mauerpark (Friends of the Mauerpark) are involved in most discussions regarding Mauerpark, and strive to create a balance between the tourists, long-established residents, various users, and newcomers. Their goal is to secure the lively and cultural use of Mauerpark as well as the special mix of visitors (tourists, locals, artists, etc.) and to prevent the loss of these qualities

	during events like the park expansion and upgrade, (Grün Berlin Stiftung, 2019).
Grün Berlin Stiftung	Grün Berlin Stiftung are responsible for the project and construction management, and project development at Mauerpark. Grün Berlin Stiftung are a group of state owned companies which organize, maintains and upgrades parks in Berlin.

04. Table of Contents

05. Table of figures

06. List of tables

07. Introduction

In this thesis noise abatement from buskers at the public park Mauerpark in Berlin in Germany is explored. The park is internationally renowned as cultural node because musicians and performers from all over the world come to share their unique musical performances with the public on Sundays from spring to fall. The musical performers are called “Buskers”, and they are “busking” which is the act of playing music on streets or other public spaces in exchange for donations. They can be solo or in groups.

The buskers perform when and where they want in the park because there is no organizer for the Sundays at Mauerpark.

The park also hosts a popular karaoke event and flea market on Sundays from spring to fall. The park is further described in chapter 8.a.

The downside to the popularity of the eventful Sundays at the park is the amount of noise pollution generated by the high amount of visitors, commercial events in the park, and several buskers playing at the same time. The noise levels at Mauerpark is discussed in chapter 8.e.

Increased activity and busking in the park during the summer of 2018 lead to a record number of noise complaints from the neighbours, especially concerning the buskers. The noise complaints are discussed in chapter 8.d.

Several discussions and proposals arose to find a solution to the noise issue which are discussed in chapter 8.f, but none were implemented except for new rules for music in the park which are discussed in chapter 8.h.

The research question is what noise abating measures should be implemented at Mauerpark to abate the noise pollution without reducing the diversity of buskers because the diversity of buskers is an important part of why the park has become so famous.

a. Rationale

The purpose of this research is to recommend the most suitable noise abatement measures to reduce the noise pollution from buskers at Mauerpark on Sundays because exposure to noise pollution can lead to health issues like annoyance, disturbed sleeping pattern, dropped

performance at work, increase risk of hypertension, cardiovascular disease, and impaired cognitive performance in children, (Basner et al. 2014).

Noise is defined as “A sound or sounds, especially when it is unwanted, unpleasant, or loud.” by the Cambridge Dictionary, and noise is subjective because sounds that are unpleasant by some might be pleasant to others, and because the perceived loudness and hearing sensitivity is based on exposure, (Zytrax, 2019). This means that a person who is used to listen to music from a certain busker might consider it pleasant while another person who hears the busker for the first time might find it unpleasant and noisy because it is the first time the person hears it, and that a person who has had very little exposure to noise is more likely to be negatively affected by it when suddenly exposed to it.

Humans can hear sounds between 20 hertz (Hz) and 20 kilohertz (kHz), but the human hearing is generally most sensitive between 300Hz and 5kHz, especially around 2kHz to 4kHz. This phenomenon is known as the Fletcher-Munson curve, and is a human trait which has evolved over a very long time and is possibly connected with sounds perceived as danger throughout human history, (Ibid.). Music is often made in the sensitive frequency range because it is easier to listen to for humans which means that noise generated from buskers should be abated because humans are extra sensitive to it.

Long exposure to loud noises will also cause health damaging effects such as hearing loss or tinnitus. Table 3 shows the maximum exposure time to certain levels of sounds before health damage would occur. For comparison a whispered conversation between two people can be at 30dB, a busy office can be at 70dB, very busy traffic at 80dB, a jack hammer operates at around 90dB, and a rock band performing in concert hall can reach levels of 110dB, (Acoustic Products, 2019).

Table 3 Maximum exposure time to certain sound levels before health damage occurs, (Zytrax, 2019).

dB(A)	**Max. Exposure Time**
82	16 hours
85	8 hours
88	4 hours
91	2 hours

94	1 hour
97	30 minutes
100	15 minutes
103	7.5 minute

Table 3 shows how long visitors or neighbours can endure the noise at Mauerpark before hearing damage might occur if the buskers play at levels above 80 decibels adjusted to the equal-loudness curve of the human ear (dB(A)).

DIN 18005 is the standard used in Germany for noise abatement in town planning. It does not state anything regarding abating noise from music in parks, but it does provide a table with decibel-levels for when noise reducing measures are suggested by experts (See table 4)

Table 4 decibel-levels for when sound insulation is suggested by experts (3.1.2.1 DIN 18005-1 Sound insulation in urban development).

Area	**Day dB(A)**	**Night dB(A)**
Pure residential areas	50	40
General residential areas, small settlement areas, and camping areas	55	45
Cemeteries and **parks**	55	55
Special residential areas	60	45
Village areas and mixed areas.	60	50
Business park	65	55

Table 4 shows that the noise in a park should not exceed 55dB(A) during the day or night, while mixed areas which could include a park, commercial buildings and residential can have up to 60dB(A) before noise abating measures are suggested.

b. Methodology

The topic of noise abatement from buskers at Mauerpark was explored by a qualitative study of the ongoing stakeholder discussions from secondary sources like Grün Berlin Stiftung's feasibility study of Mauerpark, protocols from round table discussions with stakeholders, and

news articles about buskers and the noise issue. These sources provided most of data for the qualitative study, but the author had to survey buskers, visitors, and neighbours, which are the main the main stakeholders, to supplement the available data on the issue and explore the directly affected stakeholders' experience of Mauerpark on Sundays. Different surveys were created for each stakeholder group and the questions were asked in both German and English to enable as many as possible of the participants to understand the questions correctly. The questions used for these surveys are available in appendix 1, and a summary of the results are available in appendix 2.

The surveys were distributed with help from the online channels of the organisations Freunde des Mauerpark and Berlin Street Music which distributed links to the surveys on their Facebook and Twitter pages which collectively had more than 33,000 followers. These channels were chosen to reach an audience which had experience with the park.

There were 64 contributions in total for the surveys. 31 for the visitor's survey, 14 for the busker's survey, and 18 for the neighbour's survey. There were four more contributions for these surveys than a survey presented to the stakeholders in the roundtable discussions regarding implementing restrictions on the buskers of Mauerpark which is mentioned in chapter 8.h.

The survey of buskers represented several of the regular buskers at Mauerpark, the surveyed visitors had a good local and international representations, and the surveyed neighbours were representing both the supporters and adversaries of the eventful Sundays at the park, and lived on the main streets around Mauerpark which are shown in figure 1.

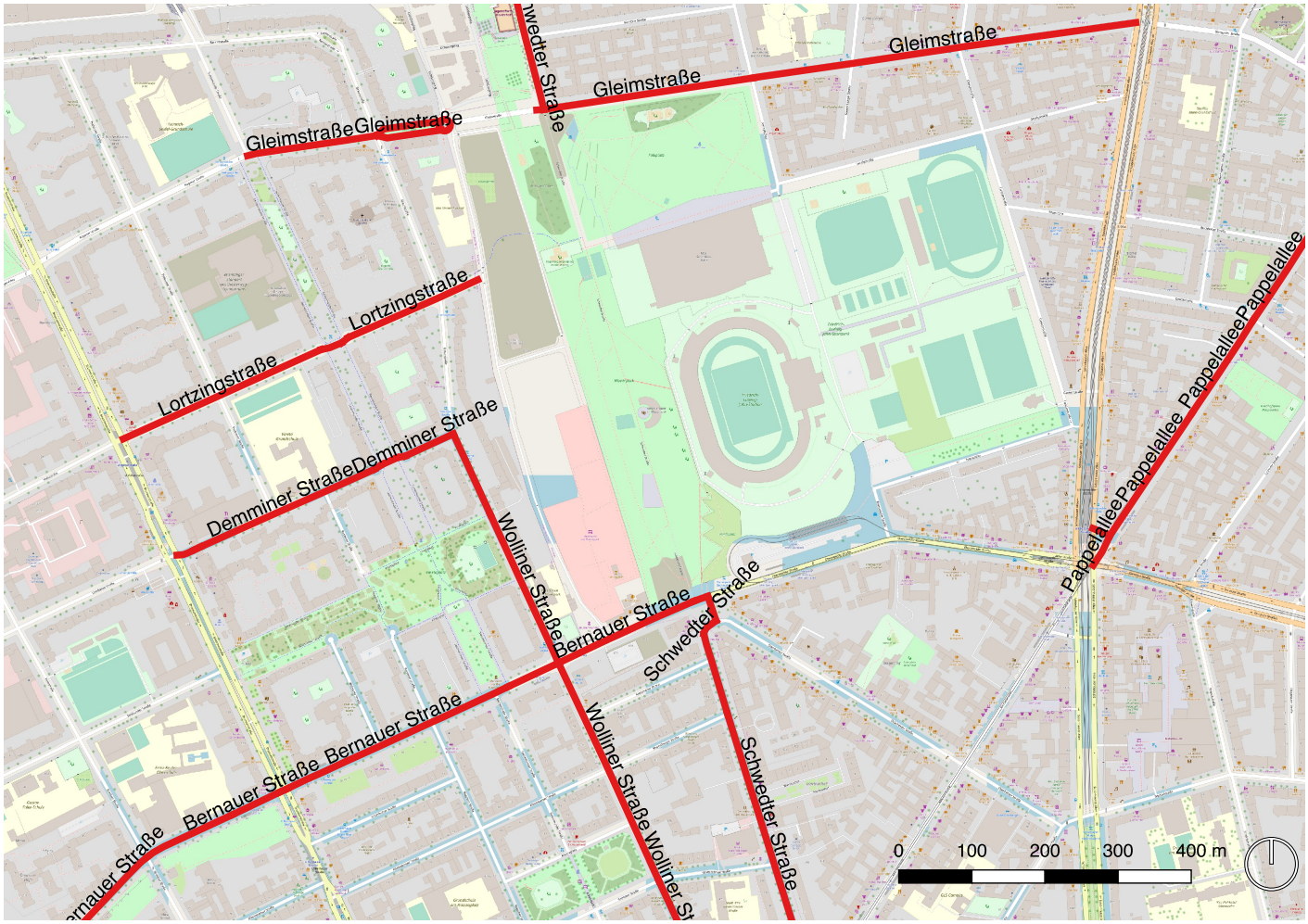

Figure 1 map showing on what streets the surveyed neighbours lived (Author, 2019)

The main stakeholders were identified as the buskers, visitors, and neighbours because they are all critical for the noise issue to exist, and because they have different sonic expectations at the park. The buskers want their music to be heard in its correct way and attract an audience of visitors, the visitors want to explore, dance, and listen to new music, and the neighbours want a noise level which does not affect their life quality or health in their apartment.

Other important stakeholders identified were Freunde des Mauerpark which is an organization which works to protect the unique culture at Mauerpark, and Berlin Street Music which is an organization which works to protect the buskers' rights in Berlin.

Several site visits were done by the author to attend meetings with stakeholders, interview stakeholders, take photos, and attend a presentation and discussion for noise abatement measures for the park.

The approach to the noise issue in this thesis was inspired by the sixth part of The Federal Emission Control Act (BImSchG), which is the German national law protecting against harmful environmental effects of air pollution, noise, vibration and similar processes, which states that a noise action plan should be created based public participation and a noise map created for the urban agglomeration (See Appendix 3). The method was scaled down to function for Mauerpark and the surrounding neighbours. The public participation was gather from the surveys and a feasibility study created by Grün Berlin Stiftung regarding the future development of Mauerpark.

The noise map was created as a heat-map of the soundscape of Mauerpark on a specific Sunday. It was created with the QGIS software to show the intensity sounds and locations of buskers. The map was based on decibel measurements taken by the author to further analyse the behaviour of the buskers and find areas of action.

The decibel measurements were recorded by standing three meters in front of the sound sources using the Sound Meter application created by ABC Apps on a Samsung s6 Egde + phone. This measurement method is similar to what is being done when monitoring the intensity of sounds from buskers in Melbourne, Australia, were they also use apps and three-meter distance from the sonic source, (City of Melbourne, 2018).

The app was calibrated using a sound level meter from RISEPRO. The idea was to use the RISEPRO sound level meter for all measurements, but using the device brought too much attention to the author and some performers changed their behaviour by reducing their volume or cancelled their acts when noticing the sound level meter.

The noise action plan is presented as the conclusion of this thesis and was created based on the action areas identified in noise maps and the benchmark of noise abatement structures.

The benchmarks were the results of an analysis of scientific sources and existing implementations of different sound reducing measures. The benchmarks were selected based on their relevance and implementation to a park in Berlin, Germany. Other studied measures which did not fit Mauerpark are available in Appendix 4.

c. Literature review

Vassilakis (2016) stated that the challenge of abating noise from music sources had yet to be properly addressed by the environmental acoustic community in the United States of America because the focus has been on abating mechanical noise such as traffic.

The scientific publications regarding public parks and soundscapes focus on abating external traffic noise. There are scientific publications regarding abating noise from large and temporary music festivals, but the measures cannot be scaled down or be implemented on a permanent basis to function in a public park.

Many cities have published their own code of conduct for buskers on how to organize themselves and behave in a specific urban space which can include noise abatement measures, but they rarely allow for buskers to play in public parks.

Mauerpark was chosen as a case study because buskers are allowed in the park on Sundays and because there is a demand for research on noise abatement for the buskers at Mauerpark from the Grün Berlin Stiftung's feasibility study and round table discussions.

Grün Berlin Stiftung published their feasibility study of Mauerpark on May 20th, 2019. The study was created to ensure the quality and usability of Mauerpark for the future. The study was a result of public participation and online communication with 220 contributions.

The topics of noise nuisance and noise protection were central alongside the demand for the introduction and implementation of new park rules. The public demanded specific rules on how to use the park for buskers and unspecified physical noise abatement measures. The report stated that there is a demand for different noise abatement measures and identified in section 2.6.1 that further research was needed regarding the specific measures to abate noise from Mauerpark, (Grün Berlin Stiftung, 2019).

Protocols from round table discussions with the stakeholders of the park were also analysed. Representatives from Grün Berlin Stiftung, Freunde des Mauerpark, Berlin Street Music, District Mayor of Pankow, neighbours, and other interested parties were present.

The first roundtable discussed the current situation of the noise problem among other issues for Mauerpark, results from tested measures were presented on the second roundtable, and the third roundtable focused on creating new rules for the park, (Löser, 2019b).

The conclusion from the round table discussions regarding noise were that there is a demand for new rules and physical measures to reduce the noise from Mauerpark, but the demands were unspecified.

08. Benchmarks of noise reducing structures

a. Sound Barrier

Sound barriers are walls which reflect the sound back towards its source rather than absorb it. They are highly effective and are often used along high ways to screen traffic noise from residential areas. They can be made out of different materials like wood, concrete, bricks, glass, and metal. The sound reduction, shown as transmission loss, of different materials for sound barriers are shown in Table 5 below.

Table 5 Collected data on transmission loss of different materials for noise barriers, (Öztürk, Öztürk, and Calis, 2013).

Material	Thickness (mm)	Surface density (kg/m^2)	Transmission loss dB(A)*	Transmission loss dB(A)**
Polycarbonate	8-12	10-14	30-33	-
Acrylic [Poly-Methyl-Meta-Acrylate (PMMA)]	15	18	32	-
Concrete block 200x200x400 light weight	200	151	34	34
Dense concrete	100	244	40	40
Light concrete	150	244	39	39
Light concrete	100	161	36	36
Brick	150	288	40	-
Steel, 18 gal	1.27	9.8	25	25
Steel, 20 gal	0.95	7.3	22	22
Steel, 22 gal	0.79	6.1	20	20
Steel, 24 gal	0.64	4.9	18	18
Aluminum sheet	1.59	4.4	23	23
Aluminum sheet	3.18	8.8	25	25
Aluminum sheet	6.35	17.1	27	27
Wood	50	32.7	-	24
Wood	25	18	21	21
Wood	12	8.3	-	18
Plywood	13	8.3	20	20
Plywood	25	16.1	23	23
Absorptive panels with polyester film backed by metal sheet	50-125	20-30	30-47	-
Glass, Safety	3.18	7.8	-	22
Plexiglass	6	7.3	-	22

* Hong Kong EPD (EPD Guideline, 2003), ** FHWA (Fleming et al., 2000).

Table 5 shows that concrete and brick are the most effective stand-alone material to use when reducing noise, only beaten by absorptive panels with polyester film backed by metal sheet. Different materials are often used to reduce the negative aspects of sound barriers which are the obstruction of view, natural light, and air flow.

The most effective sound barriers have an overhanging part on the top of the wall because it will also reduce and reflect some of the noise which is moving upwards.

Figure 2 shows an example sound barrier made from different materials like concrete, metal with ventilation slits, glass for reduced obstruction of view, and an overhang.

Figure 2 example of sound barrier with overhang (Photo: https://www.alibaba.com/product-detail/Wholesale-railway-sound-barrier-noise-barrier_62083262658.html?spm=a2700.7724857.normalList.7.4356580dRyuPBK&s=p l Visited on 30th July, 2019)

Sound barriers function the best when they are as close as possible to the sonic source. Figure 3 below shows a common issue were sound barriers are only reducing noise for the lower floors of a building due to the sound waves which travels above the sound barrier.

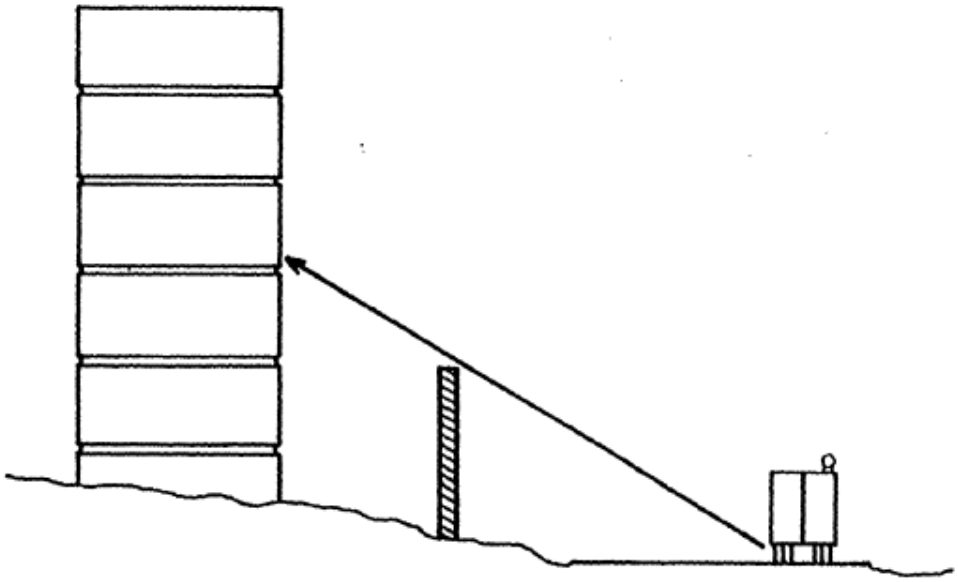

Figure 3 showing how barriers might only reduce noise pollution for the lower floors. (source: https://www.fhwa.dot.gov/ENVIRonment/noise/noise_compatible_planning/federal_approach/audible_landscape/al04.cfm Visited on 30th July, 2019)

Sound barriers are not common in parks, but structures which exist in parks have similar features. Historical walls and walls used for sports both have the qualities of a short sound barrier when made of sound reflecting materials like concrete and the sound source is placed in close proximity to the wall.

Figure 4 shows a busker playing in front of the remains of the Berlin Wall which is an example of reusing an historical wall as a sound barrier.

Figure 4 Busker playing in front of the Berlin Wall which functions as sound barrier (Source: https://www.alamy.com/stock-photo-musician-busking-on-street-beside-berlin-wall-at-the-east-side-gallery-58225682.html Visited on August 19th, 2019)

It is unknown why the busker chose this location, but it is likely due to access to tourists and not the noise abating effect of the wall, but there will be a significant noise abating effect for the people behind the wall since the wall is made of concrete and the busker is playing so close to it.

Examples of sport walls with sound barrier qualities in parks are climbing or bouldering walls (see figure 5), and tennis, football, or American handball walls (See figure 6).

Figure 5 example of bouldering wall which would function as a sound barrier (Photo: Dina Mishev from https://rootsrated.com/jackson-hole-wy/climbing/teton-boulder-park visited on August 1st, 2019.)

The benefit of bouldering walls is that they can have an overhang due to increased difficulty for climbers.

According Walltopia (2019), which is an international manufacturer of artificial climbing walls with offices in Germany, a commercial climbing wall cost from 160EUR per square meter in Germany.

Figure 6 American handball court (source: https://bikecolleenbrown.wordpress.com/2010/06/29/the-damn-handball-court/ visited August 20th 2019.)

An American handball court also functions as a tennis or football wall which are more common in Europe. The walls are made from concrete and can have side walls, shown on figure 6, which further abates noise by reducing the spreading.

The cost of a polymer concrete tennis wall with extra noise reduction measures in Germany is 1,928EUR per 100cm x 300cm, (Mailith, 2019).

b. Acoustic shell

Acoustic shells consist of a semicircular shell with a parabolic opening which reduces sounds moving in undesired directions by focusing the sounds towards the audience if the busker performs with their amplifiers inside the shell, (See figure 7). The empirical noise abatement effect measured in decibel depends on the size and material used to create the shell.

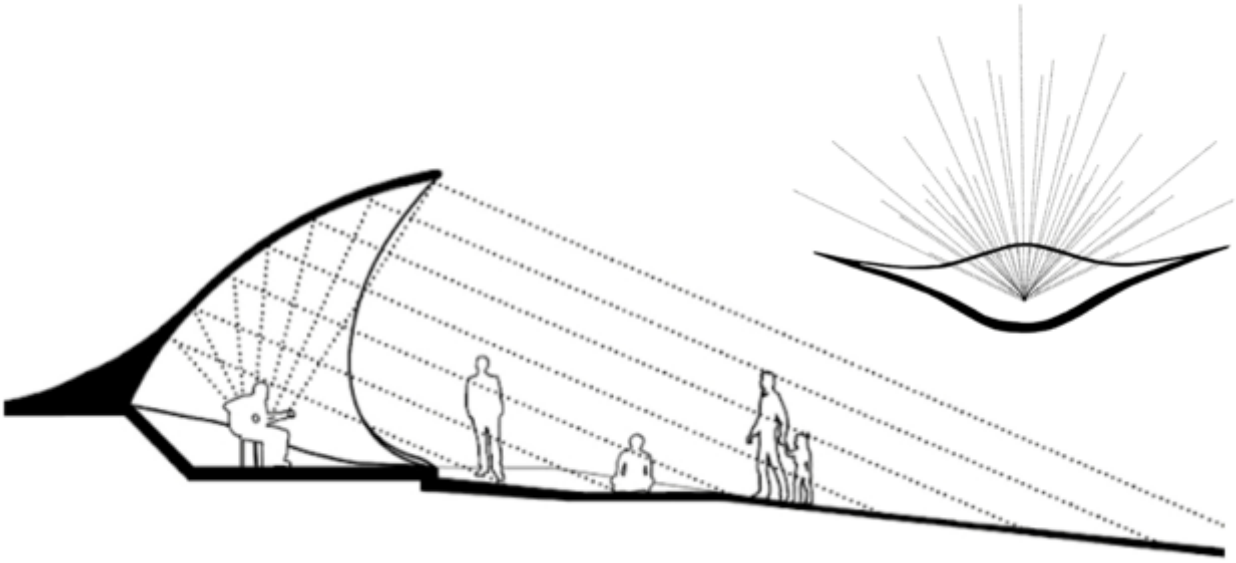

Figure 7 how an acoustic shell focusses the sound, (Flanagan Lawrence, 2019).

The shells work well with stationary performers, but restricts the performers movement. The size of the shells will also limit how many can perform inside at the same time.

Flanagan Lawrence, an architect company from the United Kingdom (UK), have created several acoustic shells in Europe. Their award winning project in Littlehampton in West Sussex, UK consisted of two acoustic shells facing away from each other shown in figure 8 below. The shells were created with shotcrete, a spray-able concrete, and the project cost 109,200EUR,

(Flanagan Lawrence, 2019).

Figure 8 Flanagan Lawrence's acoustic shell in Littlehampton, West Sussex, UK, (Flanagan Lawrence, 2019)

An acoustic shell was implemented to reduce noise pollution from buskers in Tel Aviv in 2016. The structure was created by Aviv Even who told the author that it was constructed with layers of bent wood, acoustic foam, trapped air, and a base of a more conductive material than the pavement to absorb excessive frequencies.

The small size of the shell is unsuitable for full drum kits because the reverberation of the shell's shape would make the drums sound even louder than natural which might require unnecessary amplification from other instruments, and a drum kit would take up so much space that amplifiers or other sound sources might be placed outside the shell which would significantly reduce the shell's noise abatement effect. The smaller size of the shell encourages the use of the "Cajon" which is box shaped hand drum favoured by buskers for its portability and sound. Cajon drums are also quieter than regular drums.

The creator Aviv Even told the author that the size was based on an average public bench in Tel Aviv, and that the entire structure cost less than 2,000EUR. The acoustic shell is shown in figure 9.

Figure 9 Acoustic shell in streets of Tel Aviv (Photo: Aviv Even 2016)

c. Noise Reflecting Pavilions

Some instruments send sound waves vertically up in the air due to the alignment of the sound producing surface. Pavilions made from noise reflecting materials are used in public spaces and festivals around the world to reduce the need for excessive amplifications for other instruments by reflecting vertical sound waves from drums back to its source.

Most hand drums and drums on a drum kit, excluding the kick drum and cymbals, are examples of instruments producing mainly vertical sound waves.

The pavilions do not have walls which allows for 360 degrees of horizontal view and for the wind to pass through unobstructed.

Wheatland Music Organization constructed a wooden pavilion stage for the purpose of drumming for the Wheatland Music Festival in Remus, Michigan (figure 10). The stage was intended to function for acoustic rhythmic performances and drum classes, and to not disturb other areas of the festival, (Wheatland Music Organization, 2015).

The cost of the structure is not available, but the square meter price for the frame of an Industrial structure can be used because the structure is simple. According to Kaluscheand and Herke (2016) The square meter price was supposed to be 1,037EUR in Germany in 2018.

Figure 10 Stage for drumming (source: https://www.wheatlandmusic.org/rhythm-stage/nggallery/page/1 visited on August 3rd, 2019.)

Adamsville Recreation Center in Atlanta, Georgia had a sound pavilion created for the public to use in 2003 (See figure 11). The sound pavilion featured several permanent metal hand drums and a pavilion roof to reflect the sound waves back to the drums, (Sonic Architecture, 2014). The cost of the structure is not available, but the cost of a wooden pavilion with benches which could be suitable for drum circles is 6,416EUR from https://www.jacksgardenstore.com as of August 22nd 2019.

Figure 11 Pavilion for hand drums at Adamsville Recreation Center in Atlanta, Georgia (source: http://sonicarchitecture.com/public-art/ visited on August 3rd, 2019.)

d. Greenery

The effective noise reducing greenery are evergreen trees or shrubs which keeps leaves all year around and have a high density of branches reaching all the way to the ground.

A significant reduction of six decibels or more is only achieved with a thick belt of high density trees planted on soft ground because soft grounding and soil around the trees is also able to absorb some the noise due to soils conductivity, (Dobson and Ryan, 2001). Soil will absorb more frequencies than it reflects back at the source of sound, (Nunn, 2010).

The noise mitigation effect of trees also depends on the height, and trees are usually sold at around two meters' height and take many years to grow to an effective noise mitigating size. Buying trees taller than two meters which can survive being moved is very expensive, (Borson, 2012). According to Lorberg (2019), which is a company in Berlin selling trees to parks all over Europe and Russia, the price for one four-meter tall spruce tree, which is a high density evergreen with branches reaching all the way to ground, is 2,400EUR.

Figure 12 example of high-density evergreen spruce trees (Source: https://www.fast-growing-trees.com/products/meyer-spruce-tree Visited on 31st of July 2019.

09. Case study Mauerpark

a. Mauerpark

Mauerpark is a public park managed by Grün Berlin Stiftung which is located in the Pankow District of Berlin, Germany on the coordinates 52°32'34"N 13°24'10"E. Figure 13 below shows the location of the park in Berlin. The park is situated amid Bernauer Street, Wolliner Street,

and Gleim Street.

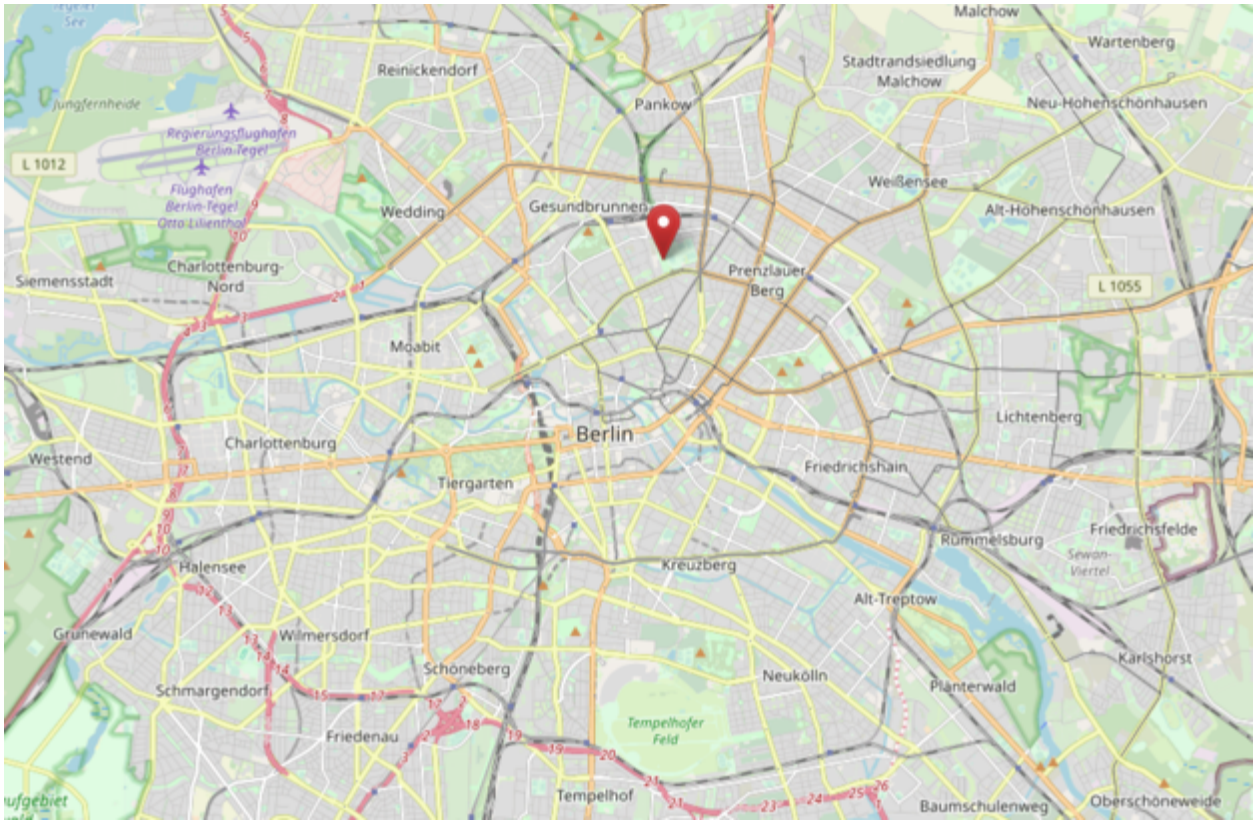

Figure 13 map showing location of Mauerpark in Berlin, Germany (Map created at https://www.openstreetmap.org/ on 30th of July 2019)

The park was part of the former death strip during the times of the berlin wall, and remains of the walls still exist in the park.

The park has eastern and western part and is 15 hectares in total, but seven hectares of the western half of the park are currently under construction.

The eastern side of the park is eight hectares and consists of a flat field with an amphitheatre, an atrium, a basketball court, a hill, a playground for children, remains of the berlin wall, and a

paved pedestrian road called Schwedter street. The western part has one warehouse, two beer gardens, and a paved area used for the flea market on Sundays

Figure 14 shows a picture of the park from 2017 with the western side being under construction.

Figure 14 Mauerpark in 2017 with western part under construction, seen from a south oriented point of view, (Photo: https://gruen-berlin.de/projekt/mauerpark Visited on 30th of July 2019)

The construction is ongoing, and the completion of the park is set to be in 2020, (BBS Landscape Engineering, 2019).

Figure 15 basketball court (Author, 2019)

The basketball court is not used by buskers because it is used to play basketball in on Sundays. There are no other recreational or sports areas in the park, but this is demanded by the neighbours, (Grün Berlin Gruppe, 2019).

Figure 16 Amphitheatre (Author, 2019)

The amphitheatre is the location for the karaoke event on Sundays, but buskers and other commercial events are able to use the location before the karaoke event starts at 15:00.

Figure 17 Atrium (Author, 2019)

The atrium is the preferred location for buskers playing drum kits and hand drums on Sundays, and drum circles usually form around the buskers playing hand drums. A talk to one buskers named Miguel from a group called “Puto Production”, and the authors experience with the area, revealed that the same drumming buskers have been playing in the same atrium for years taking turns playing every 30 minutes and sometimes playing together. This indicates that the drummers are established in this location and that the other buskers and visitors expect them to play there.

Other buskers were playing in the field or along the Schwedter street.

Figure 18 Busker playing along Schwedter street in Mauerpark on a Sunday (Photo: Author, 2019)

Mauerpark was the preferred location for buskers because of the easy access to audiences and established culture according to the survey results.

Sundays at Mauerpark is an established tourist attraction which is recommended by numerous travel magazines including http://www.visitberlin.de which is Berlin's official information platform for tourists, and Sundays at Mauerpark have been growing in popularity for more than 15 years with the flea market introduced in 2004 and the karaoke event since 2009. Weekend visitors have been recorded up to 40,000, (Hönicke, 2019).

The visitors are the people who arrive at Mauerpark on Sundays to listen to music from the buskers, relax in the park, sing karaoke, and explore the flea market. The visitors have a strong international representation and all ages are represented according to the survey results.

Figure 19 A Sunday at Mauerpark seen from the hill (Photo: Author, 2019)

The park received a special cultural status by the district council on the 27th of March 2019. The special cultural status is intended to safeguard the cultural activities in the park which has made the park so famous which includes the buskers, (Schmitz, 2019).

The status will be implemented in the preparatory land use plan of Berlin in accordance with Section 5 of the Federal Building Code (Baugesetzbuch - BauGB) which states what should be shown in the preparatory land use plan and that it should be accompanied with an explanatory statement, (See Appendix 5).

This special status shows how important it is to find a way reduce the noise from buskers in a way that will not reduce the cultural output from the park from the diversity of buskers.

b. Master plan

Approval and funding for the western expansion of Mauerpark came in the summer of 2016 from the city council, with support of the social democratic political party (SPD) and Grün Berlin Stiftung, (Loy, 2016).

The new master plan which includes the western part of the park was developed with landscape architect Gustav Lange, who had the original design of Mauerpark in 1993, and BBS landscape engineering in 2018.

The state budgeted six million euros for the expansion, (BBS Landscape Engineering, 2019). According to Grün Berlin Stiftung's feasibility study (2019) The new development will be built in accordance with the original ideas of landscape architect Gustav Lange with the same robust design and usable open spaces. The history of the development of Mauerpark is available in Appendix 6.

Multifunctional areas and secondary uses are important for the development because recreational and sport use is a demanded feature from the neighbours. The design intends to integrate the flea market and the beer gardens in the design of the park, but design these areas with a secondary recreational and sport use for weekdays, (Grün Berlin Gruppe, 2019).

The targets were to find ways to make the noise pollution bearable for neighbours, create order in the park, clarify traces of history, protect the neighbours recreational and exercise opportunities in the park, provide more shading, and protect the unique atmosphere and character which makes the park a famous tourist attraction, (Ibid.).

According to Building Senator Andreas Geisel (SPD), Jens-Holger Kirchner from the Green party (Die Grünen), and Mittes District Mayor Christian Hanke (SPD) there will be areas along the central north-south axis for buskers and other performers with small stages to promote more spontaneous culture in the park, (Loy, 2016). This is not reflected in the master plan from 2018 which is shown below on figure 20.

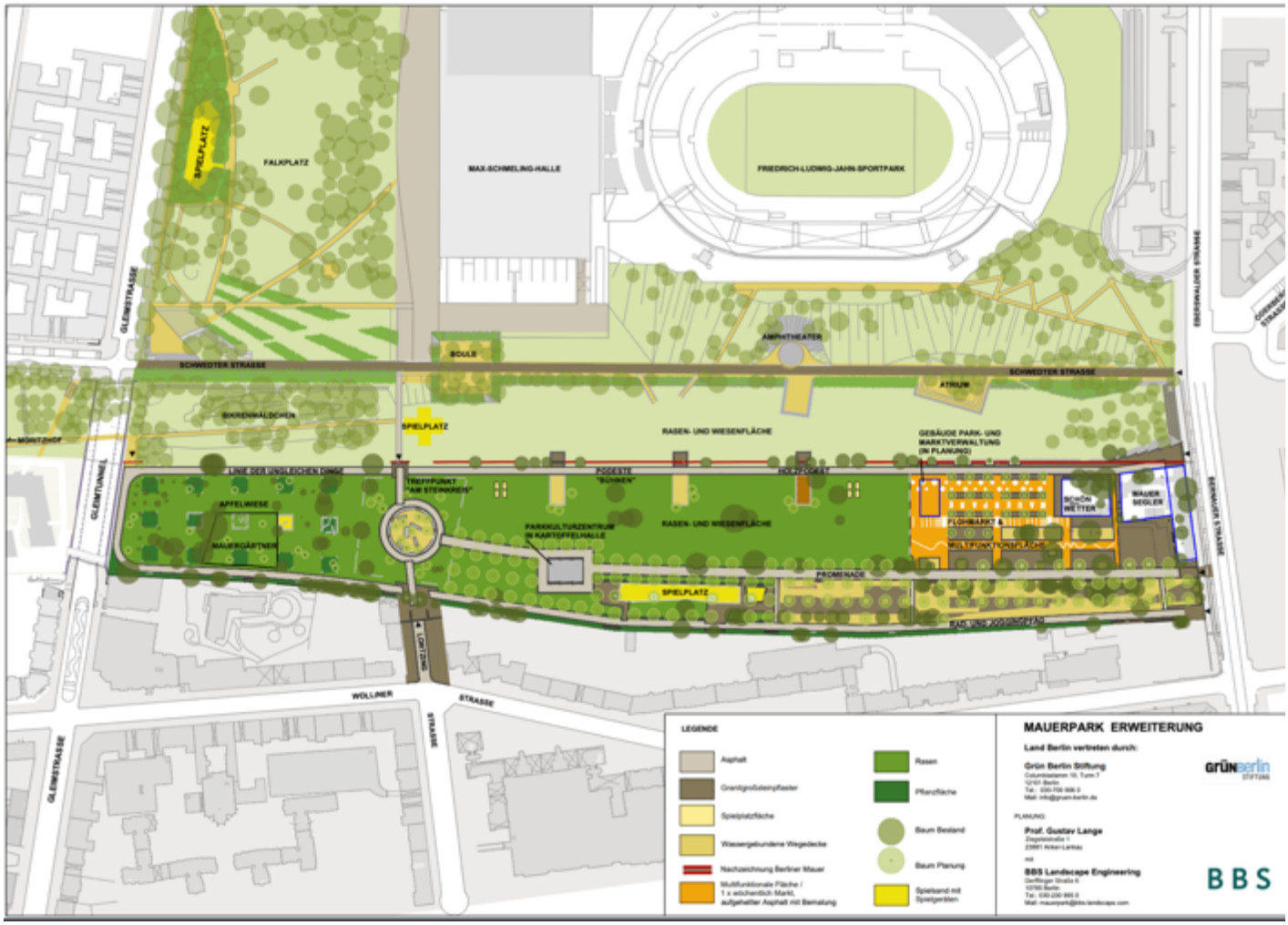

Figure 20 master plan for Mauerpark (Grün Berlin Stiftung, 2019).

The master plan features the planting of several new trees, but the noise abatement effect of the trees will not be significant unless they are fully grown evergreen trees with high density.

c. Other developments at the park

Since 2018, there has been an ongoing construction of a waste water reservoir under the park which has affected the buskers and karaoke event because there have been several temporary construction sites inside park to create ventilation shafts to the reservoir, (Bettendorf, 2019). An old tank barrier from the time of the Berlin Wall was discovered when excavating a pit for the initial drilling for the waste water reservoir in 2018. According to Wähner (2018) The Berlin Wall Foundations and Freunde of Mauerpark wanted to put this old tank barrier on display as part of a historic exhibition at the entrance of Mauerpark, but Grün Berlin Stiftung stated they

were afraid an exhibition will increase the noise pollution for neighbours due to increased flows of visitors, but this is counteracting one of their targets identified in their feasibility study which is to clarify traces of history in the park, (Grün Berlin Stiftung, 2019).

The most important feature to clarify the traces history in Mauerpark are the remains of the Berlin wall. The wall is located at the top of the hill on the eastern side of the park. The wall is famous for graffiti artists, but buskers play there as well as shown in figure 21.

Figure 21 Buskers playing next to the Berlin wall at Mauerpark (Source: https://www.alamy.com/stock-photo-musicians-buskers-by-the-wall-in-mauerpark-berlin-in-evening-light-77771365.html visited August 20th 2019.)

Parts of the wall and hill in Mauerpark will likely be brought down or moved in 2020 due to a 135-million-euro expansion of an adjacent sports arena which is hosting the Paralympics in 2023, (Hönicke, 2019). The wall functions as a sound barrier when buskers play next to it, and loss of parts of the wall would possibly increase the noise pollution from Mauerpark.

Parts of the large budget for the arena expansion should be used to compensate the park and conserve the wall due to its heritage value and the demand for a historic exhibition at the park from The Berlin wall foundations and Freunde des Mauerpark.

d. Noise complaints

Noise complaints arose during the summer of 2018 because the summer had very little rain and a lot of sunny days which led to increased activity in the park on Sundays, (Löser, 2018). The increased activity triggered an unknown number of neighbours of Mauerpark to report buskers in the park to the police for noise pollution which resulted in a record number of noise complaints for the park in 2018 with police reports increasing from ten in 2013 to 35 in 2018, (Ibid.). The police charged an unknown number of buskers with public nuisance offences, and some had their equipment confiscated, (Fruendes des Mauerpark, 2018). The police stated that they did not have the capacity to deal with all the complaints or the correct noise measuring devices to ascertain that sound levels were above legal limit, (Löser, 2018).

Eleven out of 14 surveyed buskers for this thesis had their performance stopped by the police or a regulatory officer due to noise complaints which indicates there is a need for measures to reduce the noise pollution for the sake of the buskers as well as the neighbours.

According to the round table discussions the neighbourhood movement to report the buskers to the police for noise pollution was called “Larmstopp Mauerpark” (Stop the noise from Mauerpark), and most complaints came from Wolliner Street especially on weekends between 20:00 and 24:00, (Ibid.).

Representatives from the Larmstopp Mauerpark movement said that they experienced the loudness of the music from the park on Sundays as if the buskers were playing on their balconies, and that some had to leave their apartments on Sundays to get away from the noise, (Schmitz, 2019).

The main source of noise pollution derived from amplified instruments and loud acoustic drums, especially when several buskers were playing different music at the same time, according to the neighbours in the round table discussions and the surveyed neighbours.

None of the surveyed neighbours identified singing or guitar playing as annoying sounds when asked what sonic source create the most noise for them.
Sporting events, firecrackers, karaoke, and parties during the night were other sources of noise pollution, (Löser, 2018).

The noise was also perceived differently depending on the height of the housing unit. The neighbours in apartments on the ground floor had less exposure to the noise from the park, (Ibid.).
Surprisingly, 15 out of the 18 surveyed neighbours were positive regarding Sundays at Mauerpark even though noise pollution was generated. The 3 out of 18 participants who stated they were negative to Sundays at Mauerpark because of the noise lived on Wolliner street and feared for the negative health effects of the noise.
They lived on the first, fourth and fifth floor, which indicates that the noise issue only affects a few people living in apartments on Wolliner Street which might be more exposed than other apartments.
There was ongoing construction on the façades of an apartment building facing Mauerpark on Wolliner street 28. during the summer of 2018, and the author was also able to ask a construction manager on site if there was going to be any noise abating measures implemented on the façade, they said no. This indicates that the noise levels from Mauerpark are not high enough to enforce noise abatement measures for all the apartments.

e. Noise at Mauerpark

The noise at Mauerpark on a Sunday was measured to an average of 59dB according to representatives from the Environmental and Nature Conservation Office (Umwelt- und Naturschutzamt Umweltschutzamt) who explained the current state of the noise pollution on Sundays at Mauerpark to the public and the district council of Pankow on the 3rd of April 2019, (Schmitz, 2019). It is unknown how, when, and where the noise was measured.
The DIN 18005 table, shown in chapter 6.a, suggests that there is need for sound reducing measures inside Mauerpark on Sundays because the average noise value at Mauerpark on

Sundays was 4dB higher than the expert-suggested limit of 55dB for parks, and only 1dB less than the suggested limit of 60dB for mixed areas.

An average of 60dB is also the limit for buskers at Mauerpark according to section 4.1 of The State Emmission control law Berlin (Ausführungsvorschriften zum Landes-Immissionsschutzgesetz Berlin- AV LImSchG Bln) regarding emission standards for outdoor areas from the regulations for implementing (See appendix 7). This suggests that measures should be implemented in the park to reduce the noise before it reaches the 60dB limit which might happen due to increased popularity or better amplification technology in the future. Commercial events at Mauerpark must also have average sound levels below 60dB to obtain a permit to operate by to The District Council of Pankow. The results of 59dB also enables commercial musical events at Mauerpark, like the karaoke, to obtain operational permits, (Schmitz, 2019). The permit for the karaoke is available in appendix 8.

An unknown number of the affected neighbours were not satisfied with the 59dB readings because they were average readings from 06:00 to 22:00 which are the hours when it is legal to use sound reproduction devices and musical instruments outside as long as they are not used at a volume that seriously disturbs anyone, according to section three and five of The Federal Emission Control Act of Berlin from 2004 (Landes-Immissionsschutzgesetz Berlin - LImSchG Bln), (See appendix 9).

Representatives from the Environmental and Nature Conservation Office said it was not legally feasible to create individual measurements of musical events or buskers at Mauerpark because the sound could not be isolated from other sonic sources, (Ibid.)

The traffic noise on the adjacent streets of Mauerpark are also a significant source of the noise in the area. Berliner Morgenpost (2019) created an interactive noise map of Berlin for 2018. The noise map shows level of noise pollution from cars and public transportation for apartments. The noise levels outside Mauerpark are the loudest for apartments on Bernauer street facing Mauerpark with up to 70dB during the day and 62dB at night according to this map. Apartments facing Mauerpark on Wolliner street had less noise than Bernauer street with up to 52dB during the day and 44dB during the night which indicates that the complaints regarding noise from the buskers were more likely to come from the apartments facing

Mauerpark on Wolliner Street because there is less exposure to noise pollution in this area from other sources.

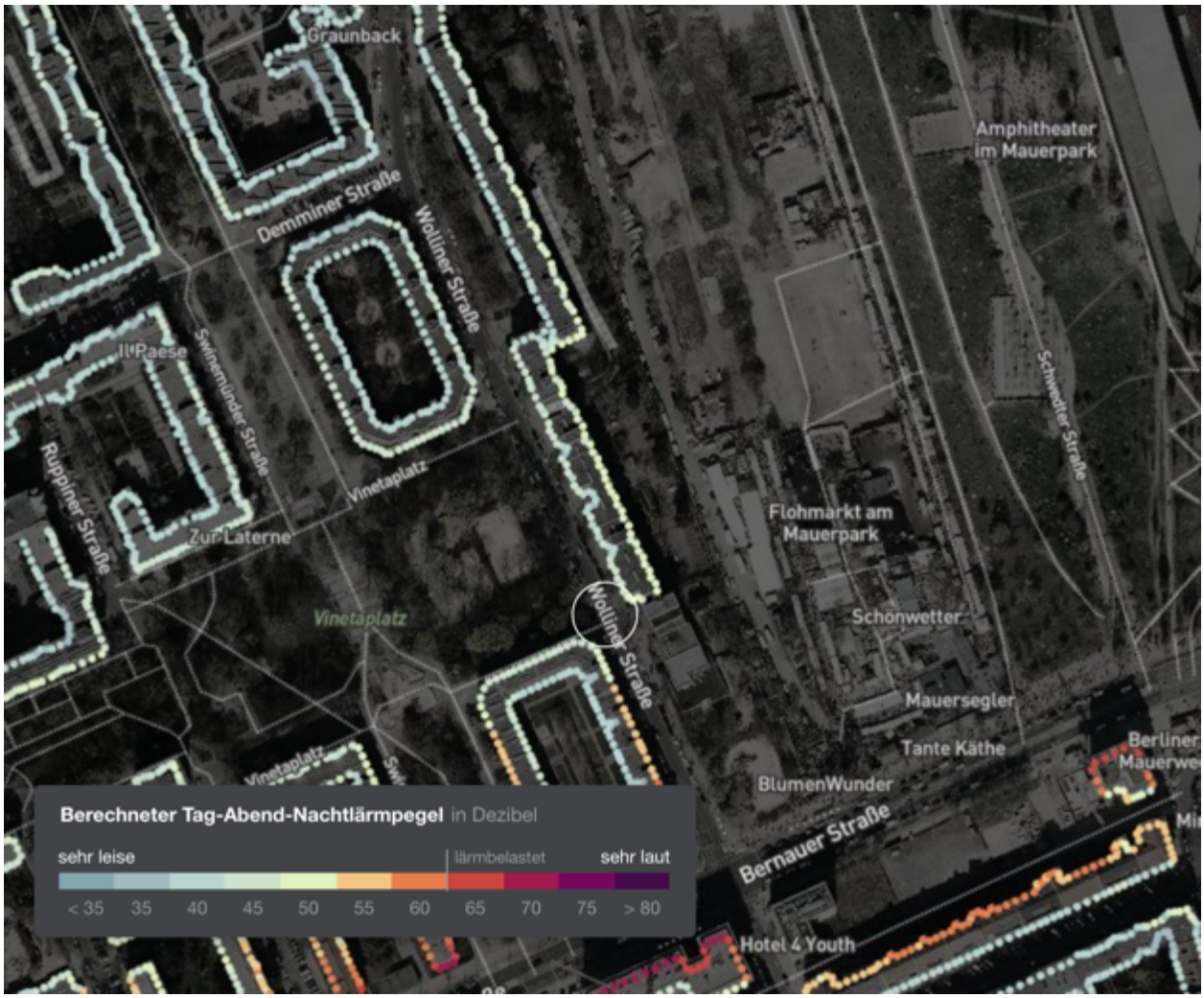

Figure 22 Screenshot of noise map showing difference in intensity of noise pollution for apartments represented by coloured dots (Berliner Morgenpost, 2019)

f. Proposed solutions

There have been several proposed solutions to the noise issue at Mauerpark, but none has been permanently implemented.

A project called “Parkläufers” (Park Runners) was tested at Mauerpark in 2018. The project consisted of 20 employees from the public order office (Ordnungsamt Pankow) who were in the park on four Sundays during the summer of 2018 to tackle different issues including the noise pollution by educating the musicians about the rules and regulations in and around the park.

The feedback was that there were not enough human resources to tackled the current situation at that time, and it was criticized for being a one-way communication channel because the buskers were not able to influence the project, (Löser, 2019a).

Maria Moorfeld, the leader of the Environmental and Nature Conservation Office proposed to enable the buskers to play legally on Saturdays in a designated area to reduce the demand on Sundays, (Schubert, 2018). This suggestion was voted against on the second round table discussion partially because there was not enough capacity to deal with Sundays from the police or the public order office, (Löser, 2019a).

On May 31st 2019 the district council rejected a motion to charge an entrance fee to Mauerpark to reduce the amount of people in the park which would reduce the noise levels among other issues. The idea came from a report concerning tourism in Berlin created by a company called BTE Tourismus- und Regionalberatung. This rejection was based on the notion that Mauerpark is common property and a public park which should unite rather than segregated, (Conrad, 2019).

Acoustic shells for the buskers was proposed by a campaign called “Save Mauerpark” which was created following the noise complaints of the summer in 2018 by the organisation Berlin Street Music together with an unknown number of buskers, visitors, and neighbours of the park.

The campaign demanded protection and support for the diverse cultural scene with buskers and artists at Mauerpark, (Berlin Street Music, 2018a). According to the protocol of the second roundtable the campaign had more than 7,300 supporters on 6th of November 2018, and 76 percent were citizens of Berlin, (Löser, 2019a).

Save Mauerpark hosted an event during the citywide music festival “Fête de la Musique” on the 21st June 2019 with buskers playing at the park to collect money for the construction of acoustic shells, (Schubert, 2019). This is showing that the buskers themselves demand a technical solution to the noise problem and that the measures should be affordable to be feasible due to lack of funding.

Save Mauerpark designed a model of a mobile acoustic shell which could be set up and taken down every Sunday shown in figure 23.

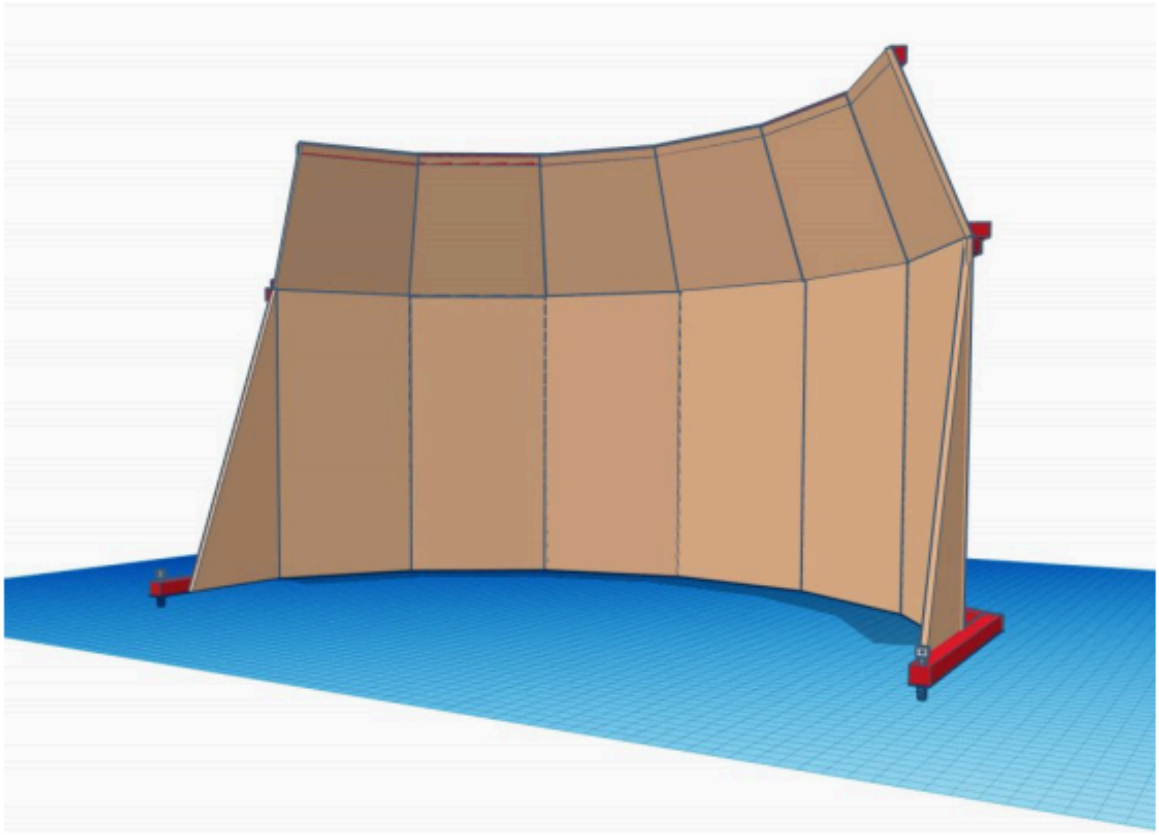

Figure 23 Save Mauerpark's proposed design for an acoustic shell, (Schweizer, 2019).

The effect of proposed shell is not known because it has not been made or tested yet, but the material which is suggested is wood which has a lower noise abating effect than concrete.
On the 21st of July 2019 Jason Flanagan from the London-based architect company "Flanagan Lawrence" who has designed large acoustic shells for other parks in Europe presented their previous work at a public event inside Mauerpark.
The anchoring of Save Mauerpark's proposed design of a mobile structure was discussed following the presentations. Wind was identified as a possible issue due to the curved design, mobility, and light weight. The shell could be moved by the wind and possibly harm someone. A base of concrete was suggested by Jason Flanagan, but wires nailed to the ground, anchoring to existing granite blocks, or underground water tanks were other suggestions to fix this issue.
Save Mauerpark also proposed suitable locations for the shells along Schwedter Street shown in figure 24. The red markers are the most suitable, and the brown markers are alternative locations.

Figure 24 Proposed locations for the acoustic shells, (Schweizer, 2019).

The locations are along the Schwedter Street and facing the hill which would be a natural noise abatement measure due to the soil of the slope's conductivity absorbing sound waves.
The district council of Pankow and the left fraction of SPD supports the proposal of implementing acoustic shells directing the sound towards the hill, (Schmitz, 2019; SPD Linksfraktion, 2019).

g. Rules for Buskers in Berlin

The rules for the buskers are also an effective measure to reduce the noise in Mauerpark.
The general rules for buskers in Berlin are made according to section three, four, and five of The State Emission Control Act of Berlin from 2004 (Landes-Immissionsschutzgesetz Berlin - LImSchG Bln) which states that "Sound reproduction devices and musical instruments must not be used at a volume that seriously disturbs anyone", and that it is forbidden to cause noise on Sundays and from 22:00 to 06:00 o'clock on weekdays. Section 15 and 16 states that instruments can be confiscated and fines can reach levels of 50,000EUR for non-compliance, (See Appendix 9).

The buskers at Mauerpark were tolerated on Sundays because of an agreement between the district council, local police, and Freunde des Mauerpark that the sounds should not carry outside of the park or be in disagreement with The State Emission Control Act of Berlin, (Keese, 2012).

Buskers in Berlin in general are allowed to play up to 60 minutes in pedestrian areas but they need to change their location every 15 minutes by at least 100 meters, (Berlin street music, 2018b). There are no specific time limits for buskers at Mauerpark.

The buskers using amplification in Berlin require a permit, but there is no city level permit which means that the requirements and rules are different between each districts. Permits are required from the public order office (Ordnungsamt) or the Environmental and Nature Conservation Office depending on the district. The application process can take up to four weeks and the enforcement of the rules is unpredictable (Ibid.)

Buskers at Mauerpark interviewed by the author said that they did not bother to get a permit because of the confusing process. The lengthy application process and the unpredictable enforcement by local authorities indicates that the rules need to be clear and communicated efficiently to encourage conformity at Mauerpark.

Berliner Verkehrsbetriebe (BVG) who operates the underground system in Berlin have specific areas for buskers at their underground stations and offers daily permits for 10EUR which can be picked up the same day as long as the busker is not playing a brass instrument because they are often very loud acoustically, (BVG, 2019). Signage in the underground is used to show were the

buskers can play and how to apply for a permit shown on figure 25.

Figure 25 sign showing the public that there is a two square meter official busker zone in the berlin underground. (Author, 2019)

Similar signage should be made for Mauerpark to show both the buskers and visitors were the buskers zones are and how to use different noise abating structures if implemented.

h. Rules for Buskers at Mauerpark

On May 7th 2019, The district office of Pankow released a statement with special park rules for Mauerpark. The rules included rules regarding buskers and music in the park based on the demands from: an agreement on the third roundtable that there was a need for new park rules to test self-regulation between the buskers, the demand for new park rules to reduce noise pollution presented in Grün Berlin Stiftungs' feasibility study, and a survey presented on the second roundtable which showed that the majority of 60 participants were positive concerning enforcing a time limit and volume control on the buskers in Mauerpark, (Löser, 2019a).

The special park rules for Mauerpark made busking with battery powered amplification legal on Sundays without a permit because a designated area was zoned for music.

The new park rules regarding music are explored below:

“Musicians can only perform inside the designated area and maximum ten meters west of Schwedter street”, (See figure 26). This rule reduces the amount of buskers playing closer to Wolliner Street and limits the buskers to only one area of the park which might limit the amount of buskers or lead to excessive loudness from buskers trying to play at the same time. Buskers used to be tolerated playing on the field which is now zoned as a barbecue area.
12 out of 14 buskers who answered the survey wanted to be able to continue playing freely on the field. 20 out of the 31 visitors who were surveyed also wanted the buskers to be able to play freely on the field which suggests that a mixed-zone for music and barbecue should be explored.
“Music can be played from 11:00 to 19:30 from Mondays to Thursdays, and from 11:00 to 20:30 on Fridays and weekends”. This rule stops the music early so visitors would leave the park earlier than before when music was tolerated until 22:00.
“Musicians should direct the music towards the hill”. The soil of the hill acts as a natural noise abatement measure because it is a conductive material.
“Musicians are not allowed to increase their volume to drown out other performers”. This rules tries to create cooperation between the buskers, and to lower the excessive noise generate when several buskers are playing at the same time.
“The use of generators to run amplifiers is not allowed”. Generators enable stronger amplifiers which can’t be powered by batteries to work in the park. Stronger amplifiers can produce louder sound levels, and generators themselves produce a lot of mechanical noise.
“Commercial events, like the karaoke, will need a special permit from the District of Pankow”. Commercial events operate under different rules than the buskers.
Other rules are regulated by § 6 and § 7 of the Green Building Act (Grünanlagengesetz – GrünanlG) which regards the use of public green and recreational areas. Section 6 Abs. 1 states that it is forbidden to cause noise that unreasonable disturbs other visitors, and section 6 Abs. 5 explains that any use of the public green and recreational area which goes beyond section 6 Abs. 1 needs an approval from the competent authority which is granted on a case by case basis, if it is in the public’s interest and remedying the consequences are ensured. Section 7

states that offences to section 6 Abs. 1 may be punished by a fine of up to 5,000EUR. The full legal texts for section six and seven are available in appendix 10.

pamphlets were handed out to musicians and visitors regarding the new rules on June 2nd 2019. The rules were not displayed on any signage at the park and the visitors who did not receive a pamphlet would only know about these new rules for the park by visiting Freunde des Mauerpark's or the District of Pankow's online channels.

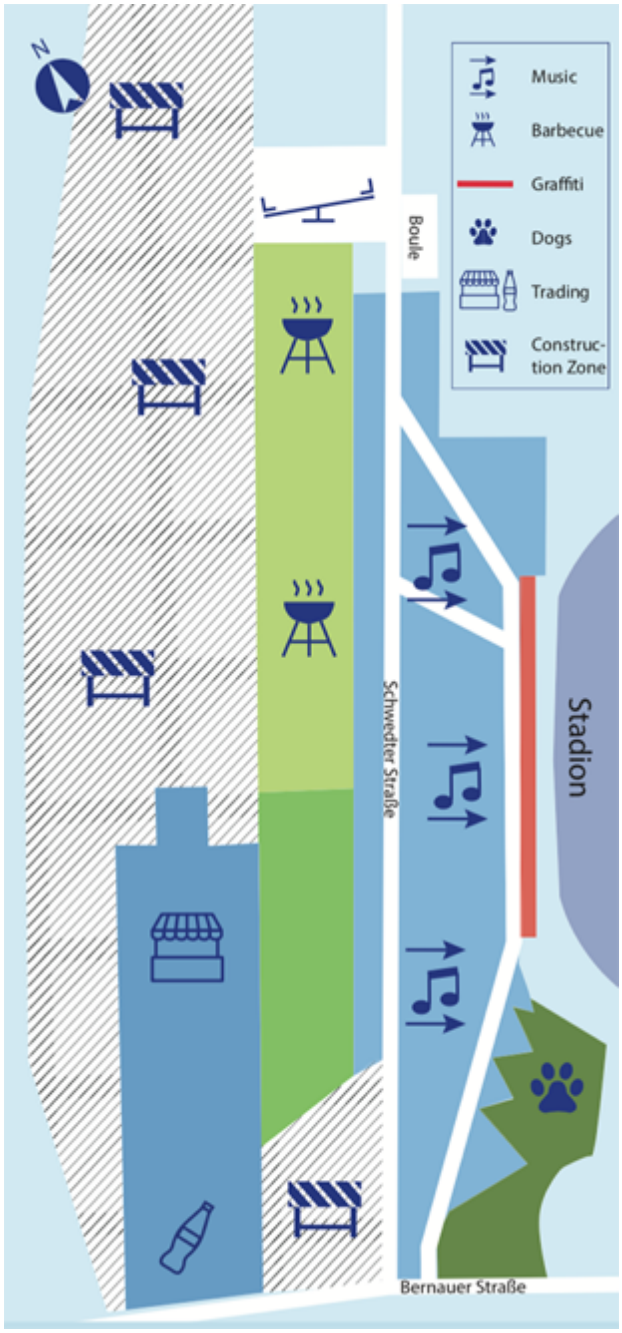

Figure 26 Map from the pamphlet showing the different zones of Mauerpark, (Mauerpark Redaktion, 2019)

The buskers who took the survey created for this thesis wanted to avoid rules regarding auditions for performers, scheduled times for individual performers, ban of amplification, watt limitations on amplifiers, bans on specific instruments, or ban on receiving donations. Additional suggestions for park rules by the surveyed neighbours and visitors were a volume limit for the buskers, limit of performers playing at the same time, a set distance between the

buskers, no buskers close to the entrances of the park, and that all artists should have the opportunity to perform.

10. Results

a. Soundscape

The author measured the sound levels and recorded the locations of buskers and other sonic sources on Sunday the 19th of May 2019 between 14:00 and 15:00. This was before the new park rules were introduced so the buskers were playing freely in the field and some used generators to power their amplifiers. The conditions were very good because it was a sunny and warm day which increased the activity in the park. The author measured three different solo artists playing acoustic guitar music, two drum circles playing different drums and rhythms, and three bands playing, funk, rock or Spanish pop songs. Other measures were of people relaxing in the park listening to music from portable speakers and from music in the shops of the flea market.

The buskers playing that day were a good benchmark because it is similar to the genres played by the surveyed buskers. Six out of the 14 participants categorized their music as rock or pop, and three out of 14 participants played solo acoustic guitar music. Other genres represented were jazz, world fusion, rhythmic percussion, blues, and acapella.

The variety of genres creates a demand for different types of noise abating structures to not limit the diversity in the buskers.

The most common instruments were acoustic drum kits, synthesizers, keyboards, acoustic guitar, electric bass guitar, electric guitar, and amplified vocals. These instruments were mainly amplified with a speaker that ran on battery or connected to a portable generator. The drums were not amplified.

The heat map in figure 27 shows the intensity of the sonic sources based on their level of dB(A) and where the sonic sources were located in the park.

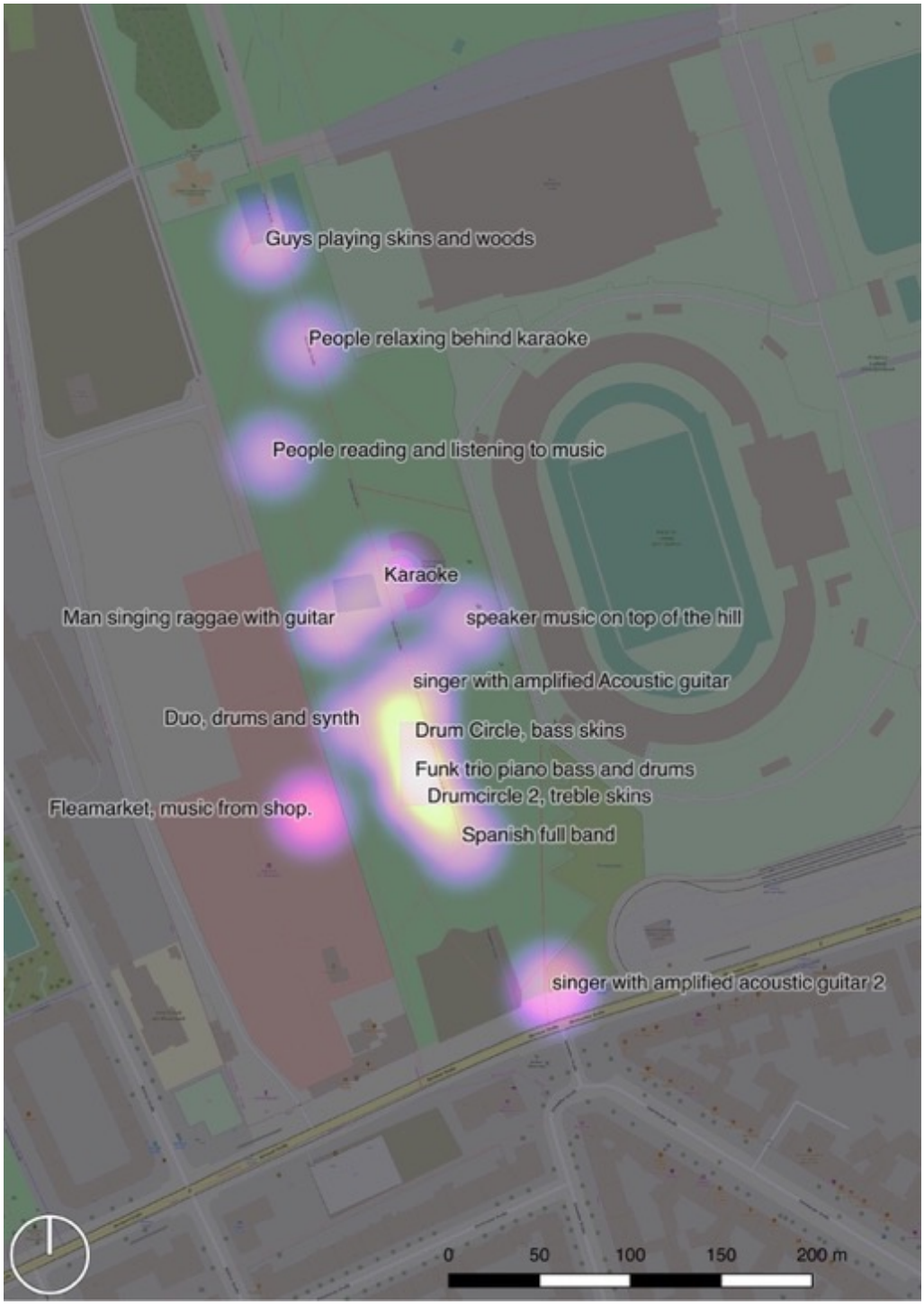

Figure 27 heat map of where the buskers were playing and intensity of the sound levels on 19th of May 2019 between 14:00 and 15:00 (Author, 2019)

The area with the highest intensity was inside the atrium because it was the preferred area for drummers, and the drums were perceived as the loudest sonic source by the author which

signifies that there should be specific measures reducing the noise created by drums in the atrium.

This map is a good benchmark because it is similar to where the surveyed buskers preferred to play. Four out of 14 surveyed buskers said they preferred to play in the atrium, three out of 14 buskers preferred to play at the entrance of the park, two out of 14 buskers preferred to play in the middle of the park, and an equal amount preferring to play anywhere in the park.

The sound levels ranged from 56dB(A) to 80dB(A) and are shown ascending in the table 6 below.

Table 6 dB(A) levels of musicians playing in Mauerpark (Author, 2019).

Title	**dB(A)**
People relaxing behind karaoke	56
People reading and listening to music	57
Speaker music on the top of hill	60
Flea market. Music from shops	65
Duo, drums and synth	67.6
Guys playing skins and woods	70
Funk trio piano bass and drums	71
Drum circle, bass skins	76.4
Man singing reggae with guitar	76.7
Singer with amplified acoustic guitar	78.2
Drum circle 2. Treble skins	78.2
Spanish full band	79.4
Karaoke	80
Singer with amplified acoustic guitar.	80.6

Table 6 shows that all the individual measurements of buskers are a lot higher than the official 59dB average measurement and the 60dB limit, which suggests that there should be noise abating measure according to Din 18005.

11. Conclusion

The findings of this study clearly shows that Mauerpark is a unique cultural location in Berlin which is important for the visitors, buskers and neighbours. The stakeholders agree that the

park should continue to be a cultural hotspot for Berlin and that there are sonic obligations to the visitors, musicians, and neighbours.

The noise pollution should be reduced, especially towards the noise sensitive part of Wolliner street which is facing the park, but this should not come at a cost to the diversity of the music played by the buskers which is what attract the visitors to the park.

The stakeholders agree that there is a need for certain physical measures like acoustic shells or sound barriers to abate the noise pollution. The physical measures should reduce the noise pollution towards Wolliner street, but also reduce the noise pollution between the buskers to reduce unnecessary amplification by the buskers.

The physical structures should be a permanent addition to the park due to the special cultural status of the park and encourage the buskers to play in a manner which will reduce unfavourable spreading of noise from the park by focusing their sounds towards the hill and enable buskers to play at the same time without excessive amplification.

The structures have to be suitable for the different buskers and their musical genres to not limit the diversity of buskers performing at Mauerpark. The structures should be multifunctional with a secondary use which allow visitors of the parks on other days to use the structures.

Signage inspired by BVG's busker signs should be used to conform that the structures are used for buskers on Sundays.

The soundscape analysis, new park rules with a designated area for music, and proposed locations for acoustic shells by the Save Mauerpark campaign has defined the action areas for physical measures along the Schwedter street and inside the atrium.

a. Acoustic Shells

There should be at least two small acoustic shells along the Schwedter street in the direction of the hill to host stationary solo acts and small groups of buskers because the acoustic shells would allow the buskers to play at the same time without creating noise for each other or the neighbours at Wolliner street due to shape of the shells. The shells should not be large because most of the buskers are solo acts or small groups with less than five buskers according to soundscape analysis, and the size would encourage the use of Cajun drums which is quieter than full drum kits.

The design should be inspired by Aviv Evan's design because it worked in Tel Aviv and have a strong concrete anchoring as suggested by acoustic shell expert Jason Flanagan.
One shell should be placed before the atrium, and the other should be placed between the atrium and amphitheatre because these locations are proposed by Save Mauerpark, and because it allows for more dynamic buskers to play between the acoustic shells.
The secondary use of the shells would be shaded benches which are demanded features of the park according to Grün Berlin Stiftung's feasibility study.

Figure 28 visualization of acoustic shell along Schwedter Street in Mauerpark. (Author, 2019) (Photo of shell: Aviv Even 2016).

b. Sound barriers

There should also be two short sound barriers along Schwedter Street in addition to the acoustic shells. One sound barrier should be created by repurposing the remains of the berlin wall, which have to be moved during the expansion of the sports arena, because the wall is made out of concrete which is a very sound reflecting material, and because it will clarify traces of history and can be part of a demanded historic exhibition in the future.

The openness of the structure would enable larger groups of buskers to play and allow the buskers to be more dynamic while reducing the sound towards Wolliner street as long as they are performing in close proximity of the wall and facing the hill.

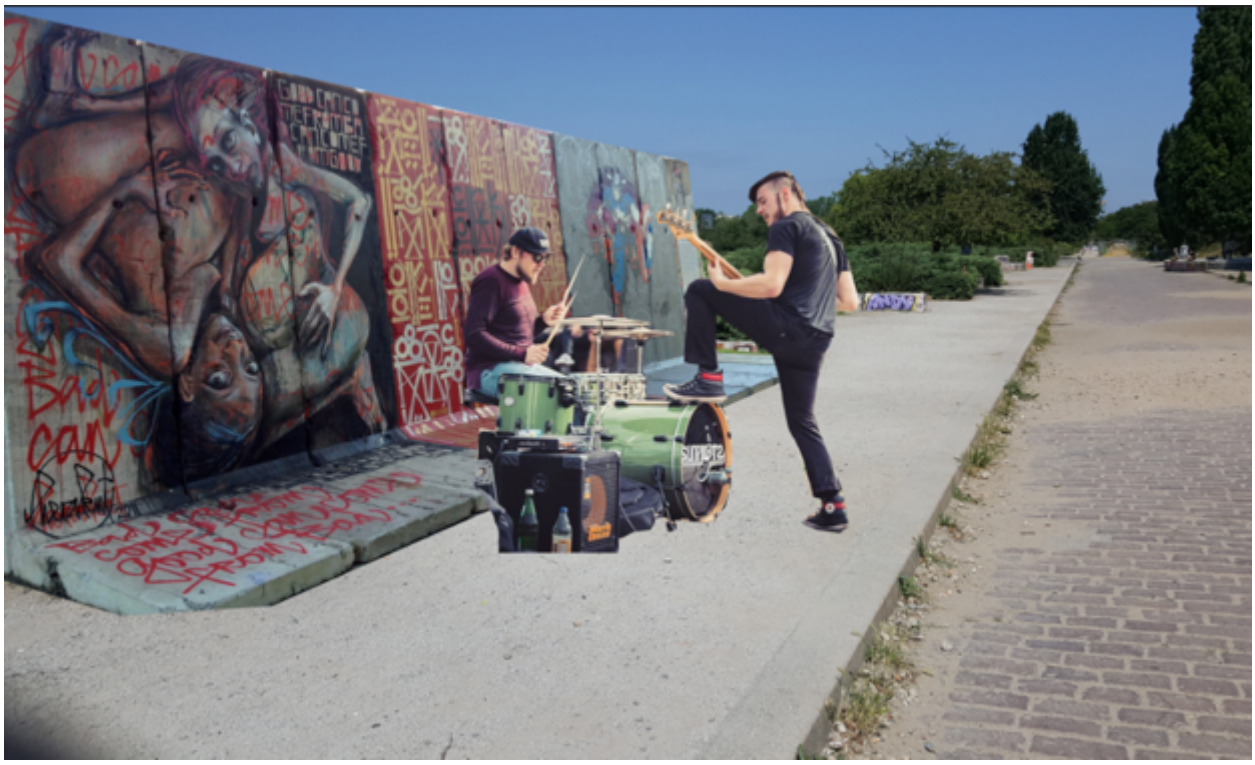

Figure 29 Visualisation of buskers playing in front of remains of the berlin wall as a sound barrier at Mauerpark.

The secondary use of the wall should continue to be public street art and graffiti, but short side walls could be added to focus the sound more towards the hill and away from other buskers, and increased the sound barriers multifunctional as a tennis or football wall during the weekdays because of the demanded sport and recreational options by the public according to Grün Berlin Stiftung's feasibility study.

The other sound barrier should also have a multifunctional sport use as a bouldering wall because it can have an overhang which will be more effective in reducing sounds than the Berlin Wall barrier while still allowing larger groups and dynamic performances on Sundays.

It should be placed between an acoustic shell and the basketball court to minimize the negative affect on other buskers because there will not be side walls on the bouldering wall.

Figure 30 Visualisation of shell and sound barrier along Schwedter street (Author, 2019).

c. Drum Pavilions

The drummers and drum circles at the atrium deserves special attention because they are well established and expected by the visitors. Two pavilions should be implemented in the atrium to reduce the noise from the established drumming buskers in the atrium. The pavilions will reduce the noise from the drums by reflecting some of the sound back to the source, but still enable visitors to view and dance around the drums from all angles.

One pavilion should be designed for drum kits and the other should be designed for drum circles to not limit the diversity of drumming buskers. The secondary use for the pavilions are shaded areas and protection from rain on weekdays.

Figure 31 Visualization of pavilion for drum kits (Author, 2019)

Figure 32 Visualization of pavilion for hand drums and drum circles (Author, 2019)

d. Rules

There is also a demand for additional park rules for the buskers at Mauerpark based on proposed busker rules from Berlin Street Music and the surveys.

The buskers who are using acoustic instruments without any form of amplification, except brass instruments and drums due to their natural loudness, should be allowed to play in the field which is zoned as a barbeque area because it will lower the amount of buskers inside the music zone on Sundays which will decrease the excessive amplification needed when buskers are playing at the same time, and because no neighbours identified acoustic guitars or vocals as a source of the noise affecting them in the survey. The loudness would also be limited by the instruments and human capacity.

There should be a rule regarding when to alternate the use of the noise abating structures if more than one busker wants to use them on Sunday to enable self-regulation between the buskers. The buskers should alternate between the physical measures every 30 minutes if there are other buskers expressing that they want to play because the 30 minute alternating is already established with some of the drumming buskers in the Atrium.

All the park rules should be communicated with signage at the park to increase conformity, and figure 33 shows a visualization of a large sign for the entrance of Mauerpark.

Figure 33 visualization of entrance sign for Mauerpark (Author, 2019)

e. Financing

The total development cost of noise abating structures and signage will not exceed 50,000EUR according to the authors calculations based on the known costs of the benchmarks (See appendix 11).

The cost of the noise abating structures and signage should be covered by the budget to upgrade the park because of the parks cultural status which depend on buskers in the park, and partially by the budget from the expansion of the adjacent sports arena as compensation because the construction will affect the park in a negative way.

This is feasible because Building Senator Andreas Geisel (SPD), Jens-Holger Kirchner from the Green party (Die Grünen), and Mittes District Mayor Christian Hanke (SPD) told the public that there would be areas and mini-stages indented to boost spontaneous culture in the park along the north-south axis.

12. Further research needed.

Testing and measuring the effect of Save Mauerpark's mobile proposal of wooden acoustic shells should be done to figure out the noise abating effect of the structure and locations, but also to see how the buskers reacts to them and how they are willing to use them.

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14. Appendix

a. Appendix 1

Survey questions for buskers:

- Where do you prefer to play at Mauerpark? / Wo spielen Sie am liebsten im Mauerpark?
- What genre is your music? (Simplified) / Zu welchem Genre gehört Ihre Musik? (Vereinfacht)
- Why do you choose to play at Mauerpark? / Warum spielen Sie im Mauerpark?
- Should there be specific areas or stages for music at the park? / Bevorzugen Sie im Park bestimmte Bereiche oder Bühnen für Musik?
- Do you consider the neighbors of the park when you play music? / Denken sie an die Nachbarn des Mauerparks, wenn sie Musik spielen?
- What rules should there be for performing music at Mauerpark? / Welche Regeln sollten für die Aufführung von Musik im Mauerpark gelten?
- What rules should be avoided for music at Mauerpark? / Welche Regeln sollten für Musik im Mauerpark vermieden werden?
- Have you had any bad experiences playing music at Mauerpark? / Haben Sie schlechte Erfahrungen mit dem Spielen von Musik im Mauerpark gehabt?
- Should the performance of music at Mauerpark be more organized? / Sollte die Aufführung von Musik im Mauerpark organisierter sein?
- Are you aware of the rules for playing music at Mauerpark? / Kennen Sie die Regeln zum Spielen von Musik im Mauerpark?
- What city are you from? (please add if not listed) / Aus welcher Stadt kommen Sie? (Bitte hinzufügen, wenn nicht aufgeführt)

- What is your age? / Was ist Ihr Alter?

Survey questions for Neighbours:

- Do you have a problem with the music and noise from the Mauerpark on Sundays? / Haben Sie Probleme mit der Musik und dem Lärm aus dem Mauerpark am Sonntag?
- What time of day is the noise the loudest? / Zu welcher Tageszeit ist der Lärm am lautesten?
- What noises are the most annoying from Mauerpark? / Welche Geräusche ärgern sie am meisten im Mauerpark?
- How do you want Mauerpark to be on a Sunday? / Wie soll der Mauerpark am Sonntag sein?
- Are there any rules you would suggest for the music at Mauerpark? / Gibt es irgendwelche Regeln, die Sie für die Musik im Mauerpark vorschlagen würden?
- What is your comment on the music from Sundays at Mauerpark? / Was ist Ihr Kommentar zu der Musik am Sonntag im Mauerpark?
- Which street do you live on? (For noise direction) / In welcher Straße wohnen Sie ? (Für Richtung der Geräusche)
- What floor do you live on? (noise affects differently depending on height) / In welchem Stock wohnen Sie? (Lärm wirkt sich zur Höhe unterschiedlich aus)
- What is your age? / Was ist Ihr Alter?
- What is your gender identity? / Was ist Ihre Geschlechtsidentität?

Survey questions for visitors:

- How many times did you visit Mauerpark on a Sunday last year between March and October? / Wie oft haben Sie Sonntags zwischen März und Oktober den Mauerpark besucht?
- How long do you stay when you visit Mauerpark on Sundays? / Wie lange bleiben Sie normalerweise, wenn Sie sonntags den Mauerpark besuchen?
- What time do you enter Mauerpark? / Wann betreten Sie den Mauerpark?

- What is the best part of visiting Mauerpark on a Sunday? / Was ist das Beste, an einem Besuch im Mauerpark am Sonntag?
- What is your opinion on having musicians performing in Mauerpark on Sundays? / Was halten Sie davon, wenn Musiker sonntags im Mauerpark auftreten?
- Should there be specific areas or stages for music at the park? / Bevorzugen Sie im Park bestimmte Bereiche oder Bühnen für Musik?
- Are you ever annoyed by the music in the park on Sundays? / Ärgern Sie sich über die Musik am Sonntag im Park?
- If yes, what bothers you about the music at Mauerpark? / Wenn ja, was stört sie speziell an der Musik im Mauerpark?
- Are there any rules you would suggest for the music at Mauerpark? / Gibt es irgendwelche Regeln, die Sie für die Musik im Mauerpark vorschlagen würden?
- What city are you from? (Please add if not listed) / Aus welcher Stadt kommen Sie? (Bitte hinzufügen, wenn nicht aufgeführt)
- What is your age? / Was ist Ihr Alter?
- What is your gender identity? / Was ist Ihre Geschlechtsidentität?

b. Appendix 2

i. Buskers

The survey for buskers were filled out 15 times by different artists and groups of musicians. They were mainly men between the age of 26 to 32, more than half were residents in Berlin, and the rest were from USA, Sweden, UK, and South Africa.

The main reasons for performing at Mauerpark on a Sunday were to have fun, to spread their music to more people, and to make money from busking.

Mauerpark was the preferred location for busking in Berlin because of the easy access to audiences and established culture.

When asked where they preferred to play, 4 out of 14 participants said they prefer to play in stone atrium, 3 out of 14 participants prefer to play at the entrance of the park, and 2 out of 14

participants prefer to play in the middle of the park and an equal amount preferring to play anywhere in the park.

5 out of 14 participants would categorize their music as rock (vocals, amplified guitar, amplified bass, and acoustic drums) and 3 out of 14 participants played acoustic guitar music (vocals, amplified acoustic guitar).

Other genres represented were jazz, world fusion, pop, rhythmic percussion, blues, and acapella.

The buskers were split between the demand for stages and/or dedicated areas for music in the park. 6 out of 14 participants wanted to play freely on the grass without any structures or dedicated music areas, while another 6 out of 14 participants wanted a mix of being able to play freely on the field and to play on small stages in designated areas.

Two buskers answered that they would rather play on stages because their music would sound better that way.

8 out of 14 participants claimed they consider the neighbours when they play music by lowering the volume and 6 out of 14 participants direct their music towards the hill. 4 out of 14 participants said they just play music, or that that they do not believe their music has ever been too loud.

When asked if performing music on Sundays at Mauerpark should be more organized 8 out of 14 participants stated no, 3 out of 14 participants said yes, and the remaining 3 out of 14 participants would like some organization if there are dedicated areas for music or the park is overwhelmed with performers.

Park rules suggested by the buskers were: to be mindful of the other musicians, noise level limits based on decibel measurements, a set time frame for music, and specific areas for music. The rules which should be avoided according to the musicians were: audition for performers, scheduled times for individual performers, ban of amplification, watt limitations on amplifiers, bans on specific instruments, and ban on receiving donations. 4 out of 14 participants did not want any rules at all.

When asked if they had any bad experiences with playing music at Mauerpark 11 out of 14 had their performance stopped by the police or a regulatory officer, 4 out of 14 participants had

experienced that visitors were not able to hear their music properly because other musicians were too loud, 3 out of 14 participants had experienced no problems.

ii. Visitors

The visitors are the people who arrive at Mauerpark on Sundays to enjoy their day. They are crucial to the park because if there were no visitors at the park there would be no audience for the music or other cultural events. The survey for visitors were filled out 31 times. Half were women, and the other was men. The ages of the visitors were very diverse. 11 out of 31 participants were between 26 and 32 years old, 7 out of 31 participants were between 18 to 25. The remaining 13 participants were between 33 to 60. The visitors at Mauerpark were a mix of residents of Berlin and tourists. 15 out of 31 participants were from Berlin. The remaining participants were international from Cape Town (South Africa), Aarhus (Denmark), Cairo (Egypt), Amman (Jordan), Oslo (Norway), Phnom Penh (Cambodia), and Grozny (Russia).
During last year's Mauerpark season, between March and October, 7 out of 31 participants visited the park less than one time per month, and another 7 out of 31 participants visited the park one time per month.
The remaining 17 out of 31 participants visited the park two times or more per month. They entered the park between 12:01 and 15:00 or 15:01 and 19:00, and 19 out of 31 participants stayed 3 hours at the park on each visit, 10 out of 31 participants stayed 4 hours or more. Live music was the best part of their visit according to 12 out of 31 participants.
7 out of 31 participants said relaxing in the park was their main reason, and 5 out of 31 participants said the flea market was their main reason for their visits. 30 out of 31 participants of the visitors said music was an important part of their visit to Mauerpark.
20 out of 31 participants would like to keep the buskers playing freely on the field, and 8 out of 31 participants would have the mix of buskers playing freely on the grass and on specific areas and/or stages.
The music in the park has annoyed 6 out of 31 of the participants because too many buskers have been playing at the same time or the drumming has been playing for too long. Suggestions for park rules were: segregated area for music, quiet zones, volume limit, only high quality music allowed, noise protection for residents, limit of performers playing at the same time, a

set distance between the artists, and that all artists should have the opportunity to perform. 10 out of 31 participants said they would not suggest any rules for playing music at Mauerpark on Sundays.

iii. Neighbours

Neighbours live in apartments which are affected by sounds and noises coming from Mauerpark on Sundays. The survey was filled out 18 times. 12 out of 18 participants in the survey were female. 8 out of 18 participants were between 41 and 50 years old. 6 out of 18 participants lived on Gleim street, 4 out of 18 participants on Wolliner street. The rest lived on Lortzing street, Pappellalle, Demminer street, Gleim street, Schwedter street, and Bernauer street.

15 out of 18 participants stated that they had no problem with the music and noise coming from Mauerpark on Sundays. The 3 out of 18 participants who stated they had a problem with the music and noise from the park lived on Wolliner street. They lived on the first, fourth and fifth floor. Only one person from Wolliner street had no problem with music and noise. That person lived on the 2nd floor. There were no significant complaints from the other streets.

All participants agreed that the noise was the loudest from 15:01 to 19:00. The most significant sources of noise from Mauerpark on Sundays were identified by the neighbours as: drums, music and yelling at night, amplifiers, applause, and bass. Vocals or guitars were options, but none of the participants identified these as annoying.

When asked how the neighbours would want Mauerpark to be on a Sunday 8 out of 18 answered that they want it like it is and spoke positively about the music, but the remaining 10 wanted it to be more quiet, have less drums, or less people.

5 out of 18 participants would not suggest any rules for Mauerpark, but the remaining 13 participants suggested these rules: No large events, no music after 20:00, no amplified music, acoustic shells for musicians, and no music at the entrance of the park. It was also suggested that several musicians should not play at the same time, and that some performers should not play the same songs several times each Sunday, each week, for several years. a noise calendar was also suggested to help the neighbours plan when they can have visitors without being disturbed by noise

c. Appendix 3

§ 47c noise maps

1. The competent authorities shall, by 30 June 2007, operate noise maps for agglomerations of more than 250 000 inhabitants as well as for major roads with a traffic volume of more than six million vehicles per year, main railway lines with a traffic volume of more than 60 000 trains in relation to the previous calendar year per year and major airports. The same applies until 30 June 2012 and every five years thereafter for all metropolitan areas as well as for all major roads and main railway lines.

(2) The noise maps shall comply with the minimum requirements set out in Annex IV to Directive 2002/49 / EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise (OJ EC No L 189, p and to provide the data to be transmitted to the Commission in accordance with Annex VI to Directive 2002/49/ EC.

2a. Public railway infrastructure undertakings shall make available to the authorities responsible for the preparation of noise maps the following data required for the development of noise maps free of charge: Data on the railway infrastructure and Data on the traffic of railways on railways.

3. The competent authorities shall cooperate with the competent authorities of other Member States of the European Union in the preparation of noise maps for border areas.

(4) The noise maps shall be reviewed at least every five years from the date of their preparation and revised as necessary.

(5) The competent authorities shall notify the Federal Ministry for the Environment, Nature Conservation, Construction and Nuclear Safety or a body designated by it by 30 June 2005 and every five years thereafter of agglomerations of more than 250 000 inhabitants, the major roads with a traffic volume of more than six Million motor vehicles per year, the main railway lines with a traffic volume of over 60,000 trains per year and the major airports with. The same applies to 31 December 2008 for all metropolitan areas as well as all major roads and main railway lines.

(6) The competent authorities shall inform the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety or a body designated by it of the noise maps referred to in § 47f of the Ordinance.

§ 47d noise action plans

(1) The competent authorities shall establish noise action plans by 18 July 2008 to address noise and noise effects

1. Places near major roads with a traffic volume of more than six million vehicles per year, the main railway lines with a volume of more than 60 000 trains per year and the major airports,

2. Metropolitan areas with more than 250,000 inhabitants.

The same applies until 18 July 2013 for all metropolitan areas and for all major roads and main railway lines. The definition of measures in the plans is left to the discretion of the competent authorities, but should also address, in particular, the priorities arising from the exceedance of relevant limit values or other criteria, taking into account the burden of several sources of noise important areas, as shown in the noise maps.

(2) The noise action plans shall comply with the minimum requirements of Annex V to Directive 2002/49 / EC and include the data to be transmitted to the Commission in accordance with Annex VI to Directive 2002/49 / EC. The aim of these plans is also to protect quiet areas against an increase in noise.

(2a) Public railway infrastructure undertakings are required to cooperate in drawing up noise action plans for places close to the main railway lines and for conurbations with railway traffic.

(3) The public is consulted on proposals for noise action plans. It will have the opportunity, in a timely and effective manner, to participate in the preparation and review of noise action plans. The results of participation are to be considered. The public is to be informed about the decisions taken. Proper time limits should be provided for, with sufficient time for each stage of participation.

(4) Section 47c (3) shall apply mutatis mutandis.

5. Noise action plans shall be reviewed in the event of significant developments in the noise situation, but otherwise every five years from the date of their establishment, and revised as necessary.

(6) Section 47 (3) sentence 2 and paragraph 6 shall apply accordingly.

(7) The competent authorities shall inform the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety or a body designated by it of the noise action plans referred to in § 47f of the Ordinance.

d. Appendix 4

i. Sonic Crystal Barrier

Sonic crystals barriers are an alternative to sound barriers because they allow more natural light and air flow through while obstructing less view and reflecting less noise back at the source. Sonic crystals barriers are several rows of poles (scatterers) of a specific geometrical shape placed a set distance from each other. They can be built by different materials like wood, concrete, or metal, and they can be resonant or hollow or a combination of both, (Fredianelli et al., 2019).

The barrier reduces sounds by scattering, reflecting, and absorbing specific frequencies of a sound. This technology is based on Bragg's law of coherent and incoherent scattering from a crystal lattice which is not explained in this thesis.

Figure 34 shows an example of sonic crystal barrier at Netherland's Eindhoven A2 highway created by Van Campen Industries.

Figure 34 sonic crystals barrier at Netherland's Eindhoven A2 highway created by Van Campen Industries (source: https://youtu.be/lzNWC0scPTY visited on July 30th 2019)

The main advantage of sonic crystals barriers is that they can target and reduce specific frequencies based on the shape of the scatterers and distance between them. The main disadvantage is that other frequencies can be amplified, (Peiró-Torresa et al., 2016).
Figure 35 shows how sonic crystals will only reduce the intensity of a specific frequency when the scatterers are angled correctly. When the scatterers are rotated 45-degrees the effect is gone for that specific frequency. The effect when the frequency is completely reduced is called a band gap.

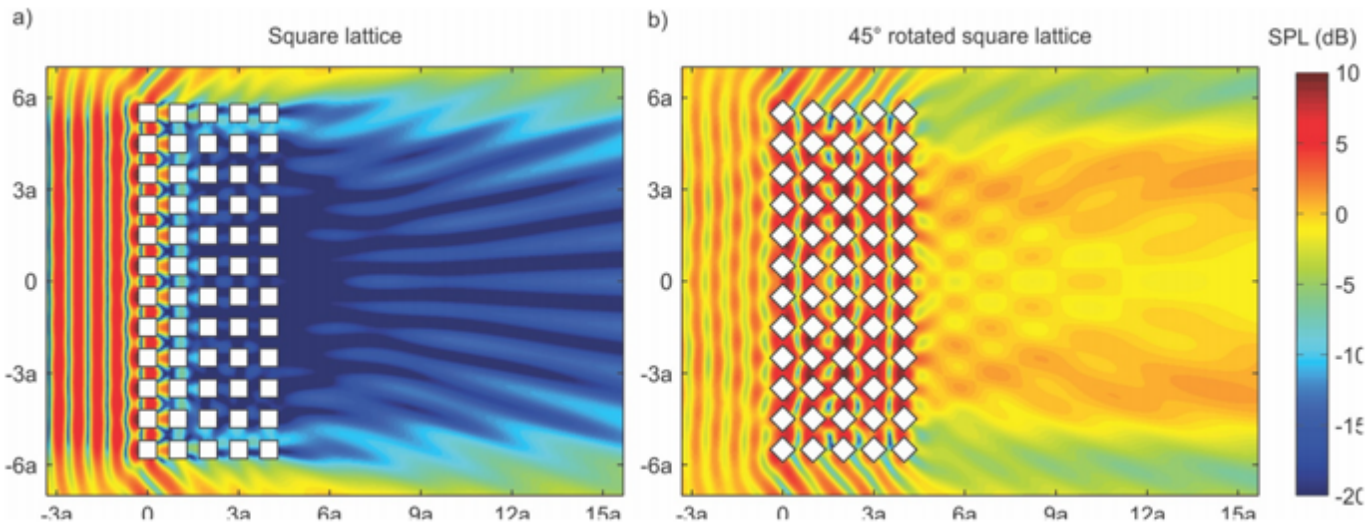

Figure 35 Birdseye view of the effect of rotating a free-field sonic crystal structures to create a band gap for a certain frequency (Albert et al. 2016).

Sonic crystals can also function as sculptures and art installations. In 1995, Eusebio Sempere exhibited a sculpture which is recognized as the first noise reducing sculpture. The sculpture had a perceived band-gap at 1,670Hz which signifies a strong attenuation of sound, (Martínez-Sala et al., 1995). The sculpture is shown below in figure 36.

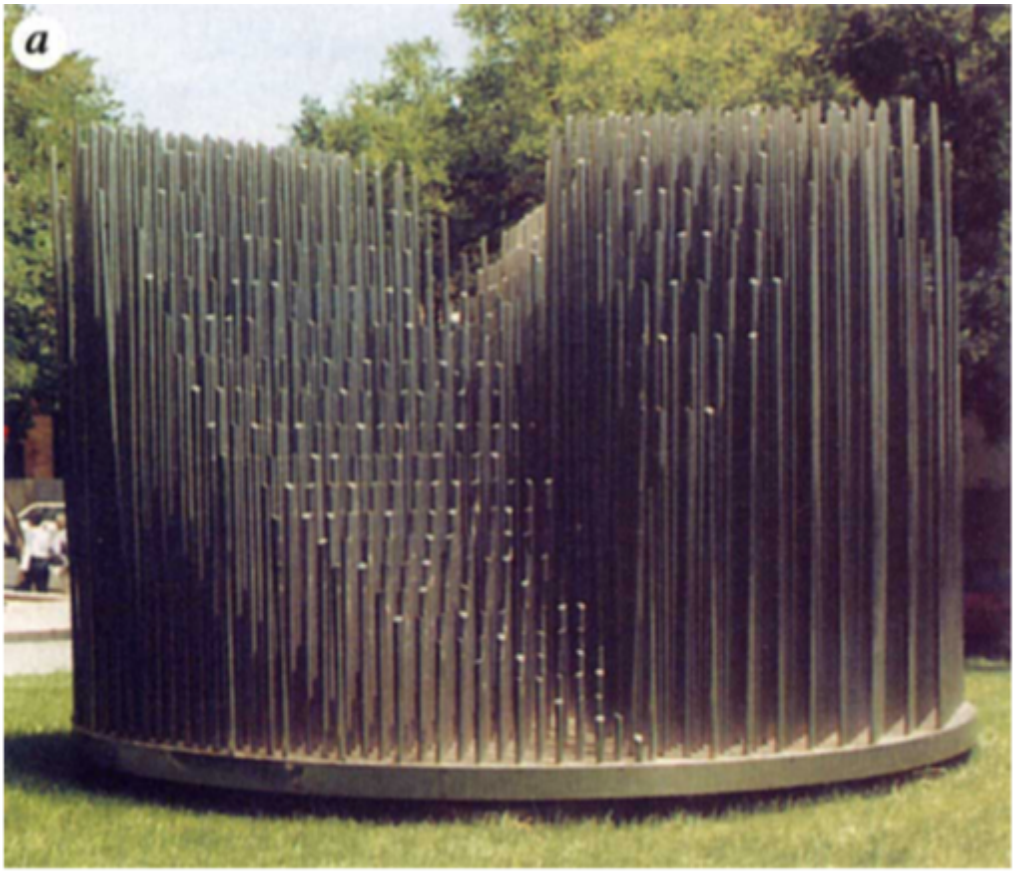

Figure 36 Eusebio Sempere's sonic crystal sculpture from 1995 (Martínez-Sala et al ,1995).

Based on Sempere's sculpture, Liminal (2011) created their sonic crystals sculpture named "Organ of Corti". The sculpture had a band gap at 1kHz. This sculpture was used as a passive instrument which altered natural sounds to create a new soundscape for people walking passed it, (Liminal, 2011).

Figure 37 Organ of Corti by Liminal (source: http://www.liminal.org.uk/portfolio/organ-of-corti/ visited on July 30th 2019)

Professor Keith Attenborough, who assisted the Organ of Corti-project, told the author in an email that sonic crystals formed by a simple array of vertical cylinders offer a very frequency-dependent sound reduction which would not be very noticeable on live music, but he told the author about Oscar Edelstein and Manuel Eguia's Sonic Crystal Room-project from 2015. This project utilized complex sonic crystals structures to change the experience of listening to music by reducing different frequencies. The sonic crystals used in this project were several arrays of different geometrical shaped scatterers which could rotate resulting in a more dynamic band gap which could alter the perceived volume of the different instruments and the perceived direction the sound was coming from, (Albert et al. 2016).

Figure 38 screenshot from Manuel Eguia's film "Sonic Crystal Room - A prototype" (Eguia, 2015).

Fredianelli et al. (2019) compiled all the recent development in sonic crystals research which shows that noise reduction from sonic crystals are most efficient on a spectrum from 250Hz to 2,000Hz based on the different distances between the poles, diameter of the poles and the materials (See figure 39). This information can be used when figuring out what the aspects are needed to abate certain frequencies with a sonic crystal barrier.

ii. Further research needed for sonic crystals and music.

Further research is needed on the field of abating noise from outdoor musical sources, especially the noise abating effect of sonic crystals barriers on fundamental frequencies from musical instruments.

Manuel Eguia (2015) made it clear that sonic crystals structures have a significant effect on music and that it can alter how the listeners experiences the music based on where the listeners standing, but it is unclear how this would work when the goal is reduce the overall loudness of sounds from several instruments at the same time.

This would likely function best on instruments with a short frequency range which is more focused around the fundamental frequency, for example vocals, brass or woodwind.

According to Fredianelli et al.(2019), the scatterers should be made of aluminium, hollow, but filled with Rockwool, rectangular shaped with five centimetre long sides, and spaced eight centimetres apart to be the most effective between 250Hz to 2000Hz, (see figure 39).

A sonic crystal sculpture would be a great addition to Mauerpark to enable buskers to play with the effects of the crystal, reduce specific frequencies of sounds, and function as a cultural addition to the park which makes sense with the parks new cultural status.

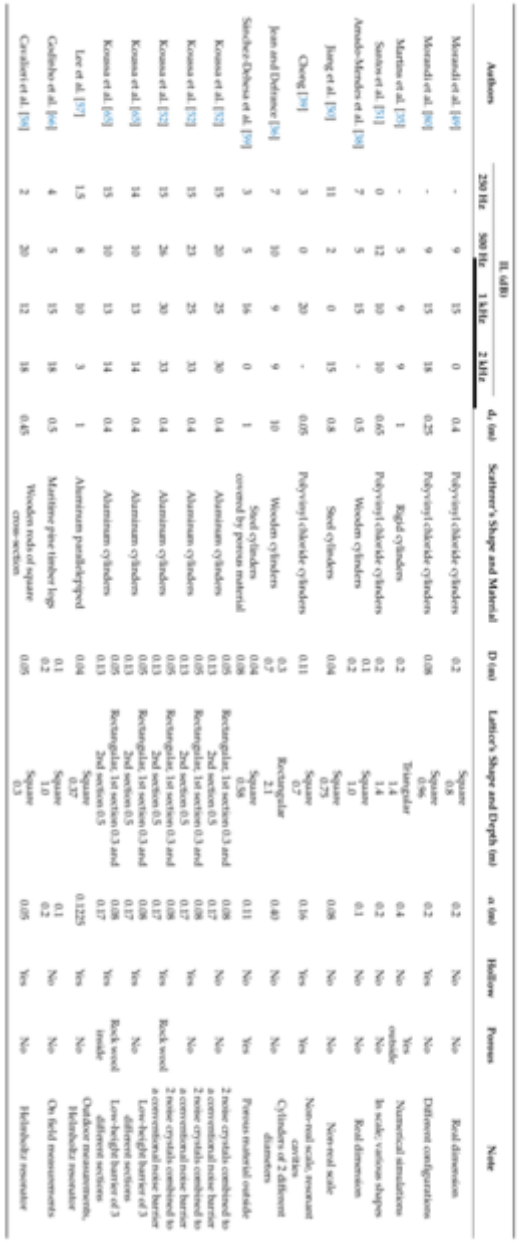

Table 1. Comparative analysis of insertion loss (IL) obtained in different studies. d_f is the distance of IL evaluation from the barrier, D is the scatterer diameter (or side), and a is the lattice constant.

Authors	IL (dB)				d_f (m)	Scatterer's Shape and Material	D (m)	Lattice's Shape and Depth (m)	a (m)	Hollow	Porous	Note
	250 Hz	500 Hz	1 kHz	2 kHz								
Morandi et al. [49]	-	9	15	0	0.4	Polyvinyl chloride cylinders	0.2	Square 0.8	0.2	No	No	Real dimension
Morandi et al. [80]	-	9	15	18	0.25	Polyvinyl chloride cylinders	0.08	Square 0.96	0.2	Yes	No	Different configurations
Martins et al. [35]	-	5	9	9	1	Rigid cylinders	0.2	Triangular 1.4	0.4	No	Yes, outside	Numerical simulations
Santos et al. [51]	0	12	10	10	0.65	Polyvinyl chloride cylinders	0.2	Square 1.4	0.2	No	No	In scale; various shapes
Amado-Mendes et al. [36]	7	5	15	-	0.5	Wooden cylinders	0.1 0.2	Square 1.0	0.1	No	No	Real dimension
Jiang et al. [30]	11	2	0	15	0.8	Steel cylinders	0.04	Square 0.75	0.08	No	No	Non-real scale
Cheng [39]	3	0	20	-	0.05	Polyvinyl chloride cylinders	0.11	Square 0.7	0.16	Yes	Yes	Non-real scale; resonant cavities
Jean and Defrance [84]	7	10	9	9	10	Wooden cylinders	0.3 0.7	Rectangular 2.1	0.40	No	No	Cylinders of 2 different diameters
Sánchez-Dehesa et al. [39]	3	5	16	0	1	Steel cylinders covered by porous material	0.04 0.08	Square 0.56	0.11	No	Yes	Porous material; outside
Kotsonis et al. [52]	15	20	25	30	0.4	Aluminum cylinders	0.05 0.13	Rectangular, 1st section 0.3 and 2nd section 0.5	0.08 0.17	No	No	2 noise crystals combined to a noise crystal; noise barrier
Kotsonis et al. [52]	15	23	25	33	0.4	Aluminum cylinders	0.05 0.13	Rectangular, 1st section 0.3 and 2nd section 0.5	0.08 0.17	No	No	2 noise crystals combined to a noise crystal; noise barrier
Kotsonis et al. [52]	15	26	30	33	0.4	Aluminum cylinders	0.05 0.13	Rectangular, 1st section 0.3 and 2nd section 0.5	0.08 0.17	Yes	Rock wool inside	2 noise crystals combined to a noise crystal; noise barrier
Kotsonis et al. [65]	14	10	13	14	0.4	Aluminum cylinders	0.05 0.13	Rectangular, 1st section 0.3 and 2nd section 0.5	0.08 0.17	Yes	No	Low-height barrier of 3 different sections
Kotsonis et al. [65]	15	10	13	14	0.4	Aluminum cylinders	0.05 0.13	Rectangular, 1st section 0.3 and 2nd section 0.5	0.08 0.17	Yes	Rock wool inside	Low-height barrier of 3 different sections
Lee et al. [37]	1.5	8	10	3	1	Aluminum parallelepiped	0.04	Square 0.37	0.1225	Yes	No	Outdoor measurements; Helmholtz resonator
Golubev et al. [64]	4	5	15	16	0.5	Maritime pine timber logs	0.1 0.2	Square 1.0	0.1 0.2	No	No	On-field measurements
Cavalieri et al. [56]	2	20	12	16	0.45	Wooden rods of square cross-section	0.05	Square 0.3	0.05	Yes	No	Helmholtz resonator

Figure 39 Table of sonic crystal structures and the effect on different frequencies, (Fredianelli et al.,2019)

iii. Noise Reducing Landscape

Landscaping can be an effective measure to reduce low frequency noise by dispersing the sound. Implementing rows of ridges designed to match the distance between the soundwaves of a specific low-frequency sound source can disperse the sound waves and reduce overall noise, shown in figure 40 below.

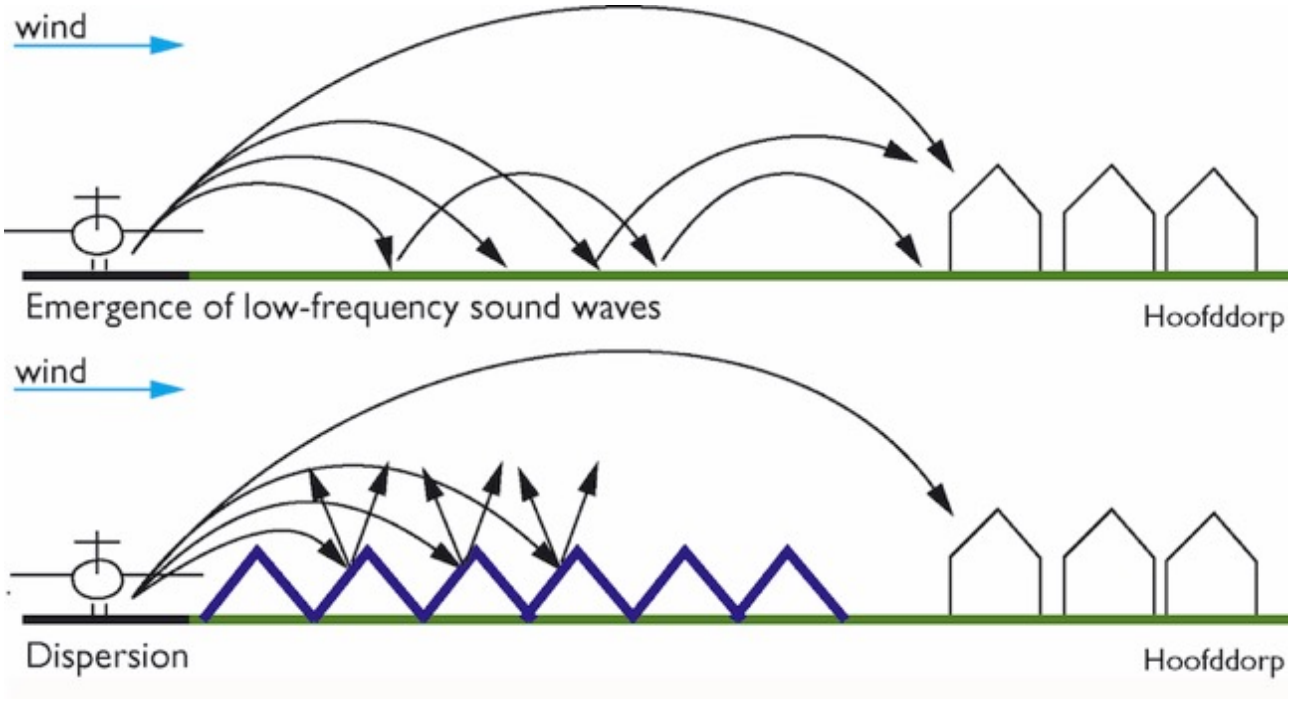

Figure 40 how the design of the park abate the noise from the airport (source: http://www.hnsland.nl/en/projects/land-art-park-buitenschot visited on July 31st 2019)

This technique was implemented next to Schiphol Airport in the Netherlands after the staff discovered that they received less noise complaints in fall because farmers were creating rows of ridges when ploughing their fields for the season, which unintentionally had a noise abating effect, (Hansman, 2015).

This discovery led to the development of the Buitenschot Land Art Park which features 150 artificial pyramids of grass. The pyramids are 1.82 meters tall and spaced eleven meters apart based on the wavelength of the airport noise. This method reduced the noise pollution in the

region by half, (Ibid.). The design was done by H+N+S Landscape Architects and artist Paul De Kort, and the park is shown in figure 41 below.

Figure 41 Buitenschot Land art Park, (Hansman, 2015).

iv. Masking

Unpleasant noise can be masked by other more pleasant sounds. Public parks with noise issues can use speakers playing calming sounds to mask the noise from traffic and other sources or structures which can amplify pleasant ambient sounds to mask the unpleasant noise. Buitenschot Land Art Park (See figure 41) features a sculpture that amplifies the ambient sounds to mask the remaining noise, (Hansman, 2015).

Figure 42 sculpture at Buitenschot park intented to amplify pleasant ambient sounds to mask noise from airport. (source: https://urbanidentity.info/projects/hoofddorp_landartpark_buitenschot/ visited August 3rd, 2019)

Nauener platz, an urban park exposed to traffic noise in Berlin, have implemented seated structures with speakers playing pleasant sounds to mask the noise. A research article by Brigitte Schulte-Fortkamp and Pamela Jordan (2016) measured the effect of a bench with sound reflective side panels with speakers playing calming music and a ring seats with sound playback. The measures were effective to create calm zones for visitors.

Figure 43 bench with side panels and activated sound playback, (Schulte-Fortkamp and Jordan, 2016).

Figure 44 Ring seats with activated sound playback, (Schulte-Fortkamp and Jordan, 2016).

v. Sound reduction at the receiver.

Noise can also be reduced at the receiver's end because the different materials used in construction of walls and facades of apartment buildings and houses can reduce a wide range of different frequencies of noise from entering the living spaces. The noise abating effect of these materials are shown in table 7 below.

Table 7 Sound absorbing coefficient of sound reducing materials like window glass and heavy drapery, (Kindig, 2019).

Absorption of Reflected Sound at Various Frequencies						
Material	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**	**4 kHz**
Brick	3%	3%	3%	4%	5%	7%
Carpet *(on concrete w/foam rubber pad)*	8%	24%	57%	69%	71%	73%
Drapes *(heavy velour)*	14%	35%	55%	72%	70%	65%
Drywall *(1/2" on 2x4s)*	29%	10%	5%	4%	7%	9%
Linoleum *(on concrete)*	2%	3%	3%	3%	3%	2%
Paneling *(3/8" on 2x4s)*	28%	22%	17%	9%	10%	11%
Plaster *(rough finish, over lath)*	14%	10%	6%	5%	4%	9%
Window Glass	35%	25%	18%	12%	7%	4%
Wood	15%	11%	10%	7%	7%	4%

The table shows the combination of window glass and heavy velour drapery is very successful because window glass absorbs the lower frequencies between 125Hz to 500Hz while heavy velour drapery is very effective in absorbing frequencies between 500Hz to 2000Hz which the glass would only reflect, (Kindig, 2019).

Ridphonic is a company which sells 245 centimeter (cm) x 135 cm sound reducing curtains in Germany for 189EUR via Amazon. They promise to reduce up to 15 dB of noise, (Amazon, 2019).

The main issues with sound reducing curtains are that they need to be very thick, heavy, and not visually transparent to have an effect, but Swiss researchers at EMPA have developed a thinner, lightweight, and translucent curtain shown in figure 45 which absorbs up to five times more sound than normal curtains to fill this market gap, (Peter, 2011). These drapes cost from

64 EUR to 110EUR per linear yard in 2013 and were available at Wolf Gordon in USA, (Forbes, 2013).

Figure 45 sound reducing curtains, (Peter, 2011).

Greenery can also be implemented on the facades, balconies, or roofs of buildings to reduce the amount of noise which will get inside of the building. Greenery absorbs mainly the high frequency wavelengths of noise, but when constructed with a substrate or a growing support it can absorb low frequencies as well.

Davis et al. (2016) conducted a measurement of the effect of a ten-square meter green facade which showed that frequencies between 250Hz and 3150Hz had an absorption coefficient of 1 with the total span of 100Hz to 5000Hz.

Figure 46 example of a green facade (source: http://www.nerolacarchedge.com/green-facades/ visited on july 31st 2019)

Azkorra et al. (2015) found that modular green facades were most efficient in absorbing noises from human voice frequencies around 60dB, and that green walls on buildings were better noise absorbents than other common building materials except for 25mm thick fiberglass, shown in figure 47 below.

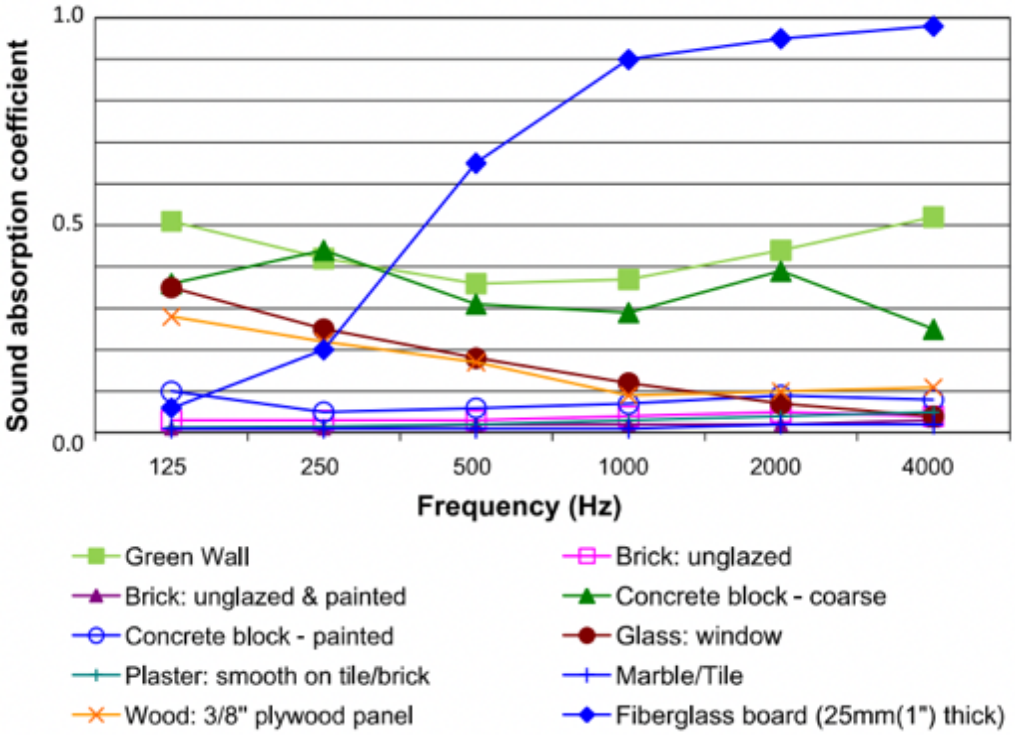

Figure 47 graph showing green facade (green wall) compared with other common building materials, (Azkorra et al., 2015)

The cost of for covering one square meter with a green facade is 254EUR in a hot climate according to Haggag and Hassan (2015) and 315EUR in Italy according to Perini and Rosasco (2013).

A green system can also be placed on the roof of a building to reduce the general noise levels of the building. Yang, Kang, and Choi (2011) found that substrate made of 60 percent limestone (<3.35 mm particle size), 20 percent loam and 20 percent organic matter is as effective as the commercial available Zinco roof garden substrate when researching the acoustic effects of green roof systems.

Green systems can be effective if installed on balconies of apartments, because balconies create a reverberation of the noise which can reinforce the perceived intensity of the noise, (Milne, 2013).

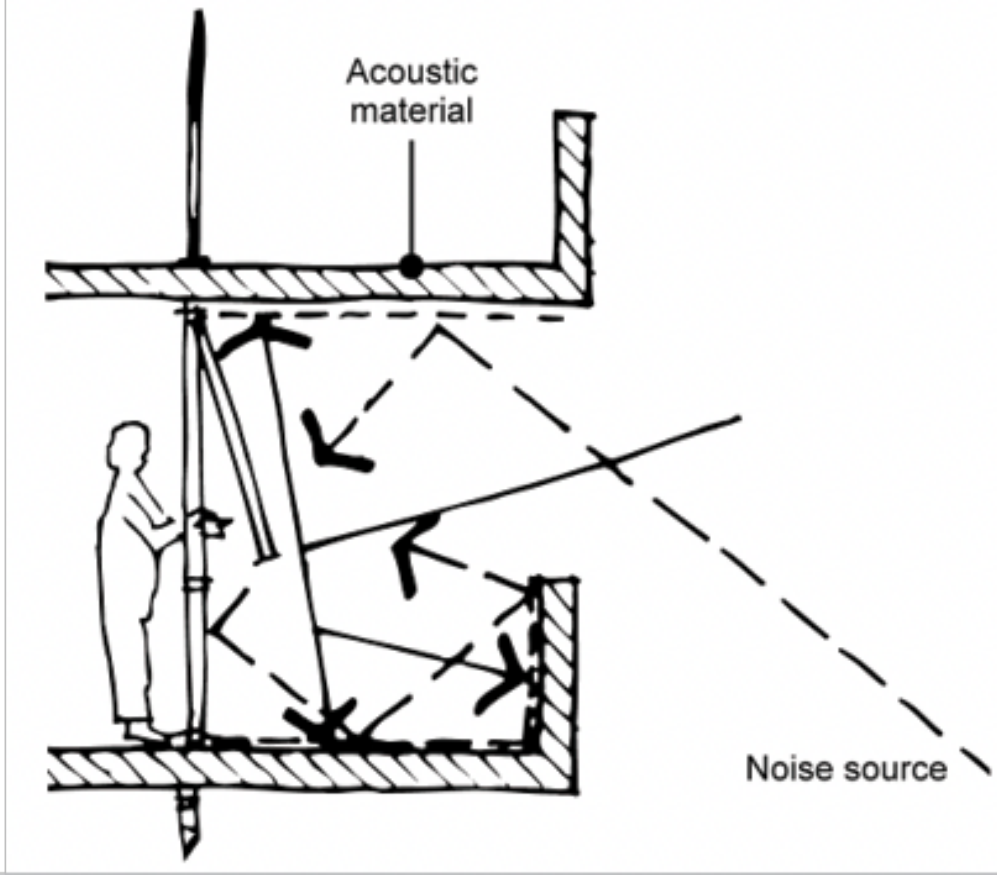

Figure 48 noise reverberation in a balcony and how acoustic materials like a green system can reduce the effect, (Milne, 2013).

The most affected apartment buildings on Wolliner street should be able to receive sound reducing measures from the government if they are able to prove that there is health damaging noise in their apartment originating from Mauerpark. The neighbours can qualify if they are able to get third party measurements or expert opinions proving exposure to health damaging noise pollution or loud noises over 82 dB for extended periods of time.
The recommended measures to affected apartments are sound reducing drapery for the apartments with windows facing the park because of the low cost or green systems on the roof and walls of the balconies facing the park to enable the use of the balcony.

vi. Additional sources for appendix 4

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e. Appendix 5

§ 5 BauGB of the Federal Building Code (Baugesetzbuch, BauGB). Section 5 The Content of the Preparatory Land-Use Plan

(1) The preparatory land-use plan shall represent in basic form the type of land uses arising for the entire municipal territory in accordance with the intended urban development which is proposed to correspond to the anticipated needs of the municipality. The preparatory land-use plan may exclude spaces and representations of other kinds, provided that the basic intention to be represented in accordance with sentence 1 is not affected, and the municipality intends to produce this representation at some later date; the grounds for this exclusion are to be included in the explanatory report.

(2) The preparatory land-use plan may in particular show:

1. the areas designated for development according to general land-use types (general land-use areas [Bauflächen]), according to specific land-use types [Baugebiete] and according to the

general level of built development; building land for which no central sewerage provisions have been made should be marked;

2. the existence within the municipal area of facilities and infrastructure for public and private provision of goods and services, in particular buildings and amenities serving the community and institutions for public needs, and in addition schools and churches and any other buildings or amenities which serve church-related, social, health-care and cultural purposes, and sports areas and playgrounds;

3. spaces for supra-local transport and the main local communications routes;

4. spaces for public utility use, for waste and sewage disposal, for tipping and for mains water supply and main sewers;

5. green spaces, such as parks, allotment gardens, sports grounds, playgrounds, campsites and bathing areas, cemeteries;

6. spaces to which use restrictions apply, or for protective measures against harmful environmental effects within the meaning of the Federal Control of Pollution Act [Bundes-Immissionsschutzgesetz];

7. water bodies, docks and areas of water designated for supply and distribution purposes, and spaces to be kept clear in the interests of flood control and to control drainage;

8. spaces for earth deposits, excavation and for quarrying for stone, earth and other minerals;

9. a) agricultural land and b) woodland;

10. spaces for measures for the protection, preservation and development of topsoil, of the natural environment and of the landscape.

(2a) Spaces for counterbalancing measures within the meaning of Section 1a para. 3 within the territory covered by a preparatory land-use plan may be assigned either wholly or in part to those areas in which intrusion harmful to nature and to the landscape is to be expected.

(3) The preparatory land-use plan shall mark:

1. spaces which, when built upon, will require special physical provisions to counter external forces, or for which special physical safeguarding measures are required as protection against the elements;

2. spaces which have mining below the surface, or which have been designated for the extraction of minerals;

3. spaces designated for building where the ground has been severely contaminated by hazardous materials.

(4) Any plans or other arrangements for use which have been determined under other statutory provisions, and any assemblies of physical structures protected as monuments under federal state law [Landesrecht] are to be included as a matter of course. Where designations of this kind are in prospect, these shall be noted in the preparatory land-use plan.

(5) The preparatory land-use plan shall be accompanied by an explanatory statement.

f. Appendix 6

The first recorded use of the Mauerpark area was as a parade ground for the Prussian army from 1825. The area was later converted to a freight yard in 1878. The freight yard was closed after the second world war. The Mauerpark area was then used as an industrial park until the construction of the Berlin Wall in 1961. The eastern part of the Mauerpark area was used as a heavily guarded death strip during the years of the Berlin Wall. The western part was converted into a commercial area, (Mauerpark Redaktion, 2019a).

Figure 49 Death strip at Mauerpark (Photo: https://www.mauerpark.info/geschichte/todesstreifen Visited on 30th of July 2019.)

After the fall of Berlin wall in 1989, city planners wanted to use the Mauerpark area as a highway ramp for the northbound ring road, but the neighbours of the park managed to

convince decision makers to upgrade the area to a park as part of the post-reunification project were former border areas became recreational public spaces, (Mauerpark Redaktion, 2019b).
A design competition was hosted for the park. Landscape architect Gustav Lange won the competition and designed the park in 1993. The original design included an eastern and western side of the park. The initial financing for the park came from city of Berlin, The Allianz Environmental Foundation (Allianz Umweltstiftung), and German railways (Deutsche Bahn AG). The park was opened on November 9th 1994, but only the eastern half was completed because the funding was not enough to cover the entire development.
The process of developing the seven hectares on the western side of the park began in 2012 when the city council made a deal with CA Immo Germany (former Vivico) which owned the remaining western areas of the park at that time. The land owner was allowed to build seven-hundred apartments north of the tunnel on Gleim Street on a 3.5-hectare area in return for donating seven hectares to the park, (Puell, 2012).
Approval and funding for the western expansion of Mauerpark came in the summer of 2016 from the city council, with support of the social democratic political party SPD and Grün Berlin Stiftung, (Loy, 2016). The master plan for the western part of the park was developed with landscape architect Gustav Lange, who had the original design in 1993, and BBS landscape engineering in 2018.
The state budgeted six million euros for the expansion. The completion of the park is set to be in 2020, (BBS Landscape Engineering, 2019).

i. Additional sources for appendix 6

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g. Appendix 7

LImSchG Bln:

4.1 Immission standards "outside"

The Immissionsrichtwerte "outside" amount for immission places outside of buildings

a) in industrial areas outside the rest period 70 dB (A) on weekdays and on Sundays and public holidays within the rest period 70 dB (A) at night 70 dB (A)

b) in industrial areas outside the rest period 65 dB (A) on weekdays and on Sundays and public holidays within the rest period 60 dB (A) at night 50 dB (A)

c) in core areas, village areas and mixed areas outside the rest period 60 dB (A) on weekdays and on Sundays and public holidays within the rest period 55 dB (A) at night 45 dB (A)

d) in general residential areas and small settlement areas outside the rest period 55 dB (A) on weekdays and on Sundays and public holidays within the rest period 50 dB (A) 40 dB at night (A)

e) in pure residential areas outside the rest period 50 dB (A) on weekdays and on Sundays and public holidays within the rest period 45 dB (A) at night 35 dB (A)

f) in spa areas, for hospitals and nursing homes outside the rest period 45 dB (A) on weekdays and on Sundays and public holidays within the rest period 45 dB (A) at night 35 dB (A).

h. Appendix 8

Special permit for Bear pit Karaoke at Mauerpark. Translation via google translate was not possible because the Author could only find picture of the legal text in German which are available at:

Beabsichtigte Nebenbestimmungen für eine Genehmigung nach § 11 Landes-Immissionsschutzgesetz Berlin- LImSchG Bln

Vorhaben:	Karaoke-Veranstaltung 2019
Zulassungszeitraum:	**26 Sonntage,** in Übereinstimmung mit der Genehmigung des Straßen- und Grünflächenamtes Pankow 14.04., 21.04., 28.04., 05.05., 12.05., 19.05., 26.05., 02.06., 16.06., 23.06., 30.06., 14.07., 21.07., 28.07., 04.08., 11.08., 18.08., 25.08., 01.09., 08.09., 15.09., 22.09., 29.09., 06.10., 13.10., 20.10.2019
Uhrzeit:	15:00- 19.00 Uhr , ggf. früheres Ende im Frühjahr und Herbst bei Sonnenuntergang
Veranstaltungsort:	Amphitheater im Mauerpark in 10437 Berlin

II. Nebenbestimmungen

allgemeines

1. Die Genehmigung wird unbeschadet Rechte Dritter erteilt und ist nicht übertragbar. Sie ersetzt nicht ggf. andere erforderliche Erlaubnisse/ Genehmigungen der hierfür zuständigen Behörden.

2. Am Veranstaltungsort hat während der Karaoke-Veranstaltungen ständig ein Beauftragter anwesend zu sein, der für die Einhaltung der Nebenbestimmungen verantwortlich ist und auftretende vermeidbare Ruhestörungen sofort abstellen kann.

   Verantwortlicher: Herr Gareth Lennon Tel.: 0157/ 80656279

3. Die Genehmigung ist am Veranstaltungsort aufzubewahren.

4. Die Anwohner*innen des Mauerparks sind in geeigneter Form (z.B. Wurfzettel, Info-Briefe) **einmalig** über die Veranstaltungen zu unterrichten und um Verständnis zu bitten. Der Verantwortliche ist namentlich und mit Telefonnummer zu benennen. Die Anwohnerinformation muss folgende Adressen erreichen:

   Graunstr. 1-9, 13355 Berlin
   Wolliner Str. 25-33, 13355 Berlin und Nr.20, 10435 Berlin
   Bernauer Str. 45 und 50, 10435 Berlin
   Kremmener Str. 1-8, 10435 Berlin
   Schwedter Str. 51 und 224, 10435 Berlin
   Oderberger Str. 27-39 und 32-35, 10435 Berlin
   Eberswalder Str. 1-9, 10437 Berlin

5. Beschwerden, die von einschreitenden Polizeibeamten oder zuständigen Behördenbediensteten nach pflichtgemäßem Ermessen als berechtigt anerkannt werden, sind unverzüglich abzuhelfen, ggf. ist die Veranstaltung abzubrechen.

6. Jede Änderung der genehmigten Veranstaltung sowohl zeitlicher als auch inhaltlicher Art, ist dem Umwelt- und Naturschutzamt sofort anzuzeigen und bedarf der Bestätigung.

7. Die nachträgliche Aufnahme bzw. die Änderung oder Ergänzung einer oder mehrerer der im Bescheid enthaltenen Auflagen bleibt nach § 36 Abs. 2 Nr. 5 Verwaltungsverfahrensgesetz- VwVfG* vorbehalten.

veranstaltungsspezifisch

8. Von Musikdarbietungen und Lautsprecherdurchsagen bzw. von anderen Schallquellen emittierter Lärm ist in Lautstärke und Umfang auf das für die Veranstaltung unbedingt notwendige Maß zu reduzieren.

9. Der Antragsteller hat sicherzustellen, dass die Nebenbestimmungen von den jeweiligen Auftretenden eingehalten werden.

10. Zum Schutz der Anwohner*innen vor unzumutbaren Belästigungen ist die Beschallungsanlage nur während des genehmigten Veranstaltungszeitraumes (max. 15.00 Uhr bis 19.00 Uhr) einzusetzen.

11. Die beiden Lautsprecher sind in Richtung Publikum/ Stadion auszurichten.

12. Es darf nur die beantragte Musikanlage der Fa. Klara Geist Berlin, Gerätenummer PROTRANS1, mit eingebautem Verstärker (2x 150 Watt) zum Einsatz kommen.

13. Folgender maximaler Immissionsrichtwert ist während der gesamten Veranstaltungsdauer am maßgeblichen Immissionsort: **Wolliner Str. 33** einzuhalten: **60 dB(A)**.

    Bei der Beurteilung des Lärmpegels ist zu berücksichtigen, dass die Publikumsgeräusche in die Betrachtung mit einfließen, da diese den Gesamtpegel nicht unerheblich beeinflussen.

14. Hup- und Hornsignale, die nicht der unmittelbaren Gefahrenabwehr dienen, sind verboten.

i. Appendix 9

§ 3, 4, and 5 of State Emission Control Act of Berlin. Translated using Google translate

§ 3 Protection of the night's sleep

From 22.00 to 06.00 o'clock it is forbidden to cause noise, which disturbs somebody in his night's sleep.

§ 4 Protection of Sunday and holiday rest

On Sundays and public holidays, it is forbidden to cause noise that disturbs someone in their peace significantly.

§ 5 Sound reproduction devices and musical instruments

Sound reproduction devices and musical instruments must not be used at a volume that seriously disturbs anyone. Further restrictions according to §§ 3 and 4 precede.

j. Appendix 10

§ 6 and 7 of the Green Building Act. Translated using Google translate

§ 6 Use of the facilities

(1) Public green and recreational facilities may only be used as they are from nature
the individual plant and its purpose. The use must be gentle, so
that planting and equipment is not damaged, soiled or otherwise impaired
and other system visitors are not endangered or unreasonably disturbed. In particular, it is forbidden:

1. to cause noise that unreasonably disturbs other system visitors,
2. to use spinning, throwing or shooting equipment,
3. Dogs, with the exception of guide dogs and handicapped dogs, or other pets free
to run or to take on children's, ball courts and lawns or to bathe in waters,
4. to light or entertain fire,
5. drive public greenery and recreational facilities by motor vehicle, except ambulance chairs, or park them or trailers there.

(2) Activities such as cycling, skateboarding, ball games, swimming, boating, horseback riding and barbecuing are
only permitted on specially designated areas. The districts are required to land
for appropriate uses to an appropriate extent, as far as this is possible taking into account city planning and urban design matters, taking into account the different user claims and including the health and environmental protection.

(3) Dog owners and leaders must ensure that their dogs are the public green and
Do not contaminate recreational facilities. You have to clear the faeces of their dogs immediately. This
does not apply to blind dog handlers.
(4) The district administration may set restrictions on certain types of use and opening hours for installations or parts of installations and regulate their use by means of bids or prohibitions.
(5) The use of public green and recreational facilities, which goes beyond paragraph 1, requires the approval of the competent authority. The approval may be granted on a case by case basis the overwhelming public interest so requires and the remedying of the consequences is ensured. In the
Decision is to take into account whether other sites have less impact on the plant
have as a consequence. The permit may be subject to conditions; a low-waste implementation must be ensured. In particular, the removal of consequences is deemed to be ensured if the applicant deposited with the approval authority money in the amount of the expected costs or one Bank guarantee. Fees may be charged for use. In the design should the economic benefit of use is taken into account.
(6) The competent authority within the meaning of paragraph 5 is the district office. For permits of overall urban significance within the meaning of § 3 (1) of the General Jurisdiction Act of 22 July In 1996 (GVBl., Pp. 302, 472), the responsible authority is the senate administration responsible for the green area.

§ 7 Offenses

(1) Offenders acting intentionally or negligently without permission
1. contrary to § 6 para. 1 sentence 2 planting or equipment damaged, soiled or
otherwise impaired or endangers or unreasonably disturbs other system visitors,
2. contrary to § 6 (1) sentence 3 no. 1 causes noise that unreasonably disturbs other system visitors,
3. contrary to § 6 (1) sentence 3 no. 2 uses slingshot, throwing or shooting equipment,
4. contrary to § 6 (1) sentence 3 no. 3 dogs or other pets are allowed to run free, on children,

Take ball courts or lawns or bathe in waters,

5. ignites or maintains fire contrary to § 6 (1) sentence 3 no.

6. contrary to § 6 (1) sentence 3 (5), public green and recreational facilities with motor vehicles, except ambulance chairs, drive or park these or trailers there,

7. contrary to § 6 Abs. 2 outside the specially designated areas cycling, skateboarding, playing ball, bathes, boat rides, riding or grilling.

Whoever intentionally or negligently acts contrary to § 6 (3) sentence 2 also acts as an offense not removed immediately.

(2) Offenders acting intentionally or negligently without permission shall also act

Green and recreational facilities beyond the regulations in § 6 paragraph 1 also used, if not already constitutes an administrative offense within the meaning of subsection (1) sentence 1.

(3) The administrative offense may be punished by a fine of up to € 5,000.

(4) The competent administrative authority within the meaning of Section 36 (1) (1) of the Law on Administrative Offenses is the district office.

k. Appendix 11

Table 8 Cost estimation of noise abating structures

Type	Price	Parameter	Cost	Price Sources
Cost of two acoustic shells	€ 2,000.00	two shells	€ 4,000.00	conversation with Aviv Evan
Climbing wall sound barrier	€ 160.00	50 square meter	€ 8,000.00	Walltopia (2019)
Drum pavilion	€ 1,037.00	15 square meter	€ 15,555.00	Kalusche, W. and Herke, S. (2016).
Drumcircle pavilion	€ 6,416.00	one time cost	€ 6,416.00	https://www.jacksgardenstore.com
Entrance Sign costs	€ 1,586.00	one time cost	€ 1,586.00	https://www.thesignchef.com/custom-signs/sandblasted-redwood-signs
Busker zone sign costs	€ 175.00	6 signs	€ 1,050.00	https://www.thesignchef.com/custom-signs/dibond-signs
Costs for architects and planners	15% of total cost		€ 5,491.05	Berlin University of Technology, Department of Urban Development, Assessment by the department 2018
Developers fee	5% of total cost		€ 1,830.35	Berlin University of Technology, Department of Urban Development, Assessment by the department 2018
Developers profit	10% of total cost		€ 3,660.70	Berlin University of Technology, Department of Urban Development, Assessment by the department 2018
		Total cost	**€ 47,589.10**	