MSc thesis in Geomatics for the Built Environment

Predicting noise nuisance from outdoor music events in the built environment

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2017

TU Delft

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M.Sc. Geomatics thesis
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November 26, 2017

The work in this thesis was made in the:

3D Geo information Group
Department of Urbanism
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In collaboration with:

Amsterdam Institute for Advanced Metropolitan Solutions

DGMR

Chasing the Hihat

Municipality of Diemen

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ACKNOWLEDGEMENTS

I want to thank all the supporting companies and organization for a fruitful collaboration and their boundless support. Especially Daniel van Drunen from Chasing the Hihat and Luuk Friebel from the Municipality of Diemen, with whom I formed a great team during the events.

Personally I doubted my whole masters education whether Geomatics was the right choice for me. I started it because with my background in industrial design I am curious in which way modern technology can solve current day problems. Geomatics is still such a novelty and many seem not to grasp the potential and wide field of application it has. In this educational journey from the beginning on I was better in telling my friends and family about the great potential of Geomatics than actually performing it, and this is synonymous as well for how I approached this thesis research. I kept thinking of new exiting things to research but the execution was often a lot harder than anticipated.

There was a moment during my thesis I had decided to quit the education. But luckily the positive and motivating effort of Jantien Stoter, Filip Biljecki, Rob Witte and my girlfriend gave me reason to continue and I am really thankful for all the wise and loving support they gave.

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1 INTRODUCTION

Sound becomes noise when it is unpleasant. Someone's sound can be anotherones noise and vice-versa. When an outdoor music event occurs in an urban area the question when does sound becomes noise, is the basis for legislation. This issue continues further in the question when does too much noise for a resident becomes a reason to alarm authorities, and if authorities are alarmed can it be stated that there was too much noise? Or is this tipping point so subjective that it is impossible to evaluate the impact of an outdoor music event? If so, what tools do regulators have to assess if an event can be held?

This master thesis is an exploration whether subjective opinions that are the result of a real-world event can be predicted by spatial analysis. Sound is a phenomenon with a spatial attribute and the knowledge of sound propagation is applied frequently in many different industries. In practice noise simulation is an important instrument to decide by authorities whether an event can take place or not, therefore a study to better understand the relationship between complaints and noise values predictions can be seen valuable. The domain of *geomatics* is about analysing and visualising geographical data and using this to solve real-world problems in an innovative way. Therefore this research will explore how *geomatics* can help making steps towards a tool to predict noise nuisance complaints from outdoor music events.

1.1 MOTIVATION AND PROBLEM STATEMENT

The Netherlands is experiencing a steady increase in festivals. According to a press release of the the Dutch association of event producers (V.V.E.M.) (36) the amount of events has risen from 708 events in 2012 to 801 in 2014, subsequently the amount of visitors went from 19.7 million to 22.7 million. The trend is still continuing according to V.V.E.M and this is most notable in the Dutch capital Amsterdam. According an article in the Dutch newspaper Het Parool (33) in 2015 350 festivals were spread over 22 weekends in Amsterdam. By advertising the increasing diversity and the growth of festivals it is clear that it is part of Amsterdam's marketing strategy to attract more visitors towards the city. This increase in festivities are coming with a downside, communities and neighbourhoods complain about nuisance. This social dilemma between what is commercially good for the city and what the residents desire is often addressed last few year in news papers, on TV and social media. There are many sources of nuisance during an outdoor festival but noise is the most occurring according the municipality of Amsterdam and numerous news articles e.g. (33) (19) (17).

The World Health Organization (WHO) document "The Guidelines for Community Noise" (4) summarized the scientific evidence that prolonged exposure to environmental noise is harmful for the public health. The European Union responded with a directive on the assessment and management of environmental noise (29). The directive's scope is to reduce and prevent the harmful effects of environmental noise by defining a common approach as well as requiring strategic noise maps. Strategic noise maps are designed for the global assessment of noise exposure in a given area due to different noise sources or for overall predictions for such an area (29). The directive obliges European Union (EU) member states to create strategic noise maps of major road, railway, airports and other agglomerations that comply to the directives specifications. Hence studies and software packages have been developed that are specialized in producing strategic noise maps for these situations. Acoustic reports about the predicted noise levels of outdoor music events are being made but are underdeveloped. Acoustic companies use the same software packages and directives used for example a railway or a highway. Correct noise predictions could be a very beneficial knowledge above measuring. It allows to simulate planned situations, test-out different configurations, and unlike noise measurements can be controllable influenced by meteorological circumstances, next to that noise predictions are cost-effective. Little to no studies have been made regarding noise caused by festivals while the city of Amsterdam and event producers could clearly benefit from knowledge that can offer better insight to this increasing problem.

1.2 OBJECTIVES & RESEARCH QUESTION

The main objective of this research is to lay the foundation for a map that effectively disseminate noise information and facilitates well-informed decision-making concerning the impact and assessment of outdoor music events.

The main research question for this thesis is:
Can a noise map be a valid tool for predicting noise nuisance from outdoor music events in the built environment?
From my research question and main objective the following goals are derived.

- Develop an accurate environmental model (a 3D data set with information on noise-relevant objects) of the relevant areas with the necessary meta-data to correctly predict noise levels.
- Simulate and understand the characteristics of the noise levels that an outdoor music event can produce.
- Choose and adapt the most suitable noise calculation method/software for the purpose of predicting noise levels of outdoor music events.
- Generate a noise model that correctly disseminate the noise levels from the outdoor music event.
- Map the location and take measurements at the site of the actual noise nuisance complaints made during an event and relate it to the event and the noise levels.

- Reflect upon the effectiveness of using expected noise levels to predict noise nuisance complaints.
- Make recommendations on how to use predicted noise levels to facilitate well-informed decision making about the impact and assessment of outdoor music events

To achieve the main objective and the goals, underlying issues and fundamental questions need to be addressed. These are not main research questions but rather intermediate steps to be able to make a well substantiated research. A couple of those first hurdles have been taken after the literature study while others need implementation and statistical testing to be overcome. A few of those first challenges are listed below.

- What are the current legal limitations and common practices concerning noise from outdoor music events in Amsterdam and how is it enforced?
- What are the (most extreme) noise levels and sound spectra that can occur during an outdoor music event?
- Is there a noise calculation software available that is capable to predict noise levels that can arise from an outdoor music festival?
- What are the requirements the environmental model and the related meta-data need to fulfil to support the most accurate output for the noise calculations software?
- Which software is most suitable for visualizing the results from the noise calculation software?
- Which demographic and social-economic datasets are needed to analyse the relation between the noise levels and the noise nuisance complaints?
- Is there a relation between the noise nuisance complaints, the noise measurements, and the simulated noise levels?
- Can the noise calculation software make valid predictions of the expected noise levels of outdoor music events?
- Can the noise calculation software make valid prediction of the expected noise nuisance complaints caused by outdoor music events?
- Is there need to change current legislation, current practices or enforcement protocol concerning noise from outdoor music events?

1.3 RESEARCH SCOPE

This thesis will focus upon the use of a noise map as a valid tool for well-informed decision-making relating to outdoor music events. This research will be limited to using existing software and methodologies to develop a noise map. Only when all available means are deficient to the situation existing methods need consideration. While the generation of the modified noise map will likely be most challenging and time consuming the novelty of this thesis should be the application for outdoor music events and the integration with information of the noise nuisance complaints.

The research will focus on popular outdoor event areas in Amsterdam and preferably electronic dance music festivals. The choice for electronic dance music festivals is because of the shear increase in popularity and amount of festivals in this genre. Preliminary research has also shown that these festivals cause the most agitation in neighbourhoods. This is a clashing contradiction with the profile of Amsterdam as dance capital of the world and host of the the biggest dance related festival in the world, the Amsterdam Dance Event (ADE).

The psychology behind nuisance complaints and the diverse reasons one could have to fill in a complaint is a different field of expertise. Many social-economic or psychological reasons could be the underlying motivation for people to experience nuisance. To define the scope of this thesis the focus in this research is on the relation between the predicted, or measured noise from an event and the nuisance complaints. Reasons to experience nuisance from an outdoor music event besides the experience of noise falls outside the scope, for example closed roads or dogs eating drugs-poop (3).

Next to the obvious reason to choose Amsterdam, namely the amount of activities, another reason is that this research is in collaboration with the Amsterdam Institute for Advanced Metropolitan Solutions (AMS). The goal of this institute is to create solutions for the complex challenges a metropolitan region such as Amsterdam is facing. Together with AMS the decision is made to focus on the interdisciplinary nature of this research and to use metropolitan data. The project will be solution oriented and societal relevant next to the engineering decisions sought by the Delft University of Technology (TU Delft).

1.4 SCIENTIFIC RELEVANCE AND CONTRIBUTION

There are little to no studies about noise levels from outdoor music events, the propagation of music in an outdoor environment or the relation with nuisance complaints. Methodologies to predict environmental noise are based upon the most common sources of nuisance namely traffic and industries. A methodology that is adapted to correctly determine noise from an outdoor music event could not be found. As mentioned in the problem statement acoustic reports are being made for this purpose but are in its infancy due to lack of research, applications and guidelines. All the legislative directives concerning environmental noise do not include noise from outdoor music events, only a surcharge for clearly audible music-sound. This lead to a shortcoming of a correct common approach to predict, visualise and measure noise from outdoor music events.

Noise nuisance is a well examined subject. However not for the momentary nuisance that an one-day event can evoke. In addition the research on the relation between the nuisance complaints and the actual noise levels from the event is a new scientific challenge cities just recently start to investigate. The relation between traffic noise and nuisance is well observed and applied in legislation and directives. Obviously this makes sense, road traffic is the most widespread source of noise in all countries and the most prevalent cause of annoyance and interferences (5). To deepen the knowledge about the impact of an outdoor music event on the residents could help create legislation and directives.

Using vital spatial knowledge to gain new insights into a spatial-temporal phenomenon is one of the values of a *geomatics* engineer. There are multiple spatial datasets that must be made, compared and combined to achieve the main objective of this thesis. Besides the usefulness for the city of Amsterdam it is an interdisciplinary challenge that requires the acquired knowledge of a *MSc. Geomatics student*.

1.5 THESIS OUTLINE

The following chapter, Chapter 2, will elaborate on the theoretical background. This is needed for the reader to understand the subject and among others the notions behind sound, and sound propagation. In Chapter 3 the conceptual framework is presented. This is the scientific approach the research follows to answer the research question. Chapter 4 is dedicated to the practical execution and implementation of the conceptual framework. In Chapter 5 results will be presented, explained and analysed. Finally in Chapter 6 an answer will be given to the research questions. Chapter 7 is to reflect about the research and the thesis and give guidelines for what could be future relevant research.

2 THEORETICAL BACKGROUND

To answer the (sub)research questions a theoretical framework must be established. This framework will demonstrate an understanding of theories and concepts relevant to the topic. It will give a basis for the choice of research methods and will clarify the relation between the thesis and existing theory and scientific literature. Finally the goal is to identify which key variables influence the phenomena that shape this project.

The backbone of a theoretical framework is a literature study. The literature study will consist of four parts that discuss the main scientific elements of this research: (a) sound propagation, (b) noise calculation methods, (c) noise nuisance, (d) legislation and current practices in Amsterdam.

2.1 SOUND PROPAGATION

This subchapter will discuss the basic principles of sound that are common practice. Although the science of sound is established knowledge, it is essential for understanding the challenges that occur during noise calculation. The formula's and definitions in this subchapter are mostly extracted from *IISc Lecture Notes Series, Volume 3 - Noise and Vibration Controll* by M.L. Munjal and *Acoustics: Sound Fields and Transducers* by Leo L. Beranek and Tim Mellow (**?**).

Sound is a longitudinal wave in air, and wave is a traveling disturbance (25). The speed at which the longitudinal disturbances travel trough a medium is called sound speed or the speed of propagation, *c*. The speed of propagation of sound is finite, this means there is an increasing delay in the arrival of the signal when the distant from the source increases (**?**). A wavelength is equal to the speed of propagation divided by the frequency of vibration.

$$\lambda = \frac{c}{f} \tag{1}$$

Where λ is the wavelength in meters, *c* is the speed of propagation of the sound wave in m/s, and *f* is the frequency in hertz (or cycles/s).

The measurable aspects of sound start with the measurable elements of the medium before a wave is initiated in it. In this thesis the focus is on waves through gases, the medium where audible sound is created. The first measurable element is the *pressure* throughout the gas and this is equal to the ambient pressure. The second element is the *density*, this equals the ambient density when there is no disturbance in the medium. The third element *Temperature* can be measured and the final measurable element is the *particle displacement*, the motion of the medium itself (e.g. wind) (**?**). When a sound wave is propagated several detectable changes occur in the medium; particles are displaced causing particle velocity, *pressure* starts fluctuating around the ambient pressure, as for the *temperature* and the *density*. The speed in which this disturbance through a medium is propagated differs for different gases.

$$c = (\gamma RT)^{\frac{1}{2}} = (\gamma P_0/\rho_0)^{\frac{1}{2}} \quad (2)$$

Here γ is the ratio of specific heats C_p and C_v, R is gas constant, P_o is static ambient pressure, ρ_o is mass density, and is the absolute temperature of the medium and c denotes the speed of sound.

When understood what happens when a wave propagates through a medium the focus now is on the measurable elements of the wave. *Sound power* is the rate at which sound energy is propagated per unit time. This unit is distance independent and the International System of Units (SI) unit is watt (W). *Sound power* is a theoretical value that is not measurable but it is the sound energy constantly transferred from the sound source Eq.(3). This sound energy generates sound pressure fluctuations in the medium. *Sound pressure* is measurable and location dependent, the SI unit is the pascal (Pa) Eq.(4). *Sound intensity* is the energy the *Sound pressure* combined with the particle velocity produces per unit area, the SI unit is the watt per square meter (W/m^2) Eq. (4).

$$P = \frac{Ap^2}{\rho c}\cos(\theta) \quad (3)$$

Here P is the *sound power* in watt, A the area of the surface, p the *sound pressure*, ρ the mass density, ϑ the angle between the direction of propagation and the normal to the surface.

$$\mathbf{I} = p\mathbf{v} \quad (4)$$

Here $\boldsymbol{I}$ and $\boldsymbol{v}$ are both vectors with direction and magnitude, respectively *sound intensity* in watt per square meter and particle velocity, p is the *sound pressure*.

When these waves enter the human ear a new scale of sound intensity, sound power and sound pressure is used. Because the ear can pick up pressure fluctuations of the order of 10^{-5} Pa to 10^3. Therefor a logarithmic unit of decibels has been created. Sound power level Eq.(5), sound pressure level Eq.(6) and sound intensity level Eq.(7) all have decibel (dB) as SI unit, this can be confusing.

$$SPL = L_p = 10\log\frac{p^2}{p_{th}^2} = 20\log\left(\frac{p}{2\times10^{-5}}\right) \quad (5)$$

$$IL = L_l = 10\log\frac{I}{I_{ref}} = 10\log\left(\frac{I}{10^{-12}}\right) \quad (6)$$

$$SWL = L_w = 10\log\frac{W}{W_{ref}} = 10\log\left(\frac{W}{10^{-12}}\right) \quad (7)$$

P_{th} is the faintest sound of 1000 Hz a human can hear namely 2×10^{-5} Pa. The corresponding I_{ref} and W_{ref} are 10^{-12} W/m^2 and 10^{-12} W.

The audible frequency range lies between 20 Hz and 20,000 Hz but 1000 Hz has been recognized as the standard reference frequency. To perceive low

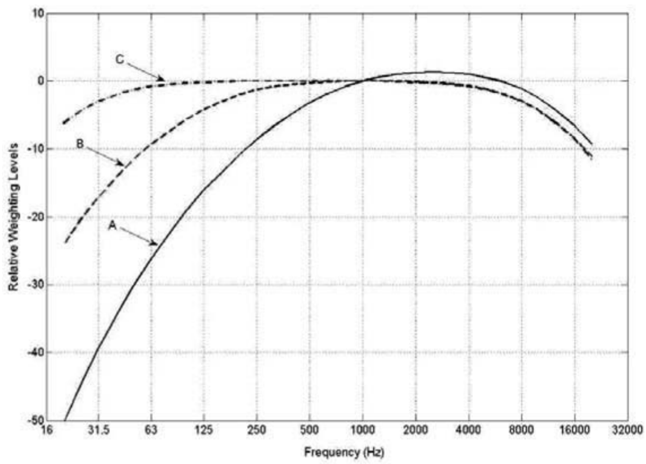


Figure 1: Approximate electrical frequency response of the A-, B-, and C weighted networks of sound level meters (25).

frequency sound the energy level should be sufficiently high, not common for most sound sources. The total audible range is divided in octaves and 1/3-octave bands. The sound pressure level increases by 3 dB when an octave band doubles from one to the next. Because the human ear reacts differently upon frequencies weighted factors have arise. The three weighted sound levels are shown in Figure 1. A-weighting is for levels below 55 dB, B-weighting for level between 55 and 85 dB and C-weighting for levels above. A-weighted sound pressure level is written L_p in dBA and is used in most noise measurements and noise limit directives.

2.2 NOISE CALCULATION METHODS

The process of noise mapping and the role GIS is explained clearly by Kluijver and Stoter in the paper "Noise mapping and GIS: optimizing quality and efficiency and noise effect studies" (15). Kluijver and Stoter begin with stating that to quantify and visualize noise effects an extended spatial database, spatial tools and computation force are needed. Their goal was to make noise effect studies more transparent, meaningful, reliable, unambiguous and the examination more efficient. The proposed process is shown in Figure 2.

The schema in Figure 2 presents a clear process and shows the relation of every step to each other. The step of computing noise levels - the noise calculation method - is done by specially developed computer models. In many countries environmental noise calculation methods have been developed, mostly related to traffic noise. Due to the different vehicle types and roads surfaces many countries use different standards for the effective analysis and prediction of traffic noise (21). As mentioned before The Environmental Noise Directive (2002/49/EC) requires EU member states to determine the exposure to environmental noise through strategic noise mapping (7). This directive resulted in for example CoRTN and PRTN by the Department of Environment in the United Kingdom, RLS-90 by Germany, MITHRA by a French firm, StL-86 by the Swiss Federal Office for Environ-

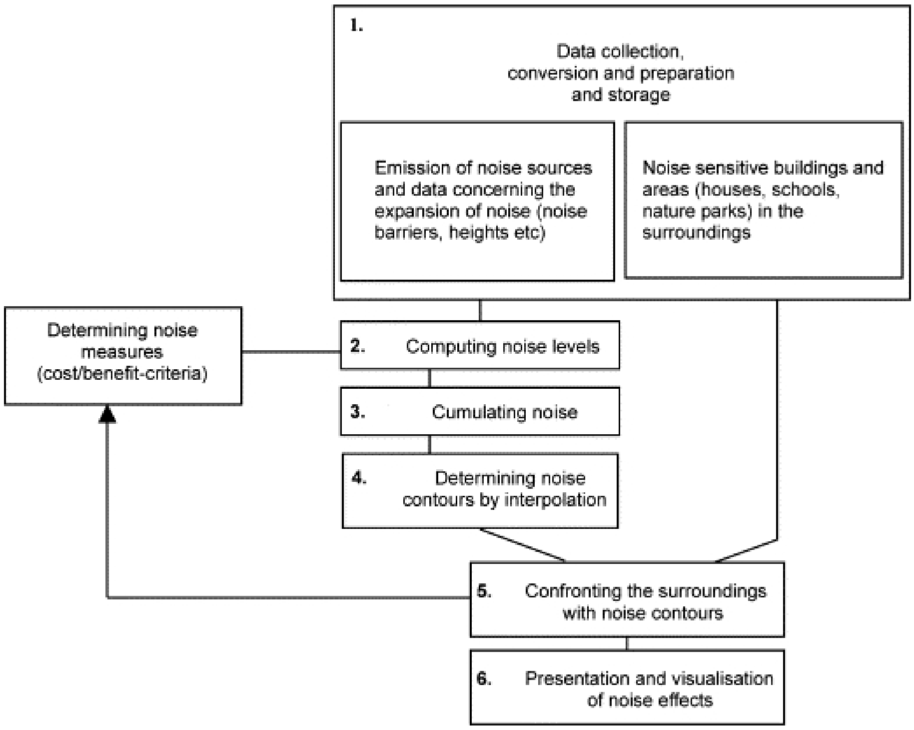


Figure 2: Schematization of the noise mapping proces (15).

mental Protection and the Dutch noise calculation methods (14). A common European methodological framework for strategic noise mapping is under development namely CNOSSOS-EU, till than the Standard Noise Calculation Method 2 is the mandatory noise calculation method in The Netherlands according to the 2012 Calculation and Measurement Regulations (12)

Another European noise propagation model is *Harmonoise*. The *Harmonoise* propagation model is an acurate engineering model for outdoor sound propagation (10). An important element of the model is the inclusion of a meteorological module. It is a flexible model and can be used both for detailed computations in case of noise assessment and for noise mapping (30).

The Standard Calculation Method (SCM1) and the Standard Calculation Method 2 (SCM2) that are used in the Netherlands are based on extensive measurements done in the 1970s and 1980s (35). SCM1 is the simplified version of SCM2. SCM2 should be used when the situation is too complicated to use SCM1, this is often the case. SCM2 defines noise paths from the source to a calculation point. This method also includes obstruction and defraction of noise by objects and buildings and their heights while SCM1 does not. Even second and third order reflections can be calculated to any number of calculation points (15). The Dutch legislation prescribes the use of SCM2 for industrial noise, the use of SCM1 and SCM2 depending on the situation for traffic noise, a derivative of SCM2 for rail track noise, every recognized main source of noise is obliged to create noise maps according to SCM1 or SCM2. The manual measuring and calcuating industrial noise (23) is the Dutch directive were all the guidelines to calculate industrial noise according the legislation is stated. The software packages mostly used or created by established acoustic engineering companies in the Netherlands are focused surrounding these calculation methods and directives.

The guidelines from the manual measuring and calculating industrial noise (23) (*HMRI*) is the directive the acoustic reports made for outdoor music events need to (partly) obligate. This is because a music event falls within the environmental management act and can be seen as a company or corporate activity, thus the *HMRI* becomes effective. The *HMRI* methodology was never specifically developed with this intended use, but it does include a special surcharge for clearly noticeable music sound. A surcharge of 10 dB is added upon the overall noise level (23). Why this surcharge was chosen could not be unravelled. This research could validate whether this indeed is appropriate.

2.3 NOISE NUISANCE

According to *D.Ouis* (28) annoyance is considered to be one of the first and most widespread reactions to environmental noise. This non-auditory effect is viewed as being stress-related. Most of the scientific knowledge about noise nuisance in this subchapter is based on road traffic noise, this is due to the absence of research about noise nuisance from music.

The research (28) elaborates quite clarifying on the complex realm of stimuli that play a role in annoyance from road traffic noise. Many of these stimuli would probably be also effective on noise from outdoor music events. The differences between individuals in assessing noise effect are difficult because of many acoustical and non-acoustical factors. The important acoustical factors are sound pressure level, duration of exposure, frequency spectrum, impulsive character and level fluctuations. The non-acoustical factors can include, time of day, time of year, and past experience. Subsequently the psychological states of a person should be taken into consideration (28). According to *Ouis* it is important to realize that the relationship between measured noise level and its effect on people is not easy to determine in a systematic way.

The non-auditory effect on health are extensively researched. Noise interferes in complex task performance, modifies social behaviour and cause annoyance (32). Most of these studies are based on long-term exposure and sleep disturbance. An outdoor music event in Amsterdam is a momentary event that commonly does not happen more that a few times a year and ends at 23:00. According to *Ouis* broadly speaking the effects of noise on people can be divided into three main categories. Psychological, social and physiological. Figure 3 depict a simplified model for the main relationship between traffic noise and its effects on the social context of people.

Figure 3 shows that noise can causes direct effect or a delayed reaction in the form of annoyance. The level of annoyance is not only dependent on the noise but on personal and attitudinal factors as well. The annoyance can lead towards behavioural modifications such as closing a window to isolate the noise, but in turn with the right amount of personal and attitudinal factors can lead to public action against the source of the noise. Attempts have been made to correlate the subjective experience and noise exposure. In an elaborate research in the 70's in which many different surveys about traffic noise annoyance was analysed it appeared non-acoustical variables

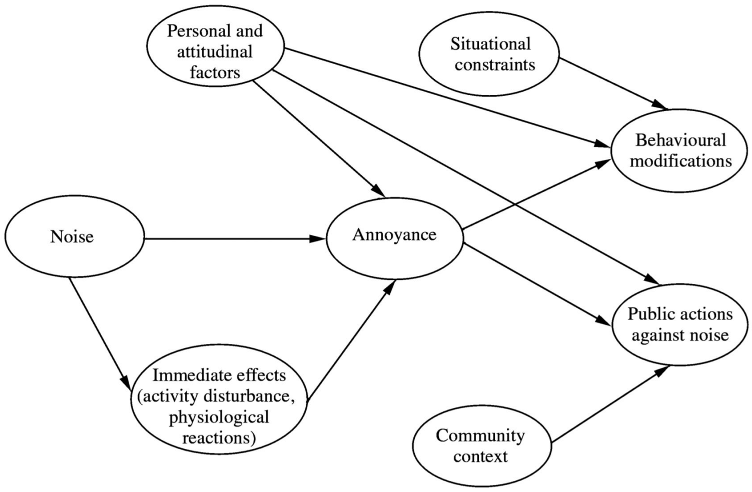


Figure 3: A model relating noise and its effects in community (26).

are highly influential (31). Extensive other work highlighted the difficulty of designing suitable interview procedures to measure annoyance. Nevertheless the measure of L_{eq}, the equivalent continuous sound power level over a specified time of measurement is most commonly used in the relation between the noise and annoyance. An important consideration when using this term is the assumption that the average sound levels over equal time periods produce equal effects. However especially in music the sound level greatly varies during time.

2.4 LEGISLATION

Governmental legislation concerning limitations or calculation methods about outdoor music events is non-existing. Thus municipalities measure the legal boundaries encircling an event by setting up an General Local Regulation (Algemene Plaatselijke Vordering)(APV). This legislation on a municipal level is far from uniform across the Netherlands. The APV of Amsterdam states that every event should be approved by the Mayor. A manual is made how to apply for approval. This application should include a "simple" noise-report were the specifications of the sound source(s) is mentioned, the music genre, the duration and the expected dB(A) value on the facade of the nearest residential house. The corresponding city district (that again can handle there own limitations concerning noise) often brings in an independent acoustic expert to validate the noise report. This validation is only done according simulation when the noise report offered includes the necessities to accomplish this. Mostly the validation is based upon past experiences, simple calculations and whether the report is set-up by another established acoustic company. The validation of the correctness of the noise report is usually honoured by the concerning city district.

Officially there are no standardized prerequisites for the sound levels of outdoor music events, the maximum sound level on the facades of local residents, which sound level weighting is used, the noise reports submitted for approval or the validation of those noise reports. What can happen is that during the event the city district executes measurements, occasionally upon request from residents, to check if the levels mentioned in the approved noise report are maintained.

To be able to follow a guideline for lack of better the *HMRI* is often used. The way the *HMRI* is used can differ a lot depending on the rules set by the municipalities. Which attenuation or surcharges are added or used when predicting the noise levels is often unspecified and inconsistent. Municipalities try to adjust the *HMRI* to fit the circumstances of an outdoor music event. This had led to ambiguities in acoustic reports before events, ambiguities in norms and legislation and ambiguities with measurements during the event.

2.5 RELATED WORK

All the topics above are related work but research that particularly involves noise nuisance by outdoor music events is scarce. In the Netherlands only few publications could be found that show in-depth knowledge or critical validation about current practices concerning this topic.

2.5.1 Dutch research

One of the most elaborate publications found is from a Dutch specialist journal (13). It offers a clear overview about how different nations cope with this issue and how the noise emissions are controlled. The author mentions the *NIMBY* (*Not in my backyard*) attitude society has about this issue. An integral action is necessary to handle all the diverse causes that shape the negative experience with regard to outdoor music events. He states that in most countries there are no national laws about this. Several criteria are used as guidelines, this includes speech intelligibility and sleep disturbance. The author continues that environmental noise should not be used as limit value because of the fortuity and ambiguity it brings. He questions the added value of the decibel surcharge for clearly noticeable music, when already the limit is based on sleep disturbance or speech intelligibility. Another policy he finds questionable is to compensate a few large scale events with high emission limits with more small scale event with a lower noise limit.

His recommendations are to have noise limits linked to specified locations. If there are no residential buildings close by that can be used as control points an alternative point close by should be chosen. Noise control points far away are too depended on meteorological influences. He finds it defensible to assume a certain isolation of a resident building in closed condition, meaning residents are deemed to first close doors and windows before a statement can be made whether the indoor noise levels are too high. Noise predictions can be used to proof an event can cope with the restrictions and to test speaker configurations, and how to optimally use the environment as noise barriers. Finally it is stated that cumulation of noise levels is important when there are multiple events simultaneously and that the residents need to be well informed and have a way to express their dissatisfaction because this will lead to a greater acceptability.

2.5.2 European research

'*Neighbour and Neighbourhood Noise - A review of European Legislation and Practices*' (22) is an extensive research from the British Environmental Resources Management of European legislation and practices relating to neighbour and neighbourhood noise. Neighbourhood noise is distinguished as noise produced in the neighbourhood from pubs, commercial or local industry and construction, but not from transportation. Outdoor music events therefore falls within this category.

The British research notes some remarkable cultural differences between the EU members concerning this topic. Scandinavian countries for example are relatively seen not very concerned with the problem of neighbourhood noise. This can be partly accounted to the high standard of thermal insulation. Mediterranean countries seem to have a much greater tolerance partly due to their lifestyle and habituation of noise intrusion caused by open windows and poorer insulation.

Few countries have national laws concerning neighbourhood noise. Powers are often devolved upon local governments that draw up local laws resulting in regional differences within in a country. The majority of complaints in Europe seem to arise during summertime when there is an increased number of noise sources and residents tend to sleep with open windows. In Dublin the majority of complaints are related to licensed premises that produce machinery noise, mechanical ventilation or amplified music.

The report does not discuss legislation or frameworks to asses possible noise effects upfront. Noise maps and noise models are not referred to. It is mentioned that enforcement practices should be shared between police and environment authorities. Because in complex situations specialist acoustic knowledge is necessary and these can be generally found at environmental health authorities.

2.5.3 Global research

An Australian research about the challenges to regulate noise from outdoor concerts is very valuable (2). It includes a case study in Brisbane and clear conclusions on which measures are successful to obtain minimal complaints.

In the introduction the unique regulatory challenge for the authorities is mentioned. The challenges occur due to variables that are in contrast with the common noise regulations made for long-term sources. Five other variables next to the noise level are mentioned as influential to annoyance and the amount of complaints.

- The nature and scale of the event
- The location and attitude of the local community
- How often such concerts occur at the location, their duration and finish times

- Meteorological conditions
- Whether or not the community has been consulted or notified prior to the concert (2).

There is a minimum amount of sound pressure necessary to make a concert function in regard to audience enjoyment, therefore the high noise levels can not be limited and the regulatory focus should be based on location, duration, frequency and finish time. In Brisbane operational experience have shown that the majority of residents accept high level of noise if they are aware of the infrequent occurrence and know the finish time.

As in Europe a national regulation is non-existent and there are regional differences in legislation. In Brisbane it was found that a limit of 110 dB(C) at the mixing desk (30 metres from the speakers) was a good balance between audience experience and residential protection. The conclusion of the paper gives recommendations after extensive operational testing.

The recommendations include the need for a multifaceted approach to regulation because the annoyance is dependent on more variables than sound pressure at a single point. To minimise complaints most importantly is the number of events per year, the duration and finish time and to inform residents prior to the event. To regulate the noise levels best practice is a noise level meter at the mixing desk. Several reasons to underpin this are given.

- Ease of self-regulation. A sound technician can easily confirm compliance and it provides instant feedback and certainty for the operators.
- Ease of enforcement. Noise is most dominant at the mixing table. In comparison receptors further away need consideration of ambient effects this creates delay where real-time interaction is needed.
- Event organisers could be required to hand-in the noise measurement data from the mixing desk to check whether they were in compliance with the limits. This is considered more practical than sporadic measurements.

2.5.4 *HMRI* validation

The *HMRI* is the only directive in the Netherlands that is customary denoted to by municipalities when measuring and predicting noise levels from outdoor music events. It is actually the only directive available in the Netherlands that mentions music. No studies could be found about the validation of the *HMRI*, not for industrial noise let alone for outdoor music events.

An article was found about a research conducted by *DGMR* (18). In this project the goal was among others to investigate whether the *HMRI* can be used for shooting noise. According to *DGMR* with some minor adjustments the *HMRI* was 98% accurate with not underestimating the sound pressure level. *DGMR*'s recommendation to use the *HMRI* for shooting noise was among others based on the ease of use and familiarity of this method for most acoustic specialist. This recommendation was granted by the Ministry of Infrastructure and Environment and is now the prescribed standard.

Another mention of the use of *HMRI* outside the common application range is from a Powerpoint presentation once again by *DGMR* (34). This presentation discusses several extraordinary applications of commonly used propagation methods in the Netherlands. Examples are sloped sound barriers, reflections against barriers lower than 2 metres, reflections of gabled roofs, and sound through underpasses. For several of those challenges a noise model could be altered in such a way that noise level calculation is possible. One slide mentions the incapability of the *HMRI* to be able to cope with coherent noise sources such as speakers. No solution to simulate this is given.

In the search for related work it seems that validation of the *HMRI*, done by a scientific institute or an university, is not existent or extremely scarce. When new acoustic challenges arise such as shooting noise or windmill noise the applicability of the *HRMI* is tested. But often the starting principle seems to be how to adjust or work with *HMRI* to make it applicable. This starting principle does not surprise when the stakeholders views are taken into account. A new methodology could have far-reaching consequences. Regulations relating to zoning, urban planning, environmental protection and permits for industries could all be affected.

3 METHODOLOGY

In this chapter a methodology will be proposed to achieve the research objectives established in chapter 1. The work-flow is based on the theoretical framework and the advice of several experts and the supervisors of this thesis. Because of the novelty and niche application of this research the methodology could not be based on previous relevant work. To achieve the goals as mentioned in chapter 1 compromises have been made. Time and workload limited the possibility to go in depth about every relevant aspect of this research. The methodology is based on the intrinsic drive to support understanding of the common practices now, show insight into possible improvements and promote the added value spatial knowledge and an interdisciplinary approach can have on a metropolitan challenge.

The goal is to collect real data from the outdoor music events. To be able to do this a collaboration is made with an Amsterdam based event production company named Chasing the Hhat BV (CTH). *CTH* is specialized in electronic dance music festivals and recognizes the need for better noise maps, quantifiable legislation and is very interested in the relation between the noise nuisance complaints, the predicted noise values, and the actual measurements. As disclosed in Section 2.4 they are obliged to hand in an acoustic report when requesting approval for an event, next to that they monitor their sound levels during the event to prove their compliance with the values agreed in advance and to be able to monitor there acoustic impact. *CTH* has given permission for the author to have insight in the made noise reports, use their measurement data and gather location data of the noise nuisance complaints addressed to their events.

The proposed methodology consist of three dataset pillars as can be seen in Figure 4: Predicted noise levels (a), the noise measurements (b), the noise nuisance complaints (c). These pillars will produce the datasets that are needed to be able to analyse the mutual relations.

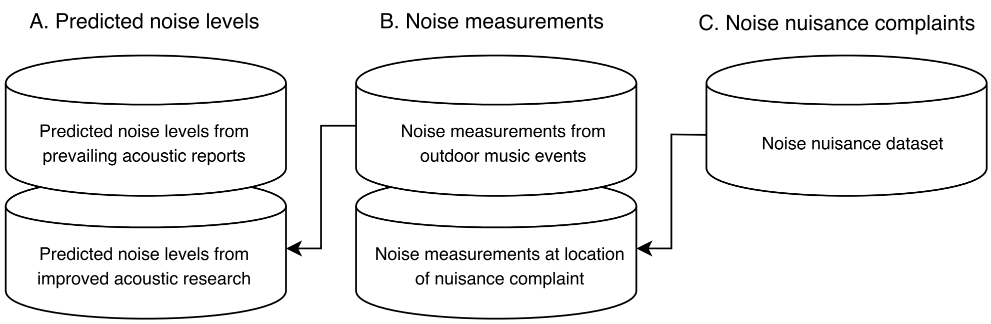


Figure 4: Methodology schema.

These datasets can offer the first insight into the effectiveness of the current practices and the overall correctness of noise level predictions. When the relation between these pillars are described the focus can be directed towards a problem solving approach. This approach will depend on the interdependent relations of the dataset. Subsequently a research will be conducted on which aspects or if any aspects from the noise predictions can be used or adapted to facilitate noise nuisance predictions. This will be the final stage. This is where the answer to the research question can be given. The goal is to discuss the fitness of a noise map as a tool to predict noise nuisance.

This chapter will first explain the testing ground where this research will be based upon. Followed by the needed datasets and their perquisites, secondly the approach to determine mutual relations and thirdly a discussion on how well this approach can lead to an actual solution.

3.1 THE TESTING GROUNDS

The reason to gather data during actual events is because the three pillars of data discussed in the front section of this chapter have not been collected previously for an outdoor music event. Each of them separately in some form have been done before but to be able to analyse the causal connection it is essential that all data are derived from the same event.

The events must be in or close to an urban area to have residents that will be effected by the noise and to be able to connect the thesis with the metropolitan challenge of Amsterdam. Another prerequisite of the event is that it is categorised as a loud electronic music festival were sound level at least reach the generally accepted maximum allowable level of 100 dB(A) in front of the stage, because preliminary research has shown these events cause the most agitation and are now the most popular genre in Amsterdam. Multiple events on the same location with the same placing of speakers is preferred to identify among others the effect from meteorological influences. The following data will be gathered at the events:

- Noise measurements from close proximity. This is done to be absolutely sure the noise levels are only from the event and are not contaminated with environmental noise and are as little as possible effected by propagation influences.
- Noise measurements at the nearest residential buildings. This is done to test the noise levels that are predicted in the prevailing acoustic model(this will be explained in Section 3.2) and to test the propagation accuracy of the prevailing and enhanced noise models.
- The noise nuisance data to analyse the causal relation between the event and the annoyance. This will be addressed in Section 3.3.
- Noise measurements at location of noise nuisance. To understand from which level on residents start to fill in a complaint.

3.2 PILLAR A, NOISE LEVEL PREDICTION

Noise levels predictions are at the core of this research but are not the scientific challenge this research hopes to address. Although to be able to make a plausible assumption of the relationship between noise level predictions and noise nuisance complaints a certain level of correctness of the predictions is desired. At least knowledge about the quality of noise level predictions now, and the quality it could have must be acquired to answer the research question. The literature research made clear that due to lack of guidelines and ambiguous legislation the common approach for these acoustic reports is sloppy. Therefore it is assumed that if there is a relation between the level of noise and noise nuisance complaints the noise levels that are predicted now are not correct enough to create a map to predict noise nuisance, or at least could be better. Possible improvement could be relativity easy, this is among others because this research does not have to oblige to imposed prerequisites from municipalities.

The goal is to create high quality noise predictions. To be able to do this contact is made with Dutch noise prediction experts. *DGMR* is a Dutch consulting engineers company that developed *Geomilieu*. *Geomilieu* is a high quality software for environmental issues. This includes topics such as industrial noise, traffic noise, and air quality. *Geomilieu* is being used by more than 300 institutions and constantly adapted to changing laws and regulations. It is the most common tool in the Netherlands to predict environmental noise levels. It includes multiple different noise propagation modules that can be implemented, including *Harmonoise* and the *HMRI*. The author made contact with ir. J. (Rob) Witte, a senior advisor industry, traffic and environment at *DGMR* and co-writer of the Dutch manual for measuring and calculating industrial noise (23)(*HMRI*). *DGMR* supports the research and acts as an advisor and provided this research with sound measurement equipment. The phased plan to achieve higher quality of noise predictions are listed in steps below.

Step 1: Obtain the acoustical reports from the events that are made in advance.

Step 2: Analyse the prevailing noise model and test the accuracy of the noise level predictions and the propagation accuracy with the noise measurements from the events.

Step 3: List elements that potentially can be improved from the prevailing noise model.

Step 4: Choose the most suited noise calculation software and propagation model to create enhanced noise level predictions.

Step 5: Make a new enhanced noise model.

Step 6: Use acquired knowledge from measurements at the event as input for the enhanced noise model.

Step 7: Test the enhanced noise model and test the accuracy of the noise level predictions and the propagation accuracy with the noise measurements from the events.

Step 8: Compare prevailing and enhanced noise model and reflect on the accuracy of noise predictions for outdoor music events.

3.2.1 Noise levels from the prevailing acoustic report

The goal is to recreate the noise model that was made prior to the events. To be able to compare the prior expected noise levels with the actual measured noise levels and the noise levels simulated with the new approach (see Section 3.2.2), a reproduction of the noise model is essential. With an exact copy of the noise model comparisons can be made on other aspects and locations than solely described in the acoustic report. In addition it gives great insight upon the methodology for event noise calculation that is commonly accepted now. These insights can help with understanding the outcome of the results of the comparison studies, and help identify elements that could be improved. *Chasing the Hihat* make the acoustic reports available and *DGMR* guided and facilitated the understanding and reproduction of the noise model.

3.2.2 The enhanced noise model

The most common used software in the Netherlands to calculate noise levels in an outdoor environment is *Geomilieu*. *Geomilieu* can perform noise level calculations using a diverse amount of methods, including *HMRI* and *Harmonoise*. Together with *DGMR* the decision was made to use *Geomilieu* and the *Harmonoise* method to gain enhanced noise level expectations.

The *Geomilieu* software environment is chosen because of the absolute expertise *DGMR* can offer with this software. Secondly because the high chance the prevailing noise model is made with the same software. For reproduction and comparison it would be efficient and less prone to error if both noise models are made in the same environment. Thirdly because *Geomilieu* is so widely used by noise experts that if this thesis will result in actual improvements, the executive professionals can understand and implement these in their common practices. The *Geomilieu* version that is used in this research is: **Geomilieu version 4.30**, it was made available by *DGMR*.

3.2.2.1 *Harmonoise*

Harmonoise will be used as the noise calculation method in *Geomilieu*. The *Harmonoise* sound propagation model was commissioned by the European Union. When the European Directive on the Assessment and Management of Environmental noise (2002/49/EC)(29) was accepted and came into force member states were obliged to produce strategic noise maps. This resulted in the need to establish a common assessment method for the production of these noise maps. Project *Harmonoise* was developed to create such a common propagation model (24). After years of development the project was stopped, the propagation model was deemed too elaborate and too computational expensive. The knowledge gained is still valuable and the method is still seen as accurate and powerful.

The reason why this noise calculation method will be used to create the enhanced acoustic model is because it is a ready to use calculation model that has proven to be accurate. It offers more adaptability especially within the meteorological parameters. Therefore the assumption is that it could be adapted better to the momentary conditions that occur during an outdoor music event. Another reason is the novelty that this model has never been used for this application, but can be rather easily used in the *Geomilieu* software environment and therefore it is easy comparable, adjustable and understandable for further research. A licence to use this calculation method inside of *Geomilieu* was granted by *DGMR*.

3.2.2.2 *Input data for enhanced noise model*

The accuracy of noise predictions weighs heavily on the correct input. In *Geomilieu* the propagation of sound depends on the source input and configurations (a), the environmental model (b), the receiver positions and the calculation settings (c).

The source input is related to the source power and the sound spectrum, the configuration can be seen as the position and directivity of the speakers. The goal is to recreate the characteristics of the speaker set-up from the events and to use the close-by noise measurements (Section 3.3) as a guide to choose the correct source power and sound spectrum.

The environmental model influences the propagation of sound. Buildings or height differences can cause diffraction, absorption and reflection. The soil type is another important aspect of the environmental model because soil absorption and reflection can have significant effect on the propagation. The environmental model should be as accurate as possibly capable in *Geomilieu*. Data to create the environment model will be extracted from the public available spatial datasets from the Netherlands.

The receiver positions are the locations in the noise model where the noise level is being calculated. Therefore it determines the path of the modelled sound ray. The positions of the receivers will be (among others) the same as the residential control points listed in the event permit. This is done because noise measurements will be made at that location and therefore it can be used to verify the accuracy of the propagation in the enhanced noise model. Next to that the results from the prevailing noise model and the enhanced one can than be easily compared. The calculation settings can define which attenuation or reflection is included and most importantly the meteorological conditions. Preliminary research have showed the huge influence these conditions can have on the noise levels. The meteorological data will be extracted from the Royal Netherlands Meteorological Institute (KNMI).

3.3 PILLAR B, NOISE MEASUREMENTS

The measurements during an event are essential for verifying the accuracy of the noise level predictions, for generating input for the enhanced noise model and for understanding the relation between the noise nuisance complaints and the noise from the event. *DGMR* again offered help in this by making a hand-held sound level meter available for use. *CTH* always monitors their noise levels using measurement equipment. They have given the author permission to use the data they gather and to make use of their equipment. The resources of *DGMR* and *CTH* combined will hopefully assure good quality data. Noise measurements are notoriously difficult due to environmental noise, ever changing environmental conditions and highly sensitive specialised equipment.

Three kind of noise measurements will be made. Close-by noise measurements (a), noise measurements at the residential control points (b), noise measurement at the location of the noise nuisance complaints (c). The close-by and the measurements at the residential control point will be done with the *MeTrao system* and the measurements at the nuisance complaints with the hand-held sound level meter from *DGMR*.

The *MeTrao* system is an acoustic measurement system developed by *Event Acoustics* and rented by *CTH*. The sound technicians at the music stages use this system during the event to see whether the noise level at the resident control points still comply with the permit. Constant control and real-time adjustments of the noise levels allows *CTH* to maximise their sound capacity without violating the law. Another function is to be able to challenge the data the municipality gathers if disagreement arises about noise levels or nuisance complaints. The *MeTrao* system as used during the use-cases is a network of sensors. Modules of the system are packed in protective cases and communicate with each other using the internet. Every station includes a sound level meter and a computer to store, send, analyse and visualize the data. Figure 5 and Figure 6 show the stations and the visual aid they provided to the technicians. The stations are placed in the so called 'front of house' (FOH). This is the position from where the sound technicians control the speakers. It is positioned on the center line between the speakers in the middle of the crowd. The other stations are placed at the residential control points appointed in the event-permit.

The *MeTrao* system's FOH data will be used to analyse exactly what the event's noise level is at the sources. These measurements from relatively close by are not contaminated with environmental noise and propagation attenuation influences are minimised. This makes it ideal to relate these measurements with the noise nuisance data and to use this data as an input for the enhanced noise model. The *MeTrao* system's residents control point stations are further away from the event. Therefore the data will be used to analyse the quality of the propagation of both noise models. Caution is needed when using this data because environmental noise could become dominant at a distance. Roads, air-planes, wind, a neighbour mowing the lawn, are all examples of possible contaminations of the data.

The noise measurements at the location of the noise nuisance complaints will be acquired by contacting the resident that complained. To be able to do this nuisance complaints data is gathered during the festival. Section 3.4 will elaborate on this topic. When agreed by the residents they will be visited and a noise measurement is made. This will hopefully give insight into the noise level from which residents start to complain. Unfortunately these measurements will probably be most prone to errors. The further away from the event the more likely the measurement is tainted with other noises and due to the ever changing music and propagation factors it is impossible to measure exactly the noise that caused the annoyance. Although short measurements at these locations can impossibly lead to a absolute threshold

Figure 5: Overview of current noise levels.

Figure 6: Real-time adjustments during event.

when residents start to complain because of the subjective realm of noise, it can lead to essential new insights about the impact of outdoor events in a residential area and about the residents who complain.

All noise measurements are made with equipment that among others allows LAeq, LCeq and noise levels for each octave band. The spectral information is especially valuable because it allows a possible distinguishing between environmental noise and music noise. The spectral distribution has great influence on the propagation of sound. With spectral measurements a spectrum can be developed that will be used as input for the enhanced noise model. Another aspect is that the spectrum of the noise could be an important factor in the nuisance experience for the residents.

3.4 PILLAR C, NOISE NUISANCE COMPLAINTS

There is a nuisance hotline in Amsterdam. It is called *MORA* (Melding openbare ruimte) and it handles complaints that relate to the public order. When a complaint is done, a form with name and address and complaint information is created and it is decided which department should resolve the complaints. This hotline is meant for all annoyance related to public order. This means in the city of Amsterdam it is very hard to relate a noise complaint to an event without knowing all the events that happen simultaneously and knowing the possible noise reach of all those events. Daniel Schipper, event coordinator from Amsterdam, explained that the city is busy with updating their nuisance hotline to better improve possible causes with complaints. During this thesis MORA was not capable of offering the data requested for this research. For this research several attributes and characteristics are important. A time-stamp with a location of the noise nuisance is most important. Secondly the knowledge that the noise is from the event. Thirdly the data must be easy accessible to quickly react and to ask whether a noise measurement can be made. There was no such infrastructure therefore I created an own event nuisance hotline.

I have set-up the website *www.festivaloverlast.nl* (meaning festival nuisance). This website acts as an on-line hotline where residents can leave their complaint by filling in a survey. The survey can be found in the appendix. This survey includes questions about the type of complaint and will ask the address. This address is than converted to latitude and longitude coordinates. All the complaints are stored with the coordinates, time-stamp, email-addresses and the answers on the survey questions in an on-line database. This allows easy data handling and smooth integration into a geographical information system.

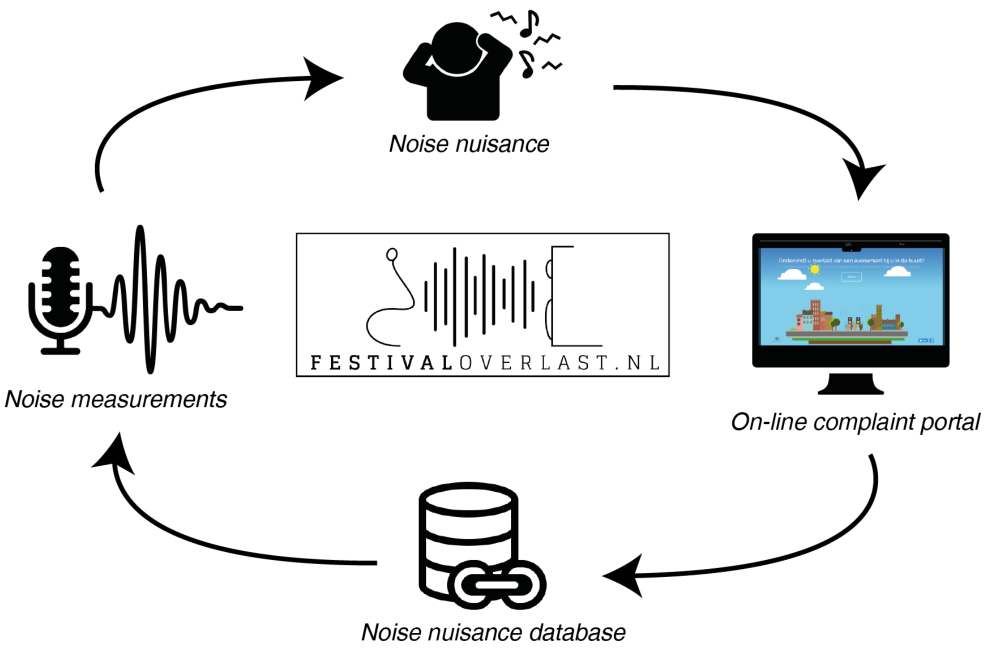


Figure 7: www.festivaloverlast.nl workflow.

Festival producers are obliged to inform the neighbourhood about the basic information of the event. This information is spread through the post addressed to the residents in a certain range from the event. To make people aware of the website, *CTH* spread the websites information through the post and agreed to use the portal with all their events. The author got official endorsement from the *Nederlandse Stichting Geluidshinder* (the Dutch foundation of Noise nuisance) (http://nsg.nl) and *AMS*. This increased the trust and validated the website and hopefully motivated the user more to share their complaint and location.

This method to gather noise nuisance complaints reached not everyone who was annoyed by the noise. Not everyone who was annoyed will make a complaint and not everyone that made a complaint was annoyed by the noise. These are facts this research can not deny or solve. This research accepts this with the reasoning that this is commonly the case with issues concerning public order and residential surveys. Nonetheless the residents who find their outlet to discontent shape the municipalities view of the public opinion, just as the complaining resident will also shape this research. How righteous someone's claim for discomfort is does often not matter. It matters that there is a nuisance experience that is related to a happening that was permitted by the municipality.

3.5 RESULT ANALYSIS

To use the three different dataset pillars to answer the research question needs several intermediate steps of qualitative and quantified analyses. The analysis of the results need a clear focus on the scope as well because this research will probably, due to the subjective and interdisciplinary nature, broach many other social-economic topics that influence the results. For the analysis the research question will be divided three-ways. Figure 8 shows the sub-research questions that arise from the main research question, these questions encapsulate the objectives listed in Section 1.1.

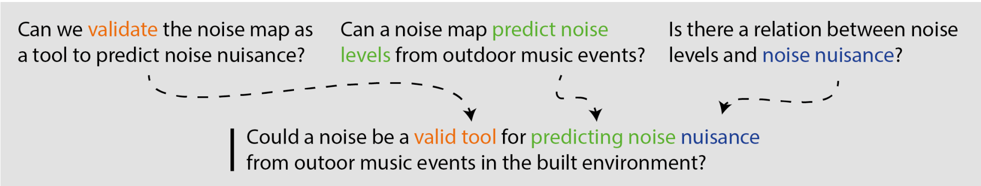


Figure 8: Sub-questions extracted from research question.

3.5.1 Analysis 1: Noise level prediction

The function of a noise map is to visualise the predicted noise levels. A noise map is of poor quality if the noise levels are not accurate. To create a high quality noise map first the quality of the noise levels from the prevailing noise model will be analysed. Secondly the enhanced noise map will be made with the knowledge gained from the prevailing noise model analysis. Finally the question will be answered whether a noise map can be made with accurate predicted noise levels from outdoor music events.

3.5.1.1 *Prevailing acoustic model*

The quality assessment will be done using the noise measurements. The FOH data can be used to check whether the sound source prediction was accurate. The measurements at the residential control point will be used to check whether the propagation was accurate. The accuracy will be determined by means of comparison of total noise level and by spectral level comparison. The comparison must be made with measurement data that is filtered from any unwanted irregularities.

The prevailing noise model is made for one hypothetical moment in time. This moment could be seen as the maximized conditions at the event that still comply with the maximum acceptable level at the residential control points as mentioned in the event permit. When comparing the noise measurements with the prevailing noise model, this should be kept in mind. Another important debatable point is that the sound technicians from the event constantly monitor the noise levels at the residential control points. Their goal is to make sure the maximum level at those points is never reached or breached. As a self fulfilling prophecy the noise levels as predicted will be matched and this due to the real-time adjustment the sound technicians make. This real-time adjustment of the sound source power on the basis of residential control point monitoring can lead to situations that are dubious. If due to meteorological conditions the noise is redirected from those residential control points the source sound power could be increased without breaking the permit. The reverse is true as well, this leads to different maximum situations from the FOH measurement data while the noise measurements at the residential control point stay similar.

Hence it is crucial to remodel the prevailing noise model, because than it is possible to not only compare the maximised situation, but to test the propagation accuracy of the acoustic model by using input based on the noise measurements of the FOH and compare the resulting calculated noise levels with the measured noise levels at the residential control points. The analyses of the prevailing noise model should lead to answers upon the following questions:

- How accurate are the noise level predictions from the prevailing acoustic report?
- How accurate are the source sound power levels?
- How often is the sound power level equal to those in the noise model?
- How often is the sound power level higher than in the noise model?
- How accurate is the chosen music spectrum?
- What are the (most extreme) sound levels and sound spectra that occurred during the outdoor music event?
- How well did the propagation method perform?

From the answers upon these questions a conclusion can be drawn about the quality of the prevailing noise model and about the amount of useful information it provided to the municipality. A list of possible improvements will be made on how to improve the environmental model and the propagation factors. The input data for the enhanced noise model will be extracted and valuable lessons will be learned about the positive and negative sides of current noise prediction practices.

3.5.1.2 *The enhanced noise model*

The first step in this analysis is to duplicate the unchanged prevailing noise model into the *Harmonoise* environment and perform the same tests that were done as described above. The results than can be compared and a conclusion can be made about the performance of *Harmonoise*.

The creation of the enhanced noise model will be based on the prevailing noise model enhanced with the improvements that were listed during the analysis of the prevailing noise model. The environmental model will be adjusted to match the current real-world situation. The enhanced noise model will be validated by using the FOH measurement data as input and verify how accurate the predicted noise levels at the residential control points are compared with the measurement data. This will determine the accuracy of the enhanced noise model. This validation will be done with multiple different meteorological conditions and a diverse amount of spectra. The accuracy analysis of the enhanced noise model will be compared with the accuracy of the prevailing noise model. The questions that subsequently can be answered are:

- Is the accuracy of the noise model improved?
- How much did the different noise calculation method contribute to the results?
- How much did the adjusted environmental model contribute to the results?
- What are the requirements the environmental and the related meta-data need to fulfil to support the most accurate output for the noise calculation software?
- Is one of this methods capable of predicting the noise levels from an outdoor music event?
- Can noise calculation software make valid prediction of the expected noise levels of outdoor music event?
- Is there need to change current legislation, current practices or enforcement protocol concerning noise level prediction for outdoor music events?

After answering the questions above a well considered conclusion can be drawn about the quality of noise predictions from outdoor music events, the elements that can be the cause of discrepancies between the expected noise levels and the measured noise measurements, and the information these acoustic reports offer to the municipalities.

3.5.2 Analyses 2: Noise nuisance

How are noise nuisance complaints related to the noise the event produces? The datasets used to answer this topic are the noise measurements at the FOH and the nuisance complaints dataset. It is important that at least one event will be extracted from the noise nuisance dataset to function as a test event later in the research.

The common mindset based on the theoretical framework concerning noise nuisance is: *The duration and the noise level determine the level of nuisance*. This notion will be tested using an acoustic analysis, a temporal analyses and a spatial analyses. The acoustic analysis is to see whether without the notion of time or place the amount of complaints relate to the noise levels at the event. The temporal analysis will be used to look upon the relation between duration and noise. Finally the spatial analysis will focus on the locations of complaints in relation to the directivity, distance, and meteorological conditions. The assumption is that they all influence the noise nuisance but the knowledge to which extent will be crucial in predicting noise nuisance.

3.5.2.1 *Acoustical analysis*

This analysis will try to find to which extent the changes in source power and sound spectra impact the residents decision to complain and at which residential noise level. Sudden changes in music style or an increase in sound power could relate to the decision to make a noise nuisance complaint. A complaint is always a delayed effect of the noise nuisance. When the tipping point is reached and a resident decide to complaint it is suggested the noise that caused the annoyance is still occurring or have occurred in the hour prior to the complaint. This hour is based on conversations with residents that made a complaint.

Every complaint will be linked with the data of the measured noise levels at the FOH an hour prior to the complaint. This data will be analysed to answer to following questions.

1. What is the relation between the cumulated noise levels of the hour prior to the complaints and the amount of complaints?
2. What is the relation between the fluctuations of the noise levels in the hour prior to the complaint and the amount of complaints?
3. What is the relation between the average sound spectrum of the hour prior to the complaint and the amount of complaints?
4. What is the relation between the fluctuations of the sound spectra in the hour prior to the complaint and the amount of complaints?

If a visit can be made to do noise measurement at the location of the residents it is valuable to see the distribution of noise levels. If a threshold could be set at which level people are annoyed enough to complain then a correct noise model is most essential and the relation between noise level and nuisance is calibrated. However the assumption is that noise measurement will not give a conclusive result. Besides this assumption the amount of visits that can be made is limited thus conclusive result is excluded in default. Although a conclusive threshold value probably will not be made the spread of the noise levels gives great understanding into the perception of too much noise.

The expectation is that indeed the highest level of noise would relate to the most amount of complaints. But this relation could also be derived due to the point in time these noise levels reach their highest peak. Another expectation is that an high fluctuation of sound levels and a high fluctuation of spectra both cause more annoyance and lead to more complaints.

3.5.2.2 *Temporal analysis*

What is the relation between the time of day and the time of the complaint. The hypothesis is: *While time passes more complaints will be made*. This expectation is based on the following assumptions:

1. The duration of noise contributes to the annoyance. The longer residents experience noise the more likely they are to fill in a complaint.
2. Residents are more likely to be at home as time passes.
3. Residents are more likely to want to go to sleep as time passes.
4. The source power is likely to be increased as the event proceeds
5. The music style and tempo is likely to be intensified as the event proceeds

There are several influences or conditions that could probably disrupt this hypothesis.

1. A change in meteorological effects during the day.
2. A change in music spectra.
3. A change in power source, for example by closing a stage prior to the official closing time of the event.
4. During daytime residents could be outside and experience the noise more than in the evening when they are inside

By plotting the complaints on a time-line with the knowledge of the disruptive influences the hypothesis will be tested.

3.5.2.3 *Spatial analysis*

To be able to understand the spatial relation first an analysis of the surrounding area should be made. The focus is upon residents, thus people living in proximity of the event. The assumption is that only one complaint will be made on behalf of an household therefore the amount of addresses with a residential function depict the amount of possible complaints. The spatial analyses should always be held in perspective with the amount of possible complaints in a certain direction or proximity.

To analyse the relation between the noise from the event and the location of the noise nuisance complaints the propagation factors that influence sound will be used as parameters. The position of the residents' house in relation to the directivity of the speakers, the distance from the event, the possible diffractions, and the meteorological conditions determines where the noise can be heard. With the use of a geographical information system a research area will be chosen surrounding the event area. The range will be based on the maximum distance the maximum sound level from the event could cover without any diffraction or attenuations till the sound pressure level reaches below 40 dB(A). This value is based on the threshold for equivalent sound pressure level at night as the lowest observed adverse effect level for night noise (WHO)(11). This is seen as a range with a high safety-margin because of all the diffractions and attenuations that are left out and the environmental noise that is often more present.

Every address with a residential function in the research range and every complaint will be labelled with attributes. The following attributes will be given.

1. The euclidean distance to the event.
2. The cardinal positions in relation to the event.
3. The shortest distance to any of the sight-lines from the speakers.
4. The amount of man-made objects with a height that cross a straight path to the event.
5. The average income of the neighbourhood
6. The buildings' year of construction

By labelling every resident address with these attributes the complaints can be compared with peers and put in perspective with the amount of possible effected residents under same comparable variables. The first four attributes will be used to compare the spatial relation to the event. The assumption is that these variables are the most important influence why residents decide to complain. In addition the fifth and sixth attributes are used to check whether anomalies in the spatial comparisons above could be explained by these socio-economic features. Social-economic aspects have potentially great influence on the motivation to complain but for time-efficiency it is decided this does not fall within the scope of this research.

The result from the acoustical, temporal and spatial analysis will give insight in which tested independent variables (predictors) are most influential. This knowledge will determine how noise levels should be interpreted for the purpose of noise nuisance prediction. The next step is to test whether a noise map can be made that has been adjusted to visualise the predicted noise nuisance complaints.

3.5.3 Analysis 3: Validating the use of noise maps as tool to predict noise nuisance

The two other analyses steps have made it possible to answer the following sub-research questions as mentioned in Section 1.1. and to achieve the goal to reflect upon the effectiveness of using expected noise levels to predict noise nuisance complaints.

- Question: Is there a relation between the noise nuisance complaints, the measurements, and the simulated noise levels?
- Question: Can the noise calculation software make valid prediction of the expected noise nuisance complaints caused by outdoor music events?

The answers to these questions is the answer to the research question but it does not end the research. The successive goals are to make recommendations on how to use predicted noise levels to facilitate well-informed decision making about the impact and assessment of outdoor music events. And if there is need to change current legislation, current practices or enforcement protocol concerning noise from outdoor music events.

4 IMPLEMENTATION

This chapter will describe the implementation of the methodology explained in Chapter 3. It will include detailed description of the steps made to acquire the needed data to answer the research question. The first subchapter will describe the details, surroundings and limitations of the use-cases. The successive subchapters explain the collection and preparation of the several different datasets. Finally the last two chapters include the reconstruction of the prevailing noise model and the creation of the new noise model.

4.1 THE EVENTS

To be able to use data from actual events *Chasing the Hihat* created the opportunity to gather data of seven separate events at the same location. The events are listed in Table 1. All the festivals are located in the Diemerbos and the amount of visitors ranged from 5000 - 8500 persons.

Table 1: Name and date of events

Name	Date
22 Fest	23-07-2016
Liquicity Festival 2016	24-07-2016
Vunzige Deuntjes Festival 2016 (day 1)	30-07-2016
Vunzige Deuntjes Festival 2016 (day 2)	31-07-2016
Zeezout Festival	03-09-2016
VunzigeDeuntjes Festival 2017 (day 1)	29-07-2017
VunzigeDeuntjes Festival 2017 (day 2)	30-07-2017

The music styles were different between events, but could be seen as a good reflection of the of the current pallet of popular music styles from festivals in Amsterdam and surroundings. The layout of the festivals are identical each year. The layout covers the amount of stages and the sound source specifications and the position of those stages. In 2016 the festival lay-out included three main stages and one mini-stage. In 2017 it included 4 main stages and one mini-stage.

4.1.1 The surrounding area

Het Diemerbos is a park situated in the municipality of Diemen. Multiple municipalities border this park. In the west is the municipality of Amsterdam, in the east Weesp and in the north-east Gooise Meren. The event area is approximately 3 hectares and is centrally located within the park. Figure 9 shows the event area with the surrounding municipalities, the neighbourhoods in a range of 5.5 kilometres and in green the residential addresses.

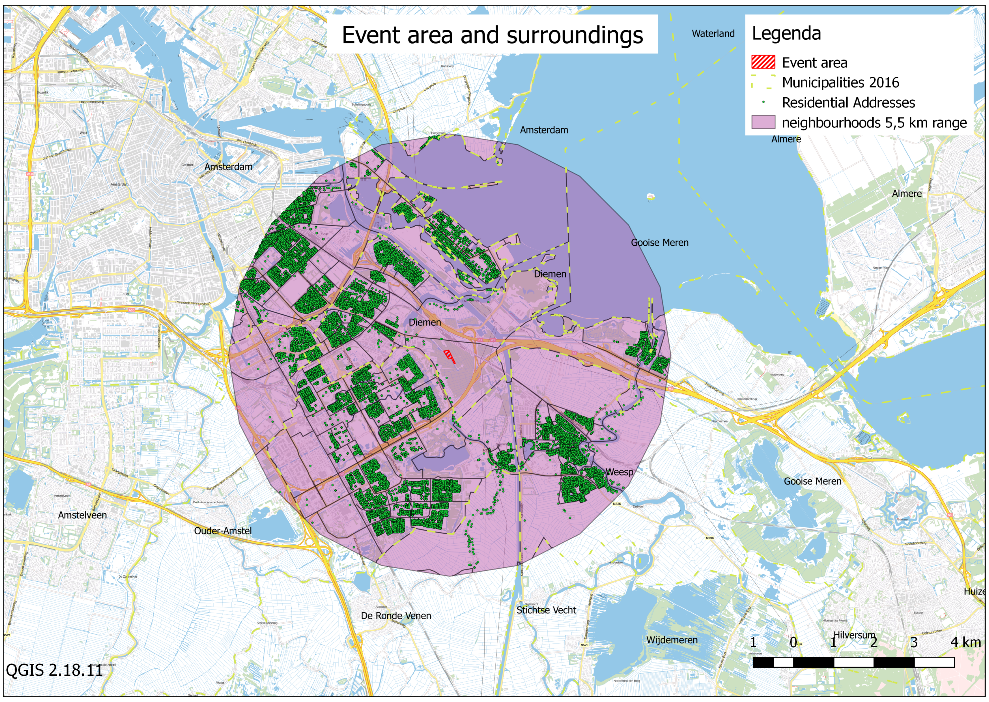


Figure 9: Event area and surroundings.

To gain insight in how complainers relate to people who do not complain it is necessary to define the maximum possible amount of residents that could complain due to noise nuisance, meaning who are able to hear the sound of the event. The neighbourhoods within a radius of 5.5 kilometres were selected from the dataset with the all geometries and key figures from the CBS (Statistics Netherlands)(6). This radius is an estimation and it was based upon the fact that the maximum sound pressure level at the façade at the nearest residential house could not exceed 65 dB(A). The nearest residential house is approximately 300 meters away. By considering the sound source as a point source a 6 dB reduction occurs if the distance from the source is doubled (23). With a radius of 5.5 kilometres it is certain the sound pressure will be 40 dB or less with this safety margin the radius of the focus area was chosen.

The focus area covers 164 neighbourhoods (6). The amount of residents was determined by clipping all addresses within the focus area from the BAG (Basisregistraties Adressen en Gebouwen, Official registration of addresses and buildings)(20) and multiplying the amount of residential addresses with average household size from that neighbourhood. The residential addresses were filtered to select only the addresses that were actually in use. The amount of residential addresses in the focus area is 98707 with an approximate of 193380 residents. The point layer with all the residential addresses in the focus area will be enhanced with several spatial attributes as mentioned in Section 3.5.2.3, this will be discussed in Section 4.3.

To inform the residents around the Diemerbos about the upcoming events a letter was send. It was send to approximately 2400 addresses. The distribution area of the letter was decided by the municipality and the event producer.

4.1.2 Legal limits

According to the legislation of the municipality Diemen an event organizer of a large outdoor event (upwards of 500 visitors) is obligated to apply for an event permit. The permit application must include the expected noise levels (27). It should be an acoustic report that includes source levels, sound spectra, duration, locations and if the event will comply with the predetermined noise limitations.

For each year (2106, 2017) an event permit was provided with the agreements under which conditions the events should be held. For the scope of this research several relevant requirements were imposed. Table 2 displays these relevant restrictions.

Table 2: Legal limitations

Date	start time	end time	limit dB(A)	limit dB(C)
23-07-2016	12:00	23:00	65 dB(A)	83 dB(C)
24-07-2016	13:00	23:00	65 dB(A)	83 dB(C)
30-07-2016	12:00	23:00	65 dB(A)	79 dB(C)
31-07-2016	13:00	23:00	65 dB(A)	79 dB(C)
03-09-2016	12:00	23:00	65 dB(A)	83 dB(C)
29-07-2017	12:00	23:00	65 dB(A)	83 dB(C)
30-07-2017	13:00	23:00	65 dB(A)	83 dB(C)

The decibel limits are related to specified positions where a sound level meter will be placed by the municipality. These positions are chosen because of the geometrical proximity to the nearest residential buildings. The nearest residential buildings and the positions of the sound level meters can be seen in Figure 10.

4.2 IMPLEMENTATION OF THE NOISE MEASUREMENTS

The noise measurements are the central dataset to be able to answer the research questions. The measurements are used to verify the accuracy of the prevailing noise model and the enhanced noise model and to determine the relationships between the nuisance complaints and the noise. This subchapter will elaborate about the gathered data and the steps that are done to prepare it for analysis.

Three parties helped to create the dataset. Engineering firm *DGMR* made it possible to do noise measurements at the locations of the nuisance complaints by making a sound level meter available. *Chasing the Hihat* used sound measurement equipment at (almost) every stage and at the two residential measurement positions. The data from this set-up was made available for this research. Lastly the *Municipality of Diemen* who gathered noise data at the two residential measurement positions and at a position to the

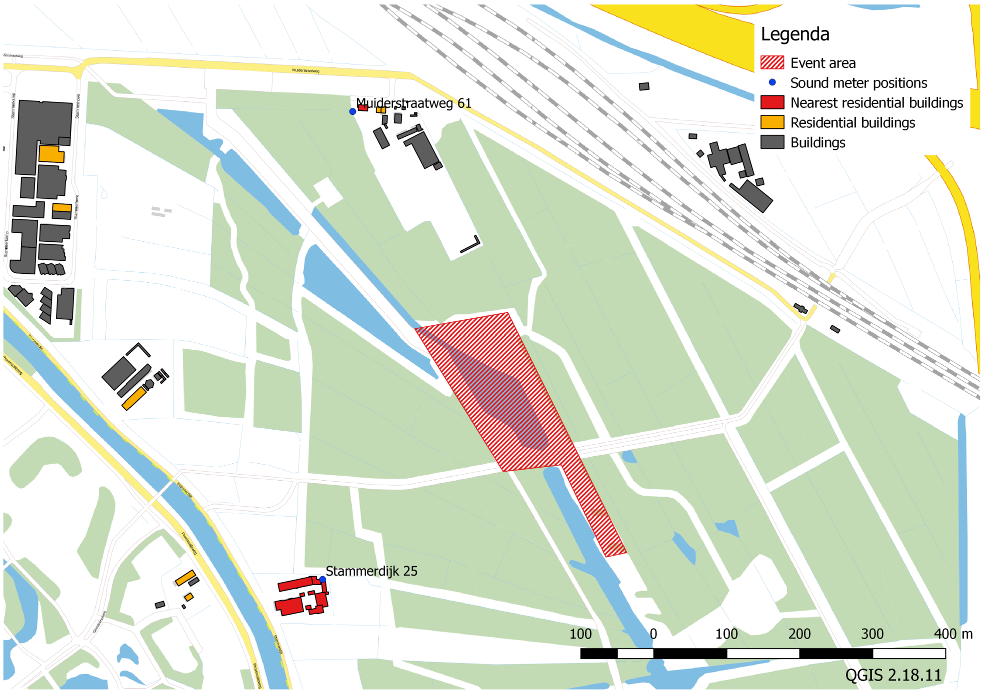


Figure 10: Sound level meter positions

east of the event (only in 2016) was willing to share the data as well. The result of this collaboration is more than 500 megabyte of data. An average of seven fixed noise measurement stations constantly measuring every event and next to that 21 noise nuisance measurements.

4.2.1 Data inventory

This subchapter will describe the measurements systems that are used, their locations and the data they produced. In both years every main stage was equipped with a *MeTrao* measuring station. In 2016 this were three stages and in 2017 four, both years the mini-stage was excluded from any measurement due to the minimal amount of sound power compared to the other stages. The location of the residential stations remained the same both years and was exactly positioned next to the sound level meters deployed by the municipality. The location of the *MeTrao* stations for both years can be seen in Figure 11.

The data gathered during the seven events is stored at the server of *Event Acoustics*. For each measuring station the data was extracted for each second. This is around 43 thousand lines per measuring point. The attributes include many different fields such as Leq (equivalent continues level) in dB(A) and dB(C) for multiple time-frames, but most importantly it includes spectral data from 25 Hz upward to 10 kHz. Spectral data is essential to better understand the propagation and perception of the noise.

4.2.1.1 Munisense *system*

The *Munisense* system was deployed by the *Municipality of Diemen* to monitor the noise levels at the positions specified in the permit. The goal is to be able to act instantly when the prevailing noise limits are being breached.

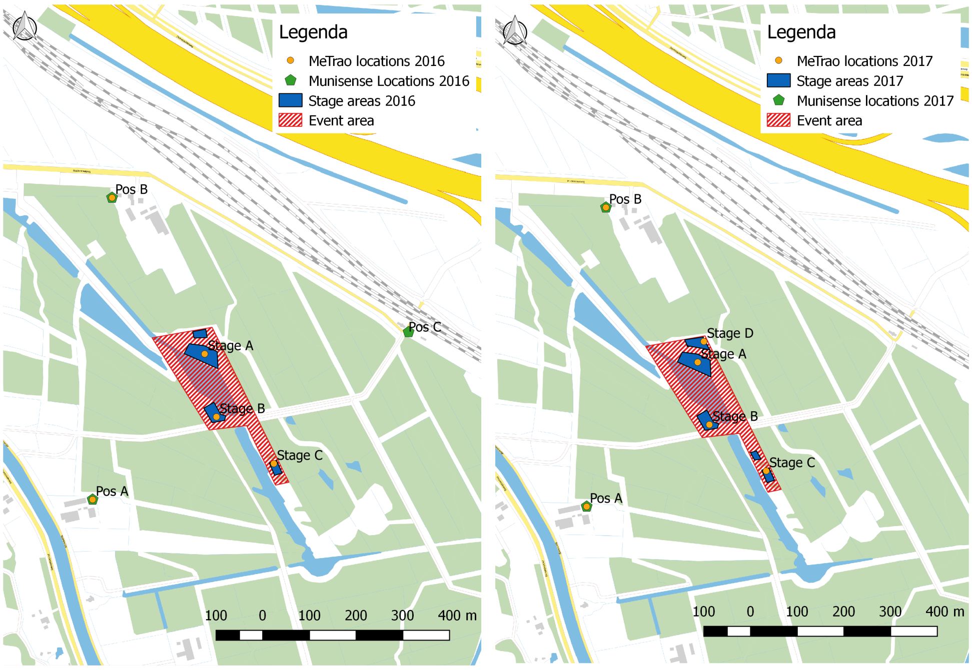


Figure 11: left, 2016 sound meter positions. Right, 2017 sound meter positions.

The system is made by *Munisense*, a company specialized in real-time and on-line measurement and control solutions. The stations are essentially sound level meters attached to a 4G-router to be able to upload the data continuously. Figure 12 shows the system next to the *MeTrao system* placed by *Chasing the Hihat*. Besides the two specified positions referred in the permit in 2016, the municipality placed a third station east of the event area. This was purely done to gain more insight, high noise levels did not have any legal consequences. In 2017 only the two legally binding locations were monitored, the positions can be observed in Figure 11. The data that can be extracted from the *Munisense* server is limited compared to the *MeTrao* system. Two values can be extracted and those are Leq in dB(A) and dB(C) with a time-frame of 10 seconds.

4.2.1.2 *Noise nuisance measurements*

DGMR made it possible to measure sound levels at actual locations residents experience nuisance. The goal was to get insight into upon which level of noise people decide to fill in a complaint. The sound level meter that was used is a *Bruel & Kjaer type 2250*, a high quality hand-held analyser. Capable of recording spectral data and a more than sufficient amount of diverse total noise values. The amount of visits that have been done is limited. This was due to the logistic challenge of gathering the nuisance complaints, contacting the nuisance notifier and travelling to the location. 21 visits and thus mea-

Figure 12: Both systems next to each other at position B, left is *Munisense* sound level meter and right the *MeTrao* sound level meter.

surements have been done spread over five event days. The noise nuisance measurements are all linked to noise nuisance measurements and stored in a list with an unique identifier to link it with the right complaint.

4.2.2 Cleaning the data

Although all data are valuable different parts of the noise measurement dataset will be used for specific ends. The noise measurements at the stages will be specifically used to see whether sound characteristics have a relation with the amount and time of nuisance complaints. To do this raw spectral data is required. The stage measurements will also be used to adequately determine the best input data for the enhanced acoustical model. To prepare the data for this purpose first a validation is made upon the quality of the measurements. All three systems are equipped with class 1 (highest level) sound level meters. The two fixed systems are often calibrated and checked according to the responsible vendors. The *DGMR* sound level meter was calibrated by myself before every measurement day. To decide from which system the data will be used for analysing the noise level at the positions where there was more than one meter, a comparison is done. This is also to verify the quality of the sound level meter. If both are calibrated correctly the discrepancies between the data should be minimal.

A sample of three hours was chosen from both datasets. The result can be seen in Figure 13. There is a slight difference, but the mean difference is only -0.001 dB and the standard deviation is 0.27 dB. For the scope of this research this result is amply sufficient. The *MeTrao* data will be the desired data set to use because of the spectral data it contains. The *Munisense* data will be used to detect or validate anomalies and when the *MeTrao* data is not available.

As expected there were several difficulties with the noise measurements. Equipment failures due to loss of internet connection, rain or loss of power. To find these contaminations, the total noise levels from every measurement point was plotted for every day. Flat lines indicate a malfunction, these parts were cut out from the analysis. Figure 14 depicts such a plot where flat lines are clearly visible. Another peculiar phenomenon in this example is that the noise measurements at the resident control points (red lines) have clear

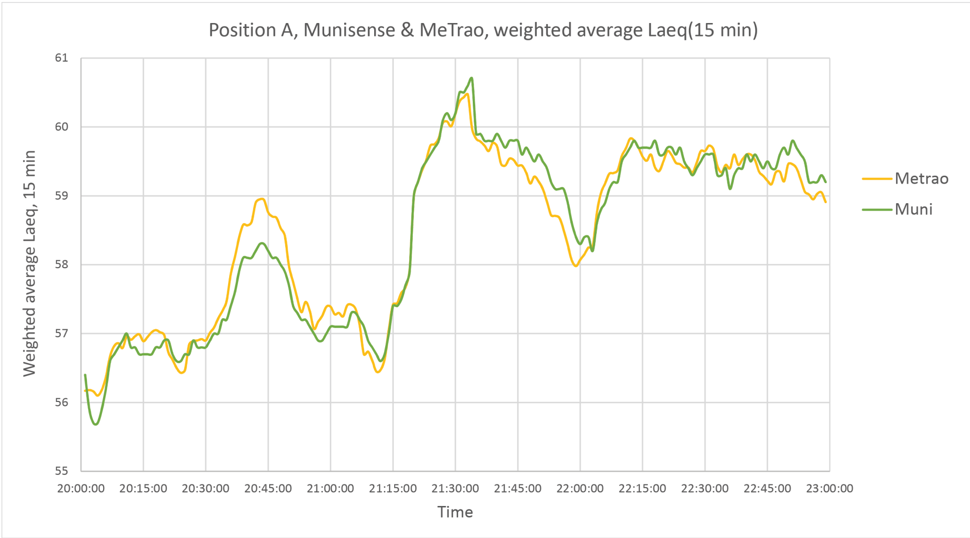


Figure 13: Laeq of *Munisense* and *MeTrao*.

fluctuations that are visible in both lines. These lines do not match with the peaks visible from the FOH measurements and it is highly unlikely they are the cause of music from the event because both points are close to different music stages and far apart from each-other. This turned out to be air-planes that fly over, the air-planes actually made more noise than the allowed maximum noise limit of the event. An example of how environmental noise can contaminate noise measurements, and the dubious situation where the apparatus that is meant to monitor whether the event does not break the law is consecutively breached by air-planes.

Figure 14: Laeq of *Munisense* and *Metrao*

All *MeTrao*-data was filtered from anomalies and stored in lists with a timestamp, LAeq, LCeq, and the unweighed spectral data from 25 Hertz till 10 Kilohertz.

4.3 IMPLEMENTATION OF THE NOISE NUISANCE COMPLAINTS

The goal was to have every complaint directed to the event processed by *festivaloverlast.nl*. There was a range of residents that were informed with a letter about the events and the website, sadly this was only 2% of the total amount of addresses in the focus area. A decision made by the municipality based on proximity and previous experience. To channel more complaints towards this research nuisance database a collaboration was made with Mr. Friebel, the inspector of enforcement from the municipality of Diemen. Diemen is the responsible municipality were the event was held and covers the most amount of possible affected residents. If a resident phoned the municipality to fill in a complaint the telephonist would fill in the complaint straight into *festivaloverlast.nl*.

Because of this very complimentary collaboration it is now a fact that *festivaloverlast.nl* has collected exactly the same amount of complaints as the municipality. Although this might not be every resident that felt annoyed by the event, and residents might have complained towards a different municipality or a different cause got the blame, but it is the same amount as is used to asses the impact of the event by the local institutions.

4.3.1 Data inventory

The website started to gain more attention than expected, the complaints about festivals were reported from all over the Netherlands. Probably the name of the website, namely festival nuisance is a popular search term for residents whom try to find an outlet to complain. It shows also the need to have a hotline for this specific form of annoyance. Figure 15 visualizes all complaints gathered with the website.

A total of 103 complaints were gathered during the 7 events, 90 of those included noise nuisance. The locations per event are visualized in Figure 16. Except a few outliers all complaints fall within the buffer-zone of 5.5 kilometres as discussed in Section 4.1.1.

4.3.2 Cleaning the data

An unforeseen difficulty was the amount of residents that complain the following day or even days later about their experienced annoyance. This will make the temporal and the acoustical analysis with the noise measurements impossible because the time-stamp can not be linked with the noise levels. These complaints will be left out of those analyses, the spatial analysis is still possible. 21 complains were made outside opening hours of the events.

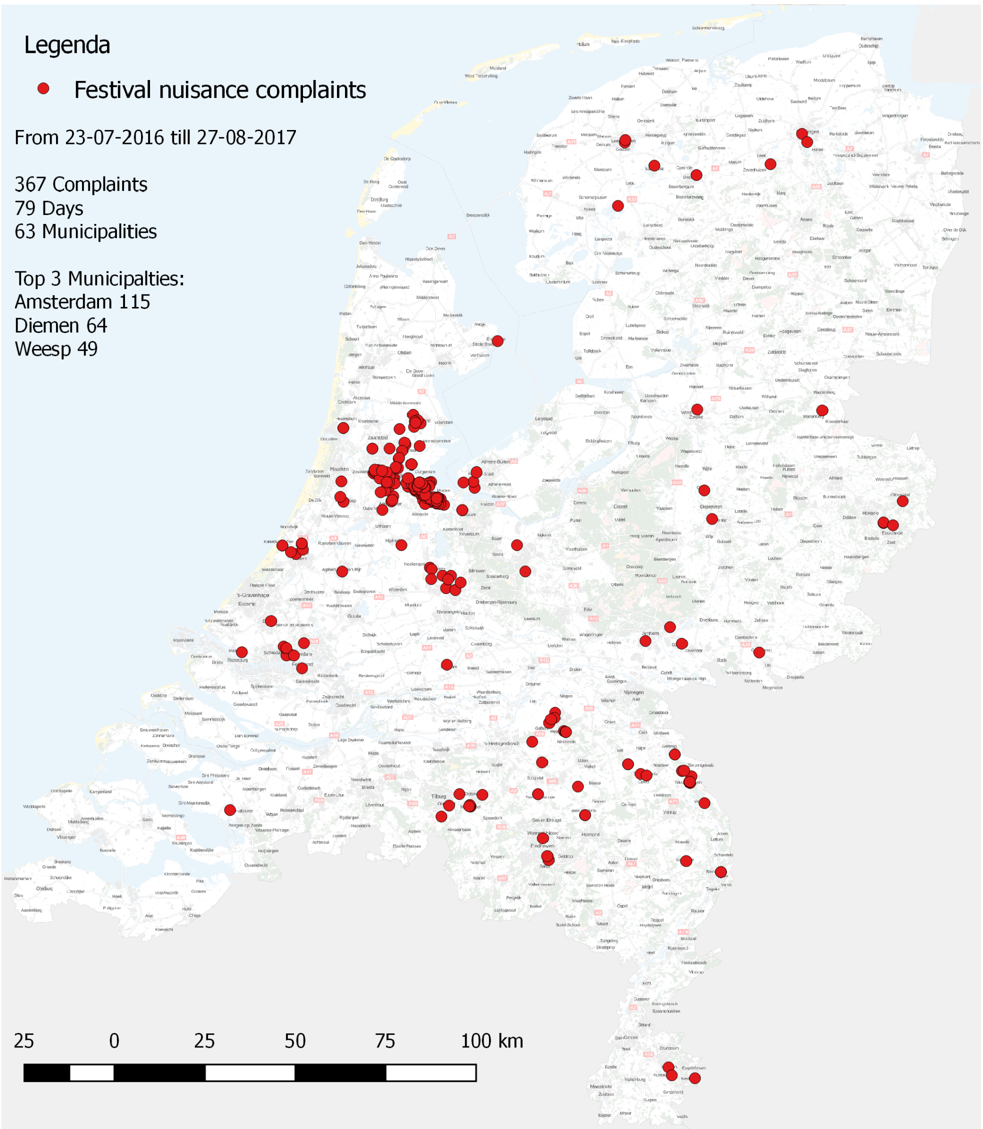


Figure 15: All complaints gathered with *www.festivaloverlast.nl*.

Another unforeseen difficulty was the amount of residents that complain multiple times. The question whether a complaint from the same resident counts as a new complaint is disputable. The choice is made to analyse only one complaints per resident per day, namely the first. The assumption is that the consecutive complaints during the same day are more a result of frustration that the nuisance is still present. Another reason is that also the municipality does not treat a second complaint as a separate complaint. These complaints were left out from analyses. There were several serial complainers, a common occurrence according to Mr. Friebel, it is known that those residents often find outlet for their annoyance concerning the public order. Figure 17 shows a histogram how often residents complain, for most residents a single complaint suffices.

Thirdly a very inconvenient setback was the presence of two other outdoor music events at the Gaasperplas. The Gaasperplas location is at a 2.3 kilometres distance south-west from the Diemerbos and falls within the responsibility of the municipality of Amsterdam. This means that there were

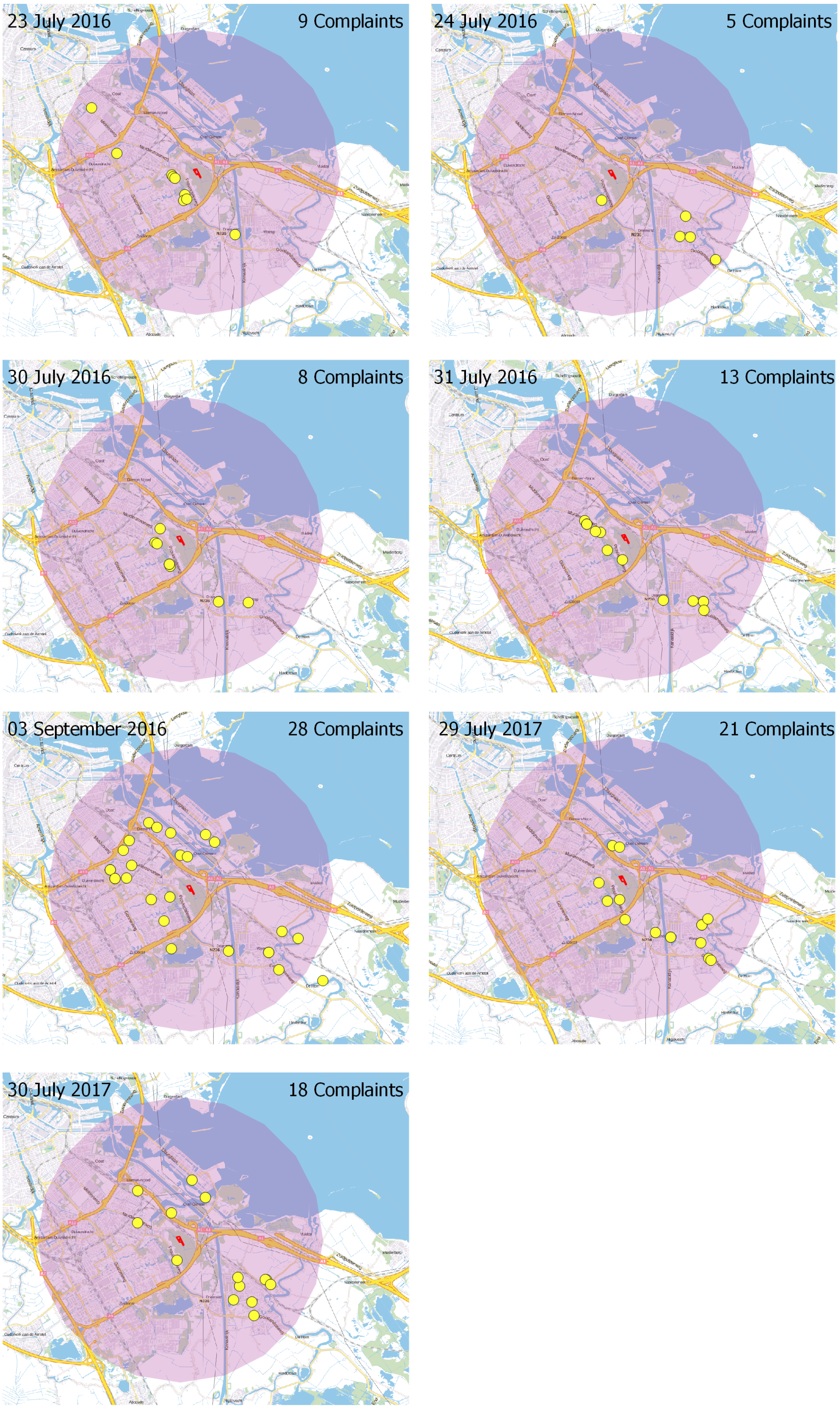


Figure 16: All complaints gathered with *www.festivaloverlast.nl* related to the 7 events of the use-cases.

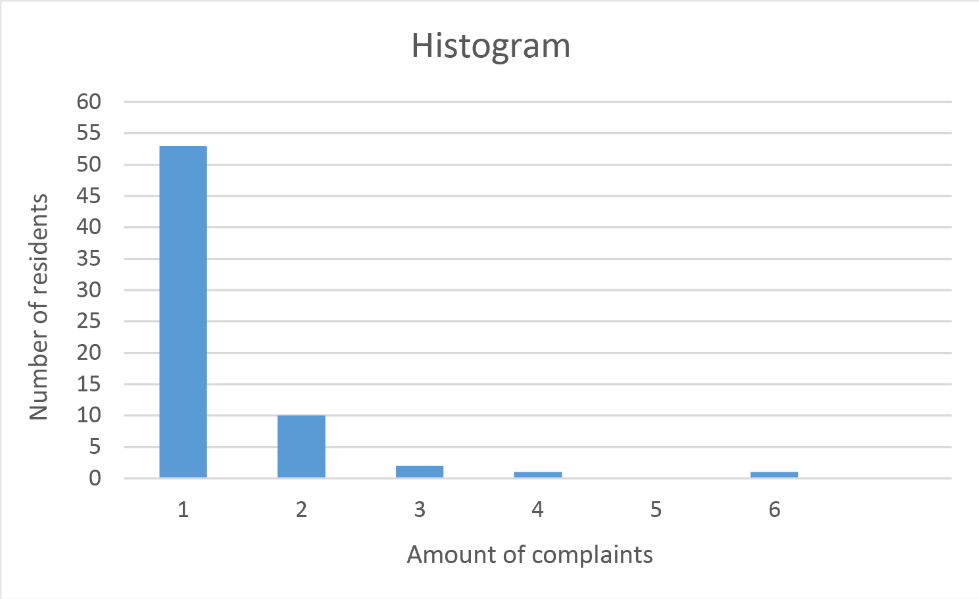


Figure 17: Histogram of complain frequency.

residents who heard both events or who mistakenly complaint about the wrong event. During these days only the complaints that the municipality of Diemen labelled as being connected with the Diemerbos are involved in the analysis.

The cleaned noise nuisance dataset was imported into a geographical information system. The same spatial attributes are added to the residential addresses as to the noise nuisance complaints. These are essential for the spatial analysis.

With the use of a geographic information system hub-lines were constructed from every complaint to the focus point of the event area. The hub-lines contain the euclidean distance and are used to determine the amount of diffractions with the buildings. The cardinal attribute was calculated by taking the azimuth between the focus point of the event and the location of every complaint. Sight-lines from the speakers are constructed by drawing a perpendicular line from every stage. All the calculated attributes were added to the original nuisance point layer. Finally the the points were extended with the CBS and the BAG data from the corresponding neighbourhood and building to add the average income and the buildings' construction year. Figure 18 show the nuisance dataset within GIS with the hub-lines and the diffraction points.

4.4 IMPLEMENTATION OF THE NOISE PREDICTIONS

First the quality of the noise levels from the prevailing noise model will be analysed. Secondly the enhanced noise map will be made with the knowledge gained from the analysis. This subchapter will discuss the steps that are done to recreate and understand the noise model and the accuracy validation using the noise measurement datasets. Subsequently the new gained understanding will be used to develop an enhanced noise model.

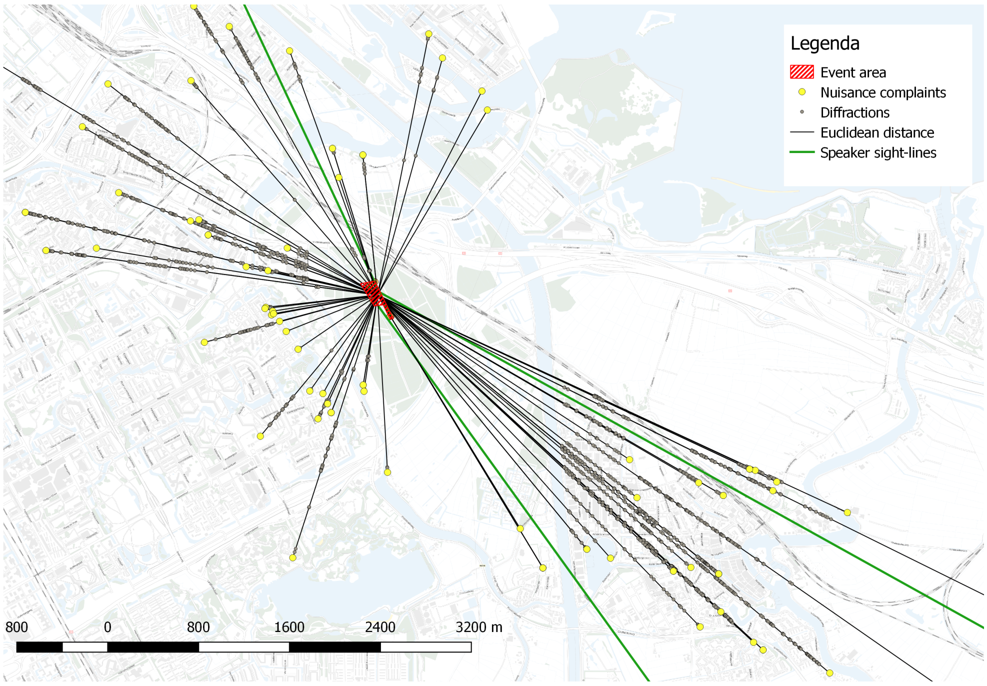


Figure 18: The creation of the spatial attributes needed for analysis.

4.4.1 The prevailing noise model

The acoustic report that was offered to the Municipality of Diemen to apply for an event permit is handed over by CTH. This report includes the following chapters.

1. Introduction and summary
2. Representative operational situation
3. Acoustic modelling
4. Acoustic facilities
5. Calculation results
6. Measurements during event
7. Annex A Input data *Geomilieu*
8. Annex B Calculation Results *Geomilieu*

4.4.1.1 *Understanding of the prevailing noise model*

To be able to reproduce the noise model and thus the predicted noise levels the following questions must be answered as a preliminary research. With those answers the reproduction of the model is done.

WHICH SOFTWARE IS USED? The signature of the data extract in Annex A and B show *Geomilieu V3.11* was used to obtain the results. There is further no sign in the report that any other software was used.

WHICH SOUND PROPAGATION MODEL IS USED? In the third chapter it is states that the calculations are made according to the manual for measuring and calculating industrial noise 1999 (*HMRI*). This propagation model is available in *Geomilieu*.

WHAT DATA IS USED TO CREATE THE ENVIRONMENT MODEL? To be able to calculate the noise levels in *Geomilieu*, an environmental model of the surroundings must be made or imported. Next to the visual aid it is also important because the environment influences which attenuations are included in the propagation model. Unfortunately the report does not include an extended description of the datasets used to make the model. There is a depiction of the model in the appendix of the report as can be seen in Figure 19. The legend of the map shows three kind of items next to the sources and the calculation points, namely soil-type, buildings and altitude lines.

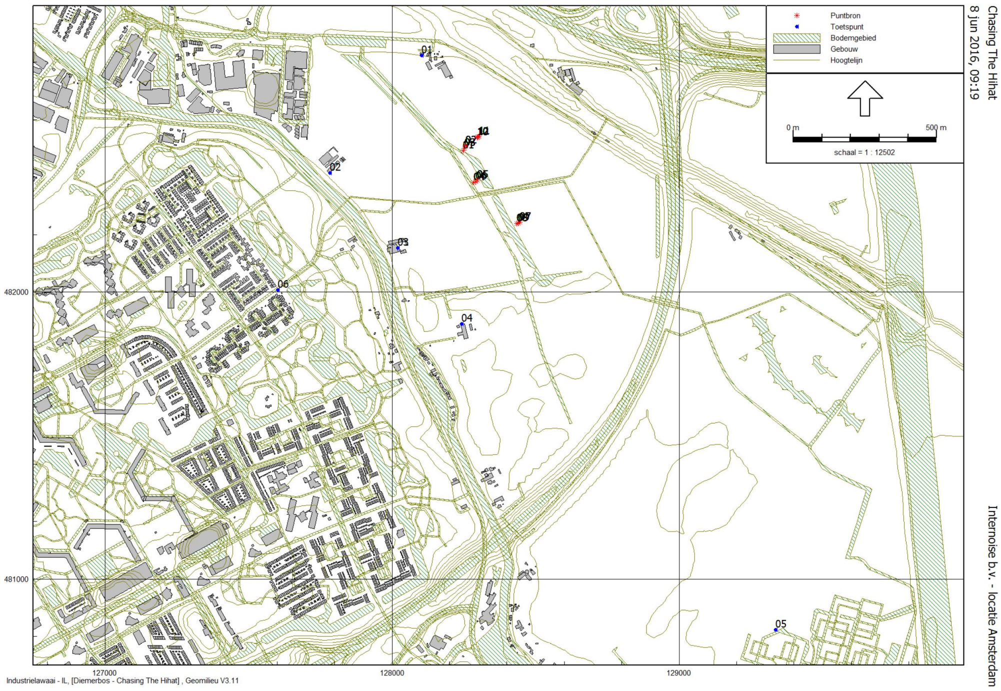


Figure 19: Representation of the *Geomilieu*-model used in acoustic report (37).

The soils have an absorption value, this is not described in the report although it influences the propagation. Figure 19 is compared to the TOP10NL map (20) seen in Figure 20. This implies that roads and water-surfaces next to ground-soils were modelled as well. Also it should be noted that the new A9 highway junction with the A1 is not modelled thus the imported environmental model is older than 2016. If other soil-types were modelled cannot be confirmed based on the acoustic report. Building polygons are visible in Figure 19. The building polygons look similar to the BAG (basic registration of addresses and buildings). It is unclear which building heights are used and which reflection factors are included. These input variables all influence the propagation model. The altitude lines do not match those in the TOP10NL map. They seem to be in greater detail, a possible explanation could be that those lines are self-made contours made from the AHN2, (Actueel hoogtebestand Nederland) the actual height map of the Netherlands.

Figure 20: The TOP10NL map of the area, with the new A9 highway junction.

WHAT ARE THE SOURCE SOUND LEVELS AND SOURCE CONFIGURATIONS? The source power of the speakers is said to be based on a sound pressure level of 98 dB(A) and 113 dB(C) at a 25 meter distance from the source. It is mentioned that with use of the standard house-spectrum and own experience with these installations a source power level is deduced. The following source power levels are used:

- Podium A: 130 dB(A)
- Podium B: 128 dB(A)
- Podium C: 127 dB(A)
- Podium D: 124 dB(A)

The speaker set-up is divided into the different speakers consisting out of line arrays, sub-woofers and stacked P.A. (public address system). The individual speakers are given different heights, locations, sound spectra, directivity and angles. The exact configuration can be found in annex A in the acoustic report, in appendix 2 a cut-out of the specifications is placed.

WHAT IS THE LOCATION OF THE CALCULATION POINTS WHERE THE NOISE LEVEL ARE PREDICTED? Six calculation points are located on the facade of the nearest residential houses, two of those are similar as the residential control points where the sound measurement equipment is placed. Annex A in the report show the exact specifications, in appendix 3 a cut-out of the position specifications is placed.

WHICH ATTENUATIONS AND REFLECTIONS WERE INCLUDED? It is mentioned that the *HMRI* is pursued concerning all attenuations. It is not mentioned what the absorption/reflections values for the buildings and soil types are. The map in the report does not rule out the use of the vegetation, screen and terrain attenuation. But it is assumed that it is not used else it would be mentioned in the report or denoted in the legend of the map.

WHAT WERE THE CALCULATION SETTINGS? There is no mention of abnormal calculations settings. It can only be read that there is no group-reduction, this is common.

WHAT ARE THE CALCULATED NOISE LEVELS? The calculated noise levels are given for each calculation point and can be found in annex B. The results are in decibel and are A-weighted. In appendix 4 a cut-out of the noise levels for a calculation-point is placed. The contribution of each podium to the sound pressure level of the calculation point is given as well. Notable are the missing values of two octave-bands, namely 31.5 hertz and 8000 hertz. It is the result of the missing source power levels for these octave bands.

4.4.1.2 *Reproduction of the prevailing noise model*

To reproduce the noise model the first step is the software. *Geomilieu V3.11* that is used in the report was introduced in October 2015. The software used to reproduce the model is *Geomilieu V4.30*, the newest edition, introduced in June 2017. This should not have any influence upon the results, since the updates did not change the propagation model (DGMR). In the software a new project was opened and the IL (industrial noise)(*HMRI*) propagation model was chosen.

The configuration for the source sound power levels and the locations of the calculation points could exactly be replicated from the report. To recreate the environment model *QGIS* was used to be able to adjust the data before importing into *Geomilieu*. The creation of the environment model started with the building polygons. The BAG 3D was extracted from *Esri Nederland*(8). *Esri Nederland* offers content for the their GIS application *ArcGIS*. The content was made using the the BAG data from *Kadaster* and the elevation data from *AHN2*. This dataset includes building polygons with height.

Another element that is clearly visible in the noise model are the soil areas. As mentioned in Section 4.4.1.1 it seems only water and road areas are included. The water data set was downloaded from the *BGT*, national registration large-scale topography map, and analysed in *QGIS*. With the use of an area calculator the water parts were filtered upon size because it seemed the acoustic report only included larger water areas. When the surface was below 2500 square meter it was extracted from the dataset. This produced the most similar result. The road data set needed filtering as well. The dataset extracted from the *BGT* included the attributes with the function and surface type of each feature. Therefore it was possible to filter out every road part that was unpaved or partially unpaved and the parts with the function; footpath on stairs and transition. This resulted in a data set similar to the one in the acoustic report.

The absorption factor of the soil types highly influences the propagation of noise. The *HMRI* distinguishes two main types of soil. A hard reflective soil with an absorption factor 0, examples as mentioned in the manual are:

water, concrete and asphalt. The other main type is the absorbing soil, with absorption factor 1, examples are: grasslands, arable land, forests and gardens. The features from the *TOP10NL* coverage indicate the soil type. All paved type features and water is imported into *Geomilieu* and labelled as a hard reflective soil all the remaining area is labelled as an absorbing soil.

As mentioned in Section 4.4.1.1 the lines that seem to be altitude lines according to the legend in Figure 19 do not match the altitude lines from *TOP10NL*. When comparing the elevation data in the acoustic report with an *AHN2* raster it did not match as well. While it is unclear which data was used it is important for the accuracy of the acoustic model to include altitude lines. Therefore it was decided to use *AHN2* data. The reasoning is although the lines do not match it is the accurate way of modelling ground level and it is assumed that this was the goal in the acoustic report too. *AHN2* Raster data that is filtered from man-made objects can be retrieved from the public available Dutch dataset database (1). A contour extraction can be done in a GIS using the Geospatial Data Abstraction Library (GDAL). The digital elevation model in raster format is than changed to a vector file with contour lines at some regular increment.

The four shape-files (water, paved surfaces, elevation data, buildings) were imported into *Geomilieu*.

4.4.1.3 *The reproduction results*

The *Geomilieu*-software was set to calculate the sound levels at the six calculation-points. The predicted noise levels and the deviation with the noise levels from the report are shown in Table 3. The spectral results were compared as well and the average difference can be seen in Table 4.

Table 3: Reproduction of noise levels from prevailing noise model

Location	Old results	New results	Abs. difference
Muiderstraatweg 61-63	59.9	60.3	0.4
Stammerdijk 23	61.6	62.0	0.4
Stammerdijk 24-25	63.7	64.0	0.3
Stammerdijk 29	63.2	63.3	0.1
Frankendael	51.7	52.7	1.0
Geerdinkhof	57.1	57.6	0.5

Table 4: Average spectral variance between reproduction and prevailing noise model

Frequency band	63	125	250	500	1000	2000	4000
Average variance	-0.7	-0.2	-0.1	-0.1	-0.2	0	0

According to the *HMRI* results should be reproducible. This means that within the constraints of the methodology the same results in a set range of accuracy should be obtained. The accuracy range should be within 2 dB according to the manual. The results achieved in the reproduction of the noise model are inside this margin and could be labelled as a correct reproduction of the noise model.

The acoustic report did not include a noise map made from the predicted noise levels. It only included the results at the residential control points. A noise map can be made using the reproduced noise model. A noise map visualisation will give a greater overview of the expected noise levels as assumed in the prevailing noise model. For this reason a noise map was made from the reproduced noise model. Figure 21 shows the noise map made from the reproduced noise model. It is made by adding a grid of calculation points at a height in the *Geomilieu* model. *Geomilieu* calculates the noise level at each grid point and subsequently interpolates the results. The raster size of the grid determines the resolution of the noise map. A smaller raster size increases resolution but also computing time. The contour shapes can be exported from *Geomilieu* and imported into a GIS for further visualisation possibilities. The noise map shows how buildings obstruct the propagation of noise and how the direction of the speakers was aimed to avert residential areas.

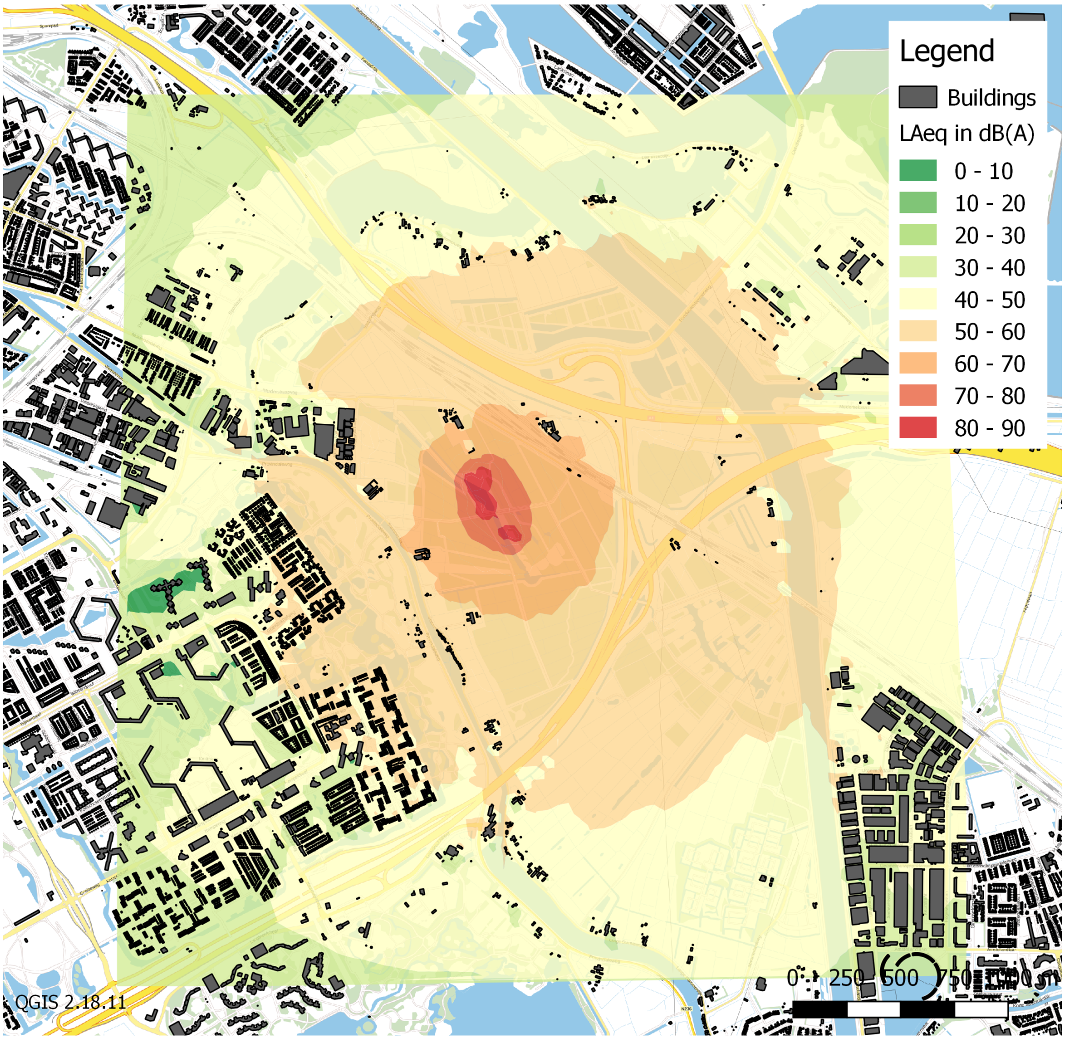


Figure 21: The noise map based on the reproduced prevailing noise model. The contours are based on 3700 x 4000 m grid with a raster size of 50 metres at a height of 5 metres.

By reproducing this noise model several remarkable findings were noted. If the goal is to model an environment as realistic as possible, than it is clear that there are several elements left out in this model. Although there are limitations of *Geomilieu* and the *HMRI* methodology the following elements could have been incorporated.

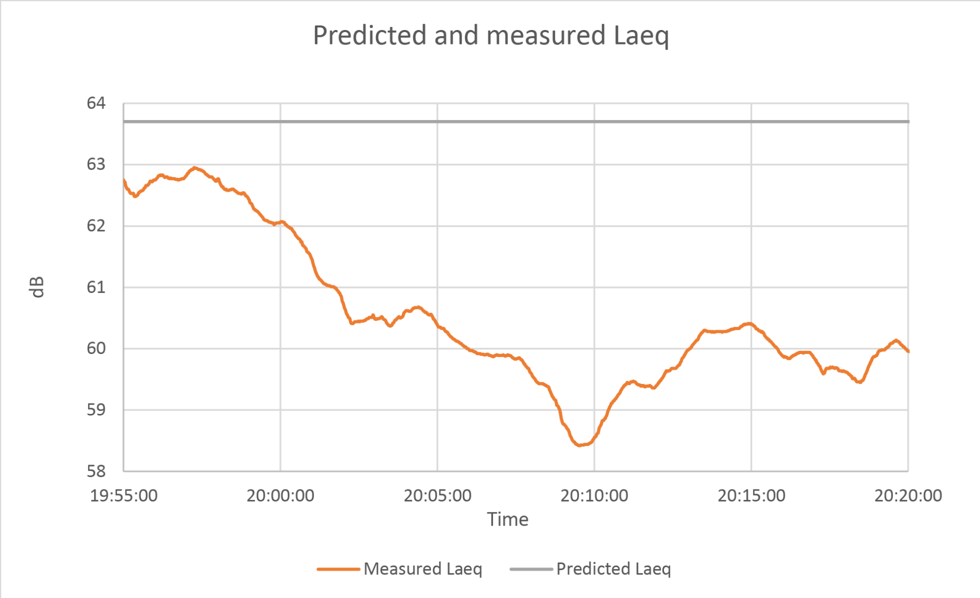
- Vegetation, the Diemerbos is a park and the sound-rays do cross at least 300 meter of trees. This has not been taken into account.
- The altitude lines that are used seem incorrect.
- Missing man-made objects like a new highway junction.
- An overall higher level of detail within the environmental model is possible.
- The source power levels that are chosen do not have any power in the lower octave band and in the highest. The lowest band than can be modelled in *Geomilieu* is 31.5 hertz. None of the sources had any source power on that octave band. This seems incorrect because the spectrum of the music that is played on these events mostly do have a significant amount of energy in the lower frequencies and subsequently the sound in the lower frequencies have been seen as the big culprit of noise complaints.

The reproduced results did not correspond exactly with the prior results from the acoustic report. The most probable reason for this is the different altitude lines. By far the largest difference was encountered at calculation point Frankendael, volkstuinvereniging. This location is not seen as an official measurement point in the eyes of the municipality because it does not refer to a residential building close to the event. The calculation points that refer to the residential control points are Stammerdijk 24-25 and Muiderstraatweg 61-63. The error margin of the reproduction was minimal on those points.

4.4.2 Analysis of the prevailing noise model

This subsection will describe the analysis of the prevailing noise model, this part is entwined with the analysis of the noise measurements. The goal is to list the possible improvement that can be applied in the enhanced noise model, this is done by reviewing the accuracy of the prevailing noise model and searching for the accurate input using the noise measurements. The questions as mentioned in Section 3.5.1.1 are the guideline for the analysis.

HOW ACCURATE ARE THE NOISE LEVEL PREDICTIONS FROM THE PREVAILING ACOUSTIC REPORT? As mentioned in Section 3.5.1.1 the acoustic report is based on a hypothetical moment in time where all speakers are producing their maximum allowable power. To compare the accuracy noise measurements must be used that depict such moment, next to that the meteorological conditions can not divert from the standard conditions the *HMRI* are based



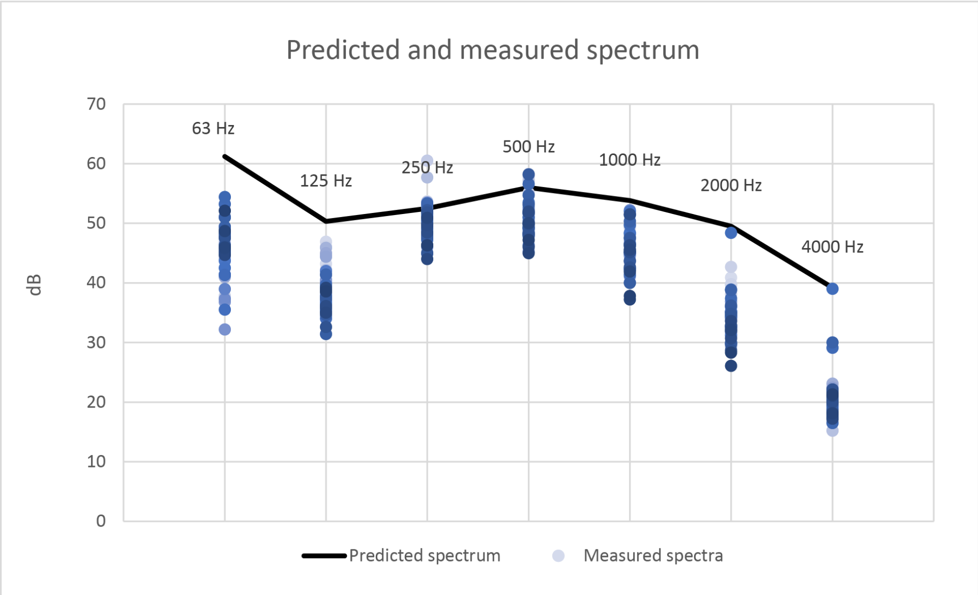


Figure 22: Comparison between the noise measurements and the predictions, above the LAeq and underneath the spectral comparison.

on. The wind should not exceed 2 meter per second and no extreme hot temperatures or precipitation. By using KNMI (The Royal Netherlands Meteorological Institute) data from the nearest meteorological station a time-frame of 70 minutes was found that satisfied these strict meteorological criteria, that is 1.6% of the total cumulated opening hours of the event. A comparison was made between the measurements and the noise level predictions during a sample of this 70 minute time-frame at a residential control point. As can be seen in Figure 22 the predicted levels are higher than the measured values. Table 5 depicts the mean percentage error as a measure of accuracy and the standard deviation as a measure of precision, this is done for both residential control points A and B.

Table 5: Accuracy and precision results of comparison between noise measurements and the prevailing noise model.

Location	Predicted value	Measured mean	Mean percentage error	Standard deviation
		Laeq		
Position A	63.7	60.5	-5.3%	1.2
Position B	59.9	51.7	-16.4%	1.4
		63 Hertz		
Position A	61.2	45.6	-35.5%	4.1
Position B	58.1	34.9	-70.8%	3.8
		125 Hertz		
Position A	50.3	38.4	-32.1%	3.4
Position B	47.9	30.1	-63,.7%	4
		250 Hertz		
Position A	52.5	49.6	-6.2%	2.9
Position B	48.1	35.6	-37.3%	3.2
		500 Hertz		
Position A	56	50.5	-11.3%	3.2
Position B	49.9	38.8	-30.7%	3.5
		1000 Hertz		
Position A	53.8	45.4	-19.5%	4
Position B	48.9	40.7	-21.5%	3.3
		2000 Hertz		
Position A	49.5	33.7	-48.3%	3.1
Position B	45.9	34.7	-34.5%	3.1
		4000 Hertz		
Position A	39.2	45.4	12.9%	4
Position B	36.8	27.3	-38.5%	3,6

Table 5 and the graphs from Figure 22 show there is room for improvement. The noise measurements are almost constantly lower than expected. The differences can be really extreme at the octave bands while the difference in LAeq noise levels are in proportion quite acceptable. It was known that the noise measurement would not exceed the predictions due to the real-time correction of the sound-technicians. The differences that arise in spectral noise levels are because of the diverse nature of music and the limited amount of octave bands that can be used in *Geomilieu*. The speakers at the event disseminate sound on each possible frequency, but in the noise model this wide spectrum must be distributed among the possible octave bands. This is the reason why the cumulated LAeq prediction is more accurate than most of the octave band levels. It could be that often the dominant frequency of the music falls outside the standard spectrum distribution. This sample test was during conditions that match the criteria of the *HMRI* but it could be that the music at this moment was very different than expected, or very different than the other 74 hours.

This research is not constricted by the noise measurement conditions as prescribed in the *HMRI*. Therefore the offset of the predicted LAeq from the measured noise levels is visualized in Figure 23. This is every measurement at the residential control points when all speakers where at maximum volume no matter the meteorological conditions. Position A had a mean error percentage of -11% and position B -9%. The goal is to improve this error margin with the enhance noise model but first the cause of this error must be determined.

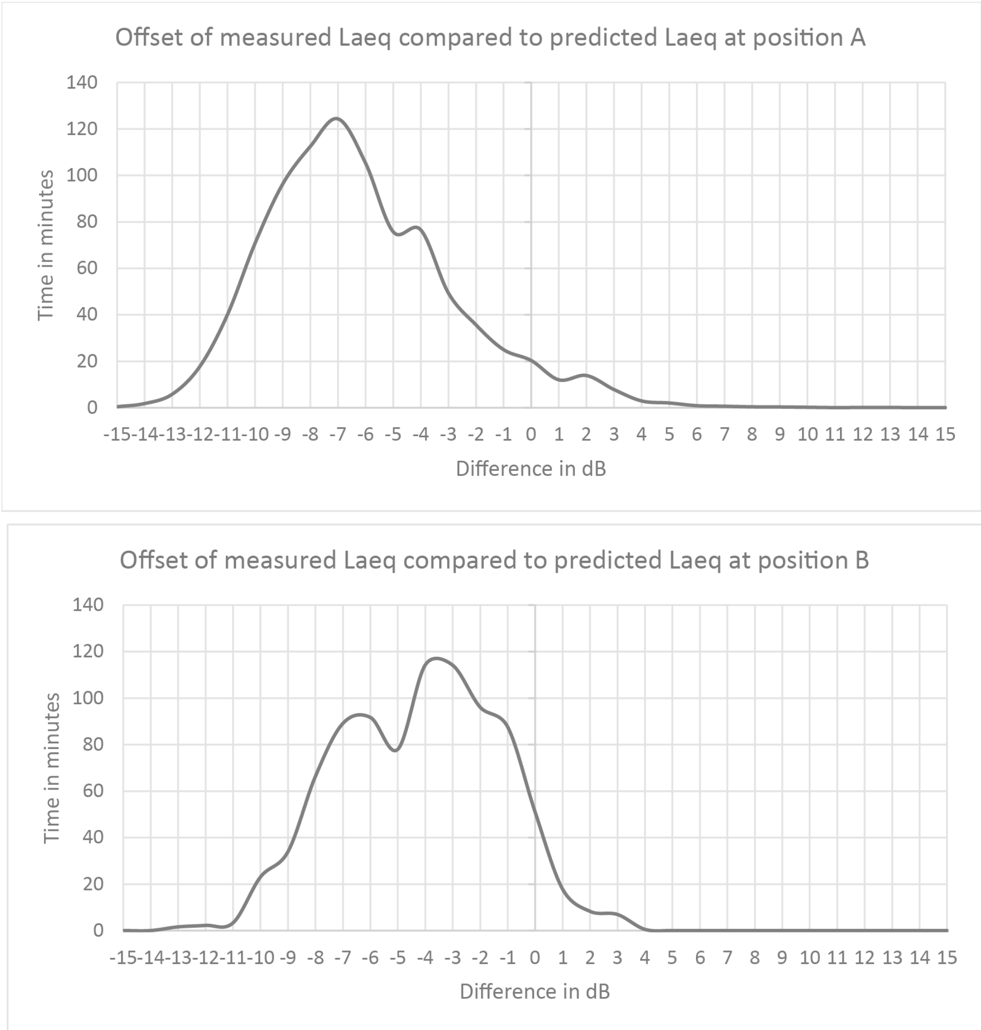


Figure 23: Visualised offset of predicted LAeq compared to measured LAeq for both residential control points for all events.

HOW ACCURATE ARE THE SOURCE SOUND POWER LEVELS? To answer this question three calculation-points will be placed in *Geomilieu* at the location of the FOH sound meters. After the noise-calculation of these points the values can be compared to the measurements. Both in real-life as in *Geomilieu* there are few till no significant attenuations or diffractions that influence the noise at such a close distance to the source. In the acoustic report it is mentioned that the source power of the speakers is chosen that the sound will generate a noise level of 98 dB(A)at 25 meter distance from the speakers. The FOH locations from the events were more in the range of 30 metres from the speakers and sometimes slightly out of plumb. The calculated noise levels were compared with the measured noise levels. First the same time-frame was chosen as in Figure 22 with the correct meteorological conditions as proposed in the *HMRI*. The accuracy of the sound power can be seen in Figure 24.

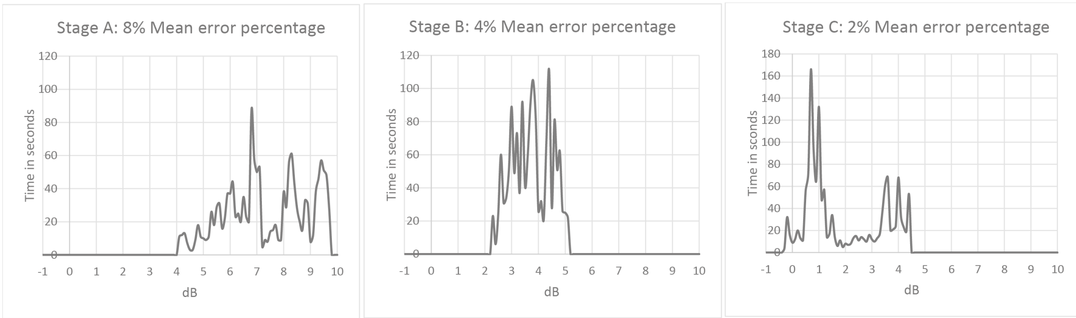


Figure 24: Visualised offset of predicted LAeq compared to measured Laeq every stage.

The predicted noise levels at the FOH are constantly lower than the measured noise measurements. This is contradictory compared to the constant higher predicted noise levels at the resident control points. Another notable feature is that the error margin is largest at the larger podiums and decreases when the podium increases.
The *HMRI* is not made for sound sources that are in phase with each other. This is probably the reason why the predicted noise levels at the FOH are lower. When sound sources are in phase with each other the amplitudes combine and instead of a 3 dB addition 6 dB is added. Sound technicians make sure the speakers are in phase at the FOH because uncorrelated sound sources do not deliver the sound that is desired. The larger stages have more of these correlated sound sources therefore the error margin is larger at stages with more speakers.

HOW OFTEN IS THE SOUND POWER LEVEL LOWER/EQUAL/HIGHER THAN IN THE ACOUSTIC MODEL? It is decided to treat the noise measurements as a continuous random variable. This is because the sound can have any value between a continuous range of values. It is random because any order of this sound can be music. To understand how often the noise model predictions were equal to the noise measurements at the FOH, the probability density functions of every stage are visualised in Figure 25. These are the measurements from all events when the music was playing. The area under the curve gives the probability that the difference between the predicted values and the measurements are between some interval, while clearly showing the mode and the distribution. The curves sudden stop at the negative side of the x-as represents the value of 100 dB(A). The sound technicians were astonishingly accurate to (almost) never breach the 100 dB(A) limit.
The probability that the noise measurement values differ less than 1 dB with the predicted levels from the acoustic model for every stage are:

- Stage A: 2%
- Stage B: 4%
- Stage C: 9%

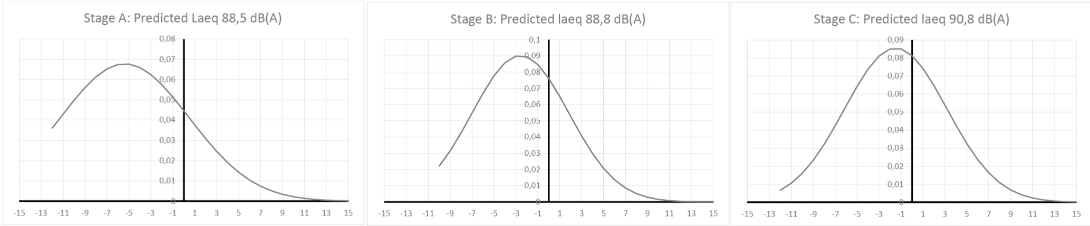


Figure 25: Probability density function of the offset between the predicted LAeq and the measured LAeq of every measurement at every stage.

HOW ACCURATE IS THE CHOSEN MUSIC SPECTRUM? In the prevailing noise model the same spectrum was used for all stages. This is common because although the music style is known it would probably be rather impossible to adjust the spectrum on the basis of the artist line-up, let alone the song choices. As mentioned before in Section 4.4.1.1 the standard house-spectrum was chosen in the acoustic model and only 7 octave bands were used while 9 could have been used in *Geomilieu*. The sound meters measure the lower, center and upper limit of a 1/3 octave band, therefore the predicted spectral levels were divided by three because they depict the combined energy of the octave band.

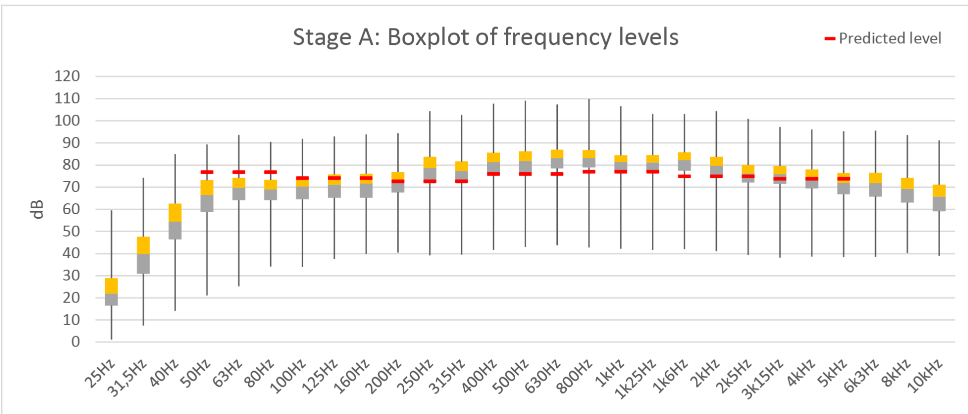
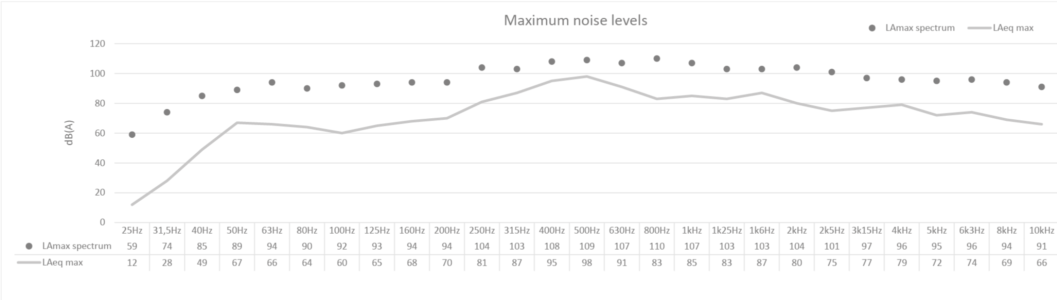


Figure 26: Box plot of the frequency levels in dB(A) and the frequency levels of the prevailing noise model in dB(A).

In Figure 26 a box-plot is shown of the measured dB(A) level per frequency from the FOH at stage A. A box plot shows with their whiskers the maximum and minimum value while the box itself depicts the first till the third quartile with the median in between. The red stripes are the spectral levels as in the prevailing noise model. The predicted levels seem to fit quite acceptable, but because decibels are on a logarithmic scale the highest values influence greatly the cumulated noise levels. If two levels are energetically combined and the difference between the two is more than 3 dB, the lower one would only contribute tenths of the total level, if they differ more than 6 dB the lower one would contribute only hundredths of the total level. The most dominant frequencies in the box plot are the 250, 500 and 1000 hertz, and on those frequencies the predicted levels are around 7 and 8 decibels lower. This can be seen as a cause of deviation between the FOH measurements and the prevailing noise model.

WHAT ARE THE (MOST EXTREME) SOUND LEVELS AND SOUND SPECTRA THAT OCCURRED DURING THE OUTDOOR MUSIC EVENT? From the box-plot of Figure 26 an assumption can be made what would be the most extreme sound levels and sound spectra. The maximum LAeq that was measured at the FOH is 101,3 dB. This could be seen as the maximal combination of frequencies that was measured. Figure 27 this spectrum is shown, what is also depicted are the extreme spectral values that have been measured, these only never took place at the same time.



	25Hz	31,5Hz	40Hz	50Hz	63Hz	80Hz	100Hz	125Hz	160Hz	200Hz	250Hz	315Hz	400Hz
LAmax spectrum	59	74	85	89	94	90	92	93	94	94	104	103	108
LAeq max	12	28	49	67	66	64	60	65	68	70	81	87	95

	500Hz	630Hz	800Hz	1kHz	1k25Hz	1k6Hz	2kHz	2k5Hz	3k15Hz	4kHz	5kHz	6k3Hz	8kHz	10kHz
LAmax spectrum	109	107	110	107	103	103	104	101	97	96	95	96	94	91
LAeq max	98	91	83	85	83	87	80	75	77	79	72	74	69	66

Figure 27: Box plot of the frequency levels in dB(A) and the frequency levels of the prevailing noise model in dB(A).

HOW WELL DID THE PROPAGATION METHOD PERFORM? The FOH data was filtered to find similar values as predicted in *Geomilieu*. At that moment in time the difference between the measurements at the residential control points and the expected noise values from *Geomilieu* will be a measure to test the propagation model. Stage B is the most dominant contributor to the noise levels at residential control point A for this reason the propagation between those two points will be analysed.

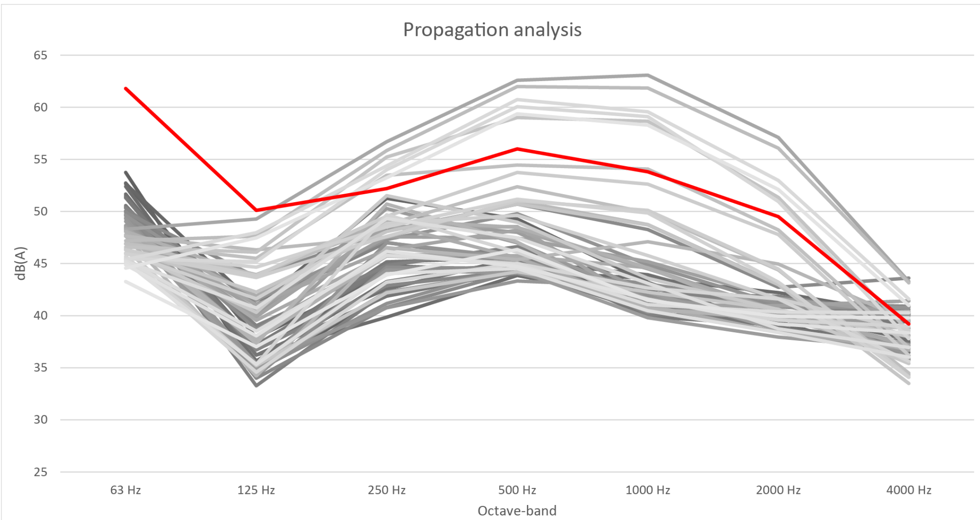


Figure 28: The grey lines are the measured noise levels per octave-band at position A while the FOH measurements are equal to the predicted values. The red line is the predicted noise level at position A.

Figure 28 depicts the great variances between predictions and measurements that occur at a distance even when noise levels close by are constant. It seems the propagation model attenuate less the lower octave bands than in real-life. The absence of the vegetation in the noise model could play a role in this discrepancy. On the total LAeq level the difference between the measurements and the predicted noise levels were on average 9 dB(A).

CONCLUSION The prevailing noise model was made for an hypothetical moment in time with meteorological conditions that were correct only 1.7% of the time during the events. The noise level predictions are constantly higher than expected while close by noise levels predictions were lower than measured. It is presumed the choice of sound spectrum has an important share in this result. The sound spectrum that was used in the noise model had a lot of energy in the 63 Hertz band while less in the 500 and 1000 Hertz compared to the measurements. The lower octave-bands cause for higher levels at the residential control because low frequencies are less attenuated and become the dominant frequency. Even close by at the FOH the low frequency was the dominant octave-band in the noise model while the measurements show a dominant frequency around 1000 Hertz. An assumption is that the music was less 'house' like and more 'pop' like than expected. The author of the acoustic report seemed accurate and knowledgeable about the speaker configurations and the emission angles, further more it is hard to understand what use it offered to the municipality. It showed that the speakers at maximum power would not violate the prescribed noise limits at the control points. It indeed did not, but this could also be the result of the sound-technicians' realtime adjustments. If noise nuisance is related to certain noise levels the use of this noise model to determine the levels would lead to results that rarely match the real-world situation.

4.4.3 The enhanced noise model

After gaining valuable knowledge when analysing the prevailing noise model this subchapter will discuss how this knowledge is used to create an enhanced noise model. The enhanced model will probably not be an improvement itself but rather a better applied and specified noise model for this particular situation. The prevailing noise model showed improvements can be made on multiple levels. The environmental model can entail a higher level of detail and accuracy. The sound source spectrum can be based on the noise measurements and the meteorological conditions should match the real world situations.

MULTIPLE METEOROLOGICAL SITUATIONS One of the most striking revelations was how seldom the meteorological conditions were as planned. The enhanced model should entail multiple conditions to make accurate noise level predictions. This is not common practice because the *HMRI* does not prescribe this.
A wind rose was made to determine the wind direction that most often occurred. The west-wind is overall the most common wind but on a daily basis heavy fluctuations can occur. The average wind direction and an example of the meteorological diversity of one day is visualised in Figure 29. In the *Harmonoise* propagation method it is possible to adjust all meteorological pa-

rameters, this enhancement will greatly influence the accuracy of the noise predictions.

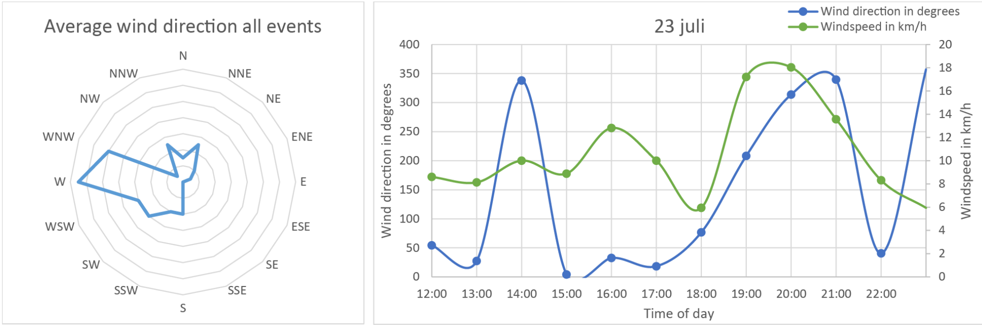


Figure 29: The average wind direction during all events on the left image, the right image shows the variation during the day.

THE ENVIRONMENTAL MODEL The environmental model will be modelled in greater detail than the prior environmental model from the prevailing noise model. Smaller water ways and roads will be implemented and an updated dataset of all man-made objects is imported. This will include the new highway junction to the east of the event area.
The *Harmonoise* method identifies eight categories of ground. The soil types around the event area will be classified correctly, this will influence the ground attenuation. The park in which the event is held, is influencing the propagation of sound but this was not incorporated into the prevailing noise model. To incorporate this will hopefully benefit the noise prediction accuracy.

SOURCE POWER AND MUSIC SPECTRUM The spectrum for the enhanced noise model will be based on the noise spectrum measured and visualised in Figure 26.
The prevailing noise model used a source power that is said to produce a sound pressure level of 103 dB(A) at 25 meters from the speakers. When the measured sound pressure level of the FOH was compared with the prevailing noise model the prediction was constantly significantly lower.
This seems odd because the acoustic report mentions an elaborate expertise in simulating these speakers, it was based on measurements, and every other detail (angels, directions) from the speaker configuration was very accurate. A possible cause for the lower predicted noise levels close by in *Geomilieu* is the fact that environmental noise propagation methods are not made for sound that is in phase. Sound in phase means that the waves of the sound sources are interfering and the crests are synchronised and overlapping. The amplitudes are than added together resulting in a higher sound pressure level. This phenomenon is rare in common environmental noise modelling but speakers are supposed to be in phase for the best music experience. The sound technicians configure the speakers as such that they are perfectly correlated at the FOH. This will lead to a surcharge anywhere between 3 till 6 decibels. This is probably the reason for the constant offset noticed in Figure 24.

NOISE LEVELS AT DIFFERENT HEIGHTS As can be seen clearly in Figure 21 the height of buildings influences noise. *Geomilieu* incorporates the elevation data embedded in the environmental model to influence the sound rays and thus the noise levels. The result is that noise levels can differ on different heights comparable as in a real world situation.

Figure 30: A vertical and horizontal noise contour grid imported into *Google Earth Pro*.

In the prevailing noise model noise levels were only predicted at an elevation of 5 metres as prescribed in the *HMRI*. Residential buildings can exceed this height, therefore if the residential annoyance is related to the noise level at the facade it would be valuable to look at noise levels at different heights. This could be especially valuable when a lot of high-rise buildings are nearby. In the prevailing noise model a vertical grid of calculation points was placed around a high-rise building near the event area (in the Bijlmer). In Figure 30 this is visualised with coloured noise level contours that are exported into *Google Earth Pro*. This image shows also the horizontal grid at a 5 meter height as common in the *HMRI*, most importantly this image shows how the horizontal grid does not depict the whole story.

4.4.4 Creation of the enhanced noise model

The goal was to use *Harmonoise* because of the option to alter the meteorological conditions. Unfortunately *Harmonoise* includes a major setback that was detected in a very late stage during this research. A crucial shortcoming is that the direction and opening angle of a sound source can not be adjusted, it stays a radiating point source towards every direction.

The prevailing noise model had adjusted the opening angles and directivity of the sound sources to mimic those of the speakers. Speakers are made to radiate most of their sound towards the front and as little to the back as can be seen in Figure 31. The speaker directivity has major influence on the noise levels. This drawback excludes the possibility to create a whole new noise model with the *Harmonoise* methodology. It also rules out the option to compare *HMRI* with *Harmonoise* using the measurement data from the events.

The *Harmonoise* method will now only be used to understand how valuable it can be, to be able to simulate multiple meteorological conditions. The other elements that can be improved from the prevailing noise model such as the music spectrum and a more detailed environmental model will be done within the *HMRI*-methodology.

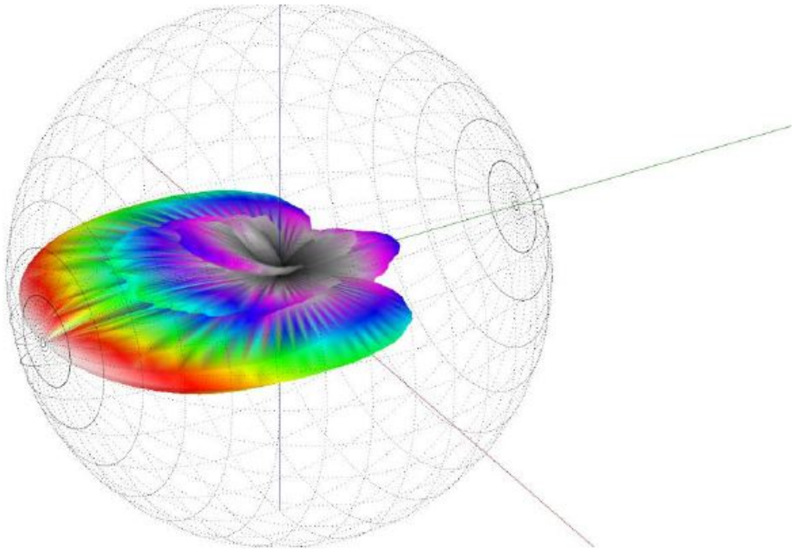


Figure 31: An impression of speaker directivity (16).

5 RESULTS AND ANALYSIS

5.1 ANALYSIS 1: NOISE LEVEL PREDICTIONS

The quality of the prevailing noise model is discussed in Section 4.4.2. This section will continue to elaborate whether improvements can be made and how effective those can be. Finally a well considered answer will be made about the accuracy of noise level prediction from outdoor music events.

5.1.1 Multiple meteorological situations

The effect of different meteorological conditions have been tested by creating noise models in *Harmonoise*. The two most opposite weather conditions that were witnessed during the events are used as an example. The opposite weather conditions are focus on three facets; wind-speed, humidity and temperature. Table 6 displays these meteorological conditions. The two conditions are chosen because they theoretically have the most diverse effect on the propagation of sound.

Table 6: The two tested meteorological conditions.

Name	wind-speed in m/s	Air humidity in %	Temperature in C
Meteo-1	2	38 %	23
Meteo-2	11	95 %	14

Figure 32 is the noise map that belongs to the conditions from Meteo-1 as mentioned in Table 6. Figure 33 belongs to the Meteo-2 conditions. The differences between the noise levels are dramatic. The differences are most apparent further away from the event area. In some areas the meteorological influences cause a 40 decibel difference. Even relatively nearby at the residential control points a 12 decibel difference is predicted.
These two noise maps depict the two most extreme divergent weather conditions witnessed during the events. Nonetheless it were actual occurring weather phenomena and it proofs the importance of the involvement of meteorological influences when assessing the impact of noise.

5.1.2 The environmental model

During the analysis of the prevailing noise model shortcomings were detected concerning the environmental model. The waterways and paved surfaces could have been in greater detail, with the missing highway as the most significant example. Next to that the vegetation around the event area was not taken into account while this theoretically would attenuate part of noise.

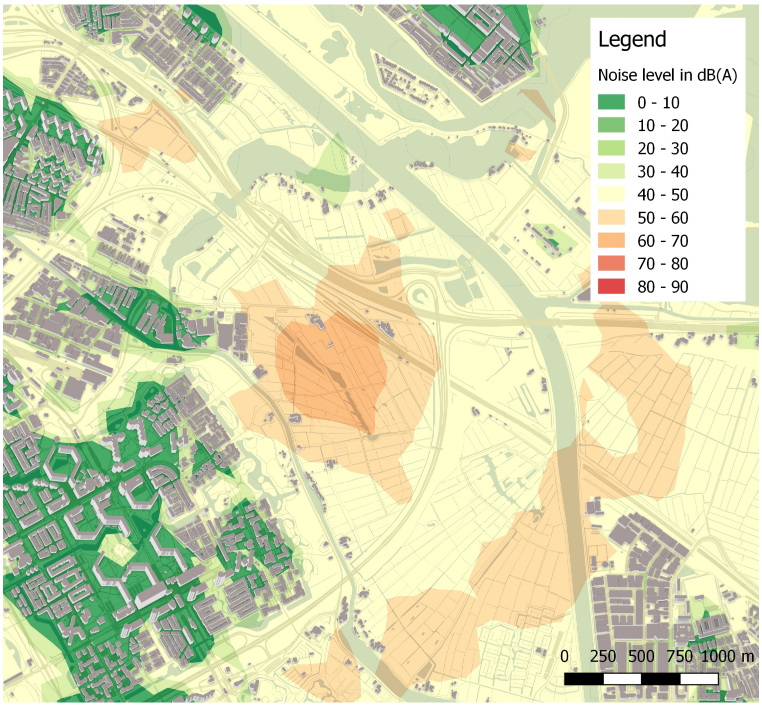


Figure 32: A noise map with the Meteo-1 conditions from Table 6.

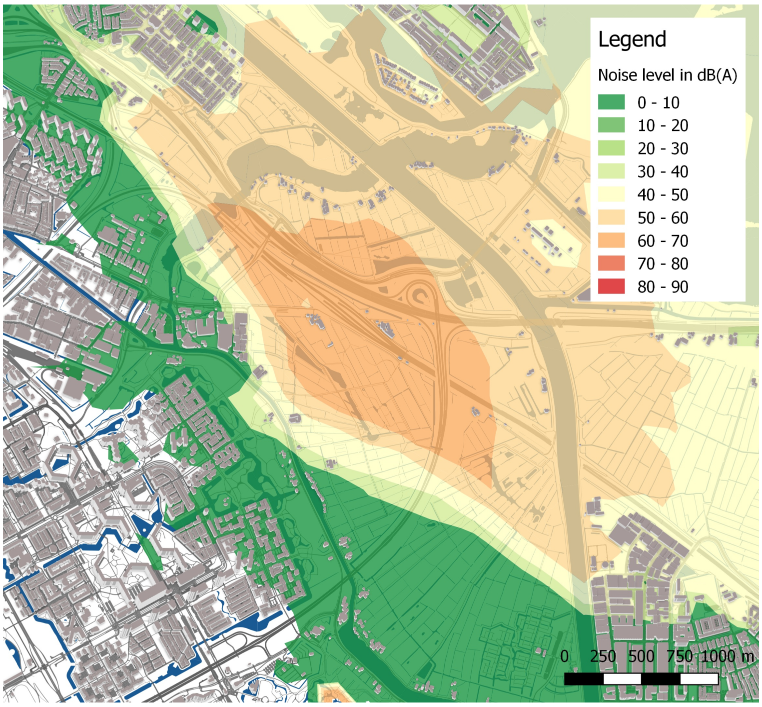


Figure 33: A noise map with the Meteo-2 conditions from Table 6.

A new environmental model was made using the TOP10NL map (20) within a perimeter of 5.5 kilometres from the surrounding area. All soil types in this perimeter are taken into account and are given an absorption value depending on the soil type. All areas within the perimeter are accounted for and as a result the map is completely filled up. The buildings and altitude lines are unchanged compared to Section 4.4.1.2. Figure 34 displays the input polygons used to create the enhanced environmental model in *Geomilieu*.

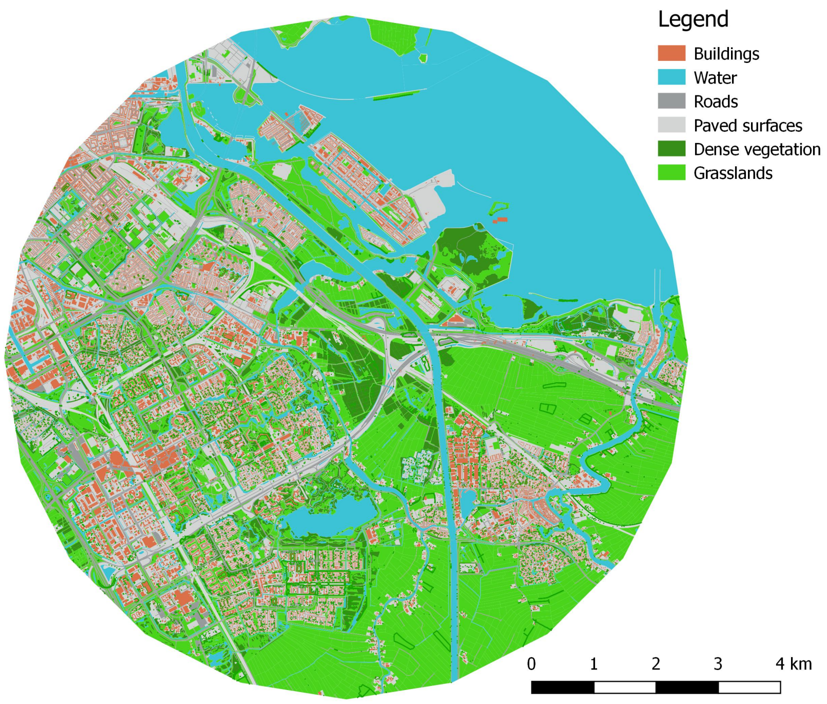


Figure 34: The input soil types and buildings to be used into the enhanced *Geomilieu* environmental model.

The results from *Geomilieu* surprisingly almost did not differ from the prevailing noise map. While the process was very computational expensive the results were just slightly affected. The prevailing noise map was placed next to the noise map with the extended environmental model and variations with these decibel classes are almost non-existent. The two noise maps can be found in the appendix. Table 7 depict the results at the same calculation points as in the prevailing noise model. For almost each location the difference is insignificant except for the location "Stammerdijk 24-25". This is one of residential control points denoted as Position A in Figure 11. The difference must be a result of the vegetation attenuation that is included into the enhanced environmental model and most is located between position A and the event area. Attenuation from vegetation effects the higher frequencies more than the lower octave bands, this effect becomes apparent when the average spectral differences are observed in Table 8.
The elaborate and enhanced environmental model had little effect on the noise levels compared to the basic prevailing environmental model. The only adjustment that had a significant effect was the incorporation of vegetation. It is assumed that most of the detail is lost because of rounding of the numbers during noise calculation. Due to the logarithmic decibel scale these minimal differences in the environment do not seem to have any significant effect on the total noise level. Theoretically every little bump or blade of grass does have an effect on the sound pressure level, but in reallife we also do not hear the difference if there is for example a lamppost between you and the road or not.

Table 7: Noise levels from prevailing noise model and noise model with an enhanced environmental model

Location	Prev. noise model	Enh. noise model	Abs. diff.
Muiderstraatweg 61-63	60.3	61.1	0.8
Stammerdijk 23	62.0	62.3	0.3
Stammerdijk 24-25	64.0	60.6	3.4
Stammerdijk 29	63.3	63.3	0.0
Frankendael	52.7	52.3	0.4
Geerdinkhof	57.6	57.8	0.2

Table 8: Average spectral variance between the prevailing noise model and the noise model with an enhanced environmental model

Frequency band	63	125	250	500	1000	2000	4000
Average variance	-0.4	-1	0.3	1.1	1.3	1.8	2.5

5.1.3 Source power and music spectrum

A new spectrum was made based on the average measured spectrum as visualised in Figure 26. The total sound source power was kept the same because of the assumption the source power was chosen by the author of the prevailing noise model with expert knowledge of the speaker characteristics, and the knowledge that coherent sources are not taken into account.
The sound source spectra are adjusted for each stage and the noise levels at the FOH are calculated using *Geomilieu*. Figure 36 displays for each octave band a box-plot made from the FOH noise measurements, the prevailing spectrum and the new spectrum. The lower noise values are as expected because in real-life they are coherent sources while in *Geomilieu* they are not. Important is that the new spectrum follows the same curve as the measured spectrum and includes the same dominant frequencies.

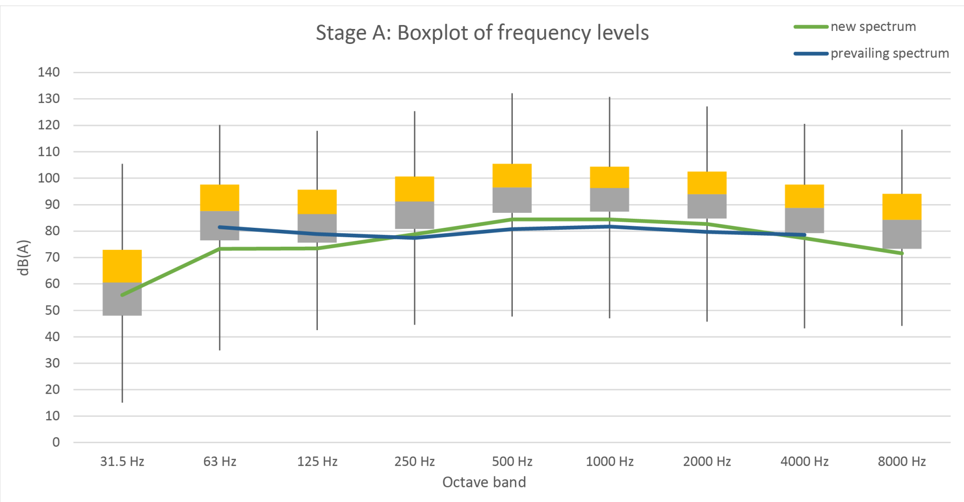


Figure 35: The enhanced and prevailing spectra at the FOH together with a box-plot of the noise measurements.

To validate whether the prediction accuracy at a distance has been improved by the new spectrum, the noise levels at the residential control points are calculated as well. Figure 35 shows an improvement compared to Figure 22. The red line is the newly predicted noise spectrum at position A and the blue dots are all the noise measurements that fulfilled the meteorological conditions as prescribed in the *HMRI*. The 63 Hertz octave band is no longer the sole dominant frequency. These results are similar at position B. The predicted spectra follow better the curves from the measured spectra, except for the higher frequencies. The predicted noise level at both residential control points were still higher than measured. Position A had a difference of 2.5 dB and position B 7.5 dB.

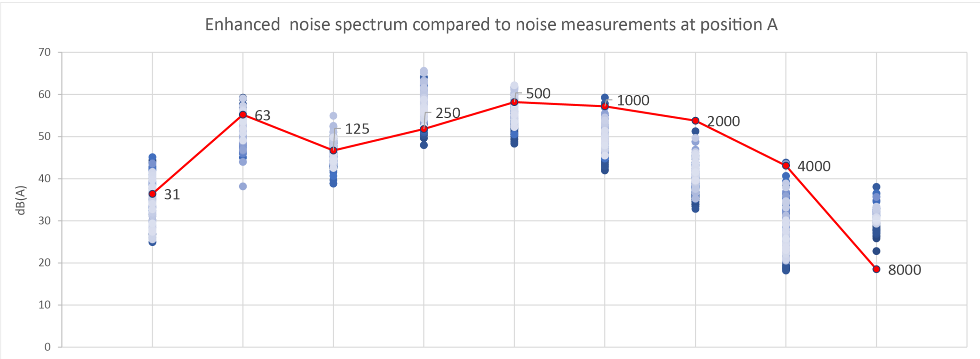


Figure 36: In blue the noise measurement levels and in red the prediction with the new sound spectrum.

The final step is to combine all enhancements to develop a noise model that would theoretically predict the most accurate noise levels. A setback is that the incorporation of meteorological conditions can not be combined with the new environment model and sound spectrum because the *Harmonoise* noise sources can not be directed. The figure below shows the difference between the prevailing noise map and the enhanced noise map. The noise levels from the enhanced noise map are significantly lower. While adjusted environmental model alone seemed to have little impact the combination with an adjusted sound spectrum created a considerable difference.
The results from the enhanced noise model were compared with the average noise levels measured at position A and position B. Only the measurements during the time that the speakers were on maximum volume were used. The resemblance between the results from the enhanced model and the recording data is unexpectedly high.

Table 9: The validation of the enhanced noise model

Location	Predicted level	Measured level	Absolute difference
Position A	55.2	54.5	0.7
Position B	57.5	53.7	3.8

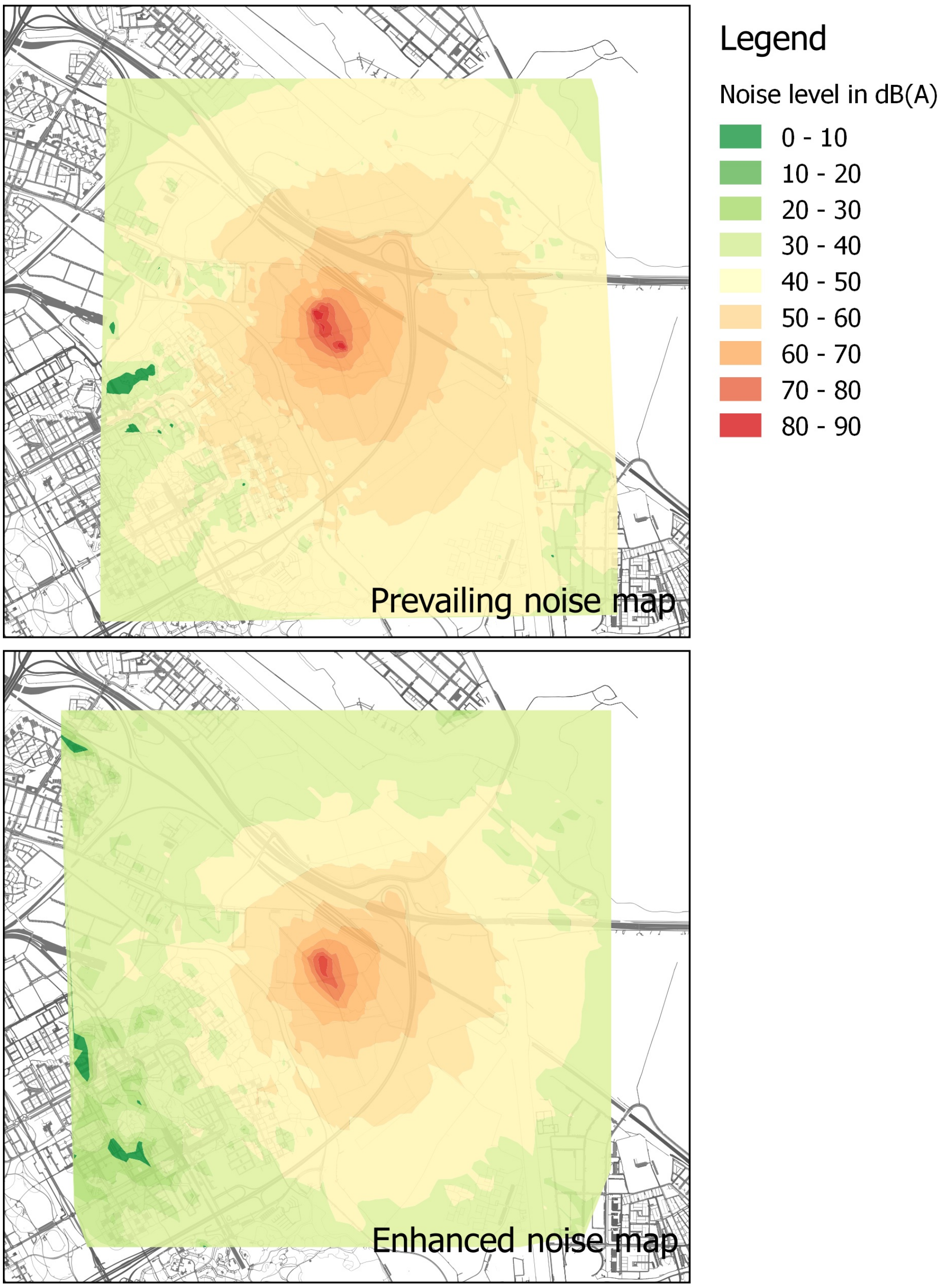


Figure 37: The prevailing noise map and the enhanced noise map.

5.1.4 Quality of noise predictions for outdoor music events

Predicting noise from outdoor music events is difficult because of the uncertainty of several important and constant changing variables. These variables are the meteorological influences and the music spectrum. Both are constantly changing and have great impact on the propagation of sound. Therefore it is almost impossible to predict the noise level at a greater distance from the event.

In the enhanced noise model one of those variables was known and a model could be made with a sound spectrum based on the noise measurements.

Although the results from position A were fairly accurate the difference at position B stayed significant. The average accuracy of the predictions during the meteorological conditions as prescribed in the *HMRI* was 5.5 decibels. The enhanced noise model predictions compared to all noise measurements at the residential control points resulted in an accuracy of 2.3 dB. This is contradicting because it was expected that the enhanced model would match best when the meteorological circumstances are as prescribed in the *HMRI*. The reason for this is probably because there were very few data with the correct weather conditions to compare, making it more likely the sound spectra were different. The higher accuracy was obtained when the average of a lot of data could be used to compare, and here lies the crux of the matter. The momentary effects can not be grasped, therefore the chance a noise prediction for an outdoor music event is accurate is very slim. Even if the correct environmental model is used and the correct sound source specifications, only on the long term the measurements would average out and the predictions become more accurate. The *Harmonoise* meteorological simulations have shown the impact weather can have, but it is impossible for the municipality and the event producer to assess every possible weather scenario. The question is whether the average prediction is accurate enough to help to predict the noise nuisance.

5.2 ANALYSIS 2: NOISE NUISANCE

5.2.1 Acoustical analysis

Every noise nuisance complaint is associated with an hour of noise levels from three stages. The sound levels will be left unweighted to observe all energy from the spectrum and avoiding that a A-weighting or C-weighting makes a distort representation of the sound pressure levels that are produced by the event. In Figure 38 for each complaint the average noise level an hour prior to the complaints is shown. The average noise level of the hour prior to a complaint was equal for all stages and was 103 dB(Z) with a standard deviation of 7 dB.

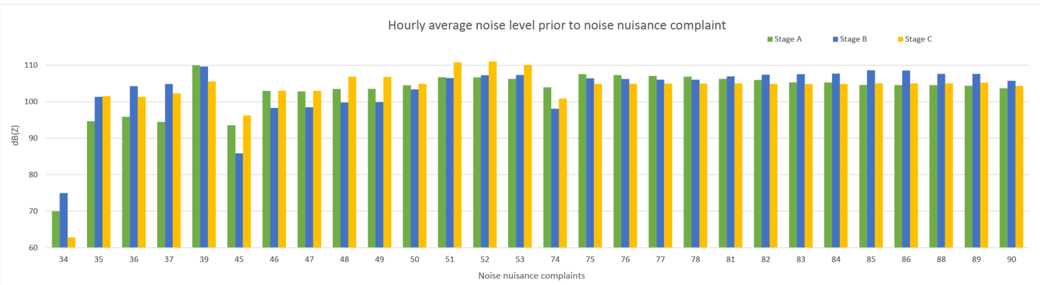


Figure 38: Average hourly noise level prior to the noise nuisance complaint.

Clearly an average of 103 dB(Z) is high and it could be cautiously stated that the complainers at least complain when there was indeed a lot of noise produced by the event. But this could also be linked with the time of day or what the most commonly produced noise level is. Figure 39 is a line histogram of the occurrence of every dB(Z) level is visualised. This shows a similarity with Figure 38 because the levels around 103 dB(Z) are the most occurring noise level. The absolute most occurring noise level was 106 dB(Z). The average noise level an hour prior to the complain is not the most common noise level and is not the highest noise level.

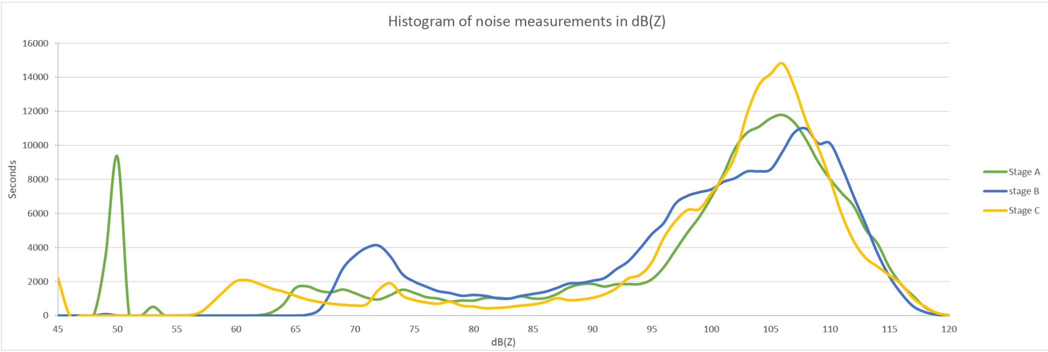


Figure 39: Histogram of noise level occurrence per stage.

It could be that fluctuations of the noise levels could trigger more or less complaints. A common way to measure fluctuations, or volatility, is by means of standard deviation. Figure 40 shows the standard deviation of every hour prior to the complaint and the average standard deviation of every stage. It seems that at the moment of nuisance the noise has been very constant for at least an hour, and constant compared to the stage average. A greater standard deviation could mean more breaks between music styles or breaks between artists. The fluctuations are becoming less as the festival passes.

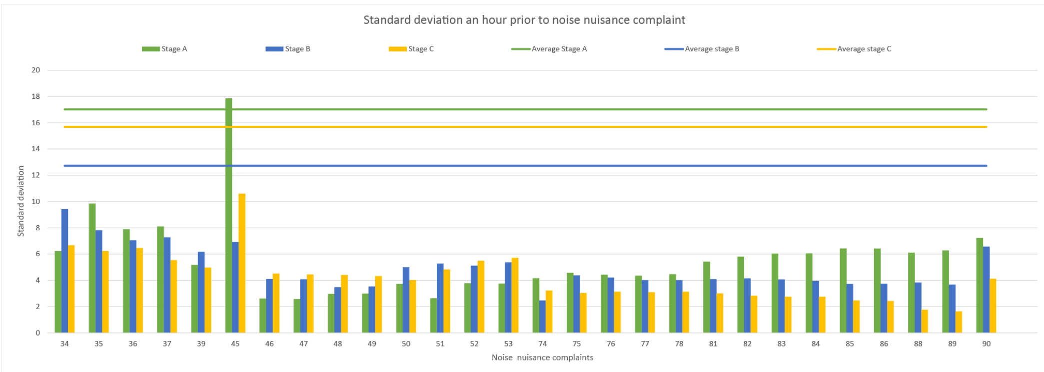


Figure 40: The standard deviation of the noise levels an hour prior to the noise nuisance complaint

The acoustical analysis up to here seems to show residents complain after a long-term exposure of constant high noise levels. An outcome that does not surprise. A spectral analysis could offer more insight into the nature of the noise an hour prior to the complaint. It is important to remember that spectral analysis is not about the amount of decibels that are produced but the mutual relationship between the octave-bands. Yet again all noise measurements an hour prior to the complaints were extracted from the FOH noise measurements. The octave-bands are added to result in a total dB(Z) level. Subsequently per octave-band is calculated what the difference is between the octave-band level and the total noise level. This will result in an absolute-difference spectrum. This will allow to combine and compare spectra that do not have the same source power.

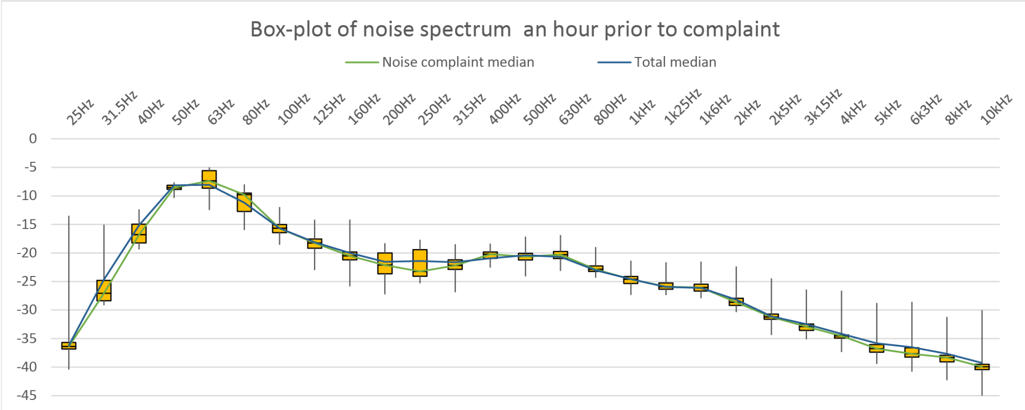


Figure 41: A box-plot of the spectral differences related to the complaints and the median spectrum of all FOH noise measurements

In Figure 41 this comparison is made using a box-plot. The box-plot resembles the distribution of the spectral difference values. The yellow boxes are the first and third quartile of the data with the median in between. The whiskers on both sides visualise the minimum and maximum outliers. Overall it shows that the dominant frequencies are around 63 Hertz in dB(Z). The blue line is de median line of the complaint noise measurements and the green is the median line of all FOH noise measurements. They are almost identical. This is in line with the total noise levels in dB(Z) comparison. Complaints do not seem to happen after noise situations that deviate from the average.
The volatility or fluctuations of the octave-bands the hour prior to the moment of complaint are yet again lower than the average as seen in Figure 42. The fluctuations become less volatile while time passes. A possible explanation could be that during the day there is more diversity between the stages, the visitors are more likely to walk around and explore different styles. As evening falls the crowd is more in an upbeat dancing mode, where repetitive continuity is desired.

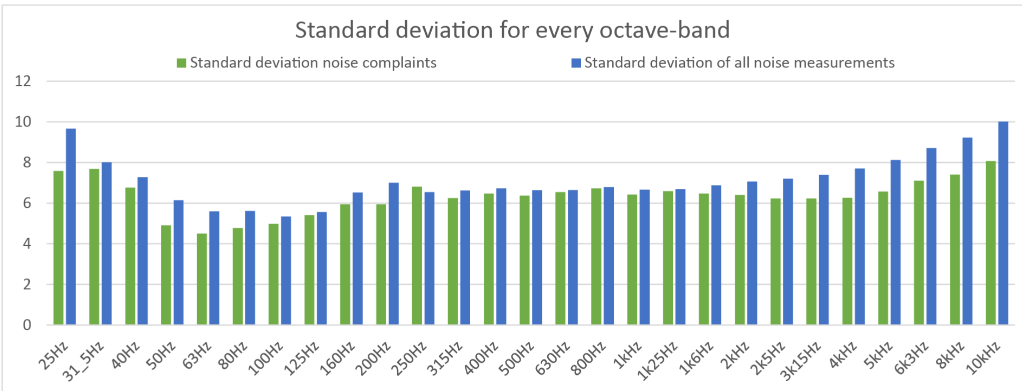


Figure 42: The fluctuations of octave-bands during complaints and during all measurements.

It is interesting to examine whether the noise measurements at the location of the residents fit the same spectral characteristics. The average equivalent noise level that was measured at the residents was 50.8 dB(A) with a standard deviation of 5.7 dB(A). In Figure 43 the results are plotted. The green area depicts the data-points that fall within the standard deviation. This standard deviation is considered high because it is more than 10% of the average and sound power need to double to increase with 3 dB. But another perception would be a measure of loudness, this is a psychoacoustics means to measure sound-sensation. It is ambiguous because it is affected by more parameters other than sound and the same sound does not create the same loudness perception by every human. According the loudness scale a 5 dB difference would be perceived as a 1,5 doubling of the noise. With this view the standard deviation of the noise is pretty dense and the perception of noise at residents location does not differ too much from one another.

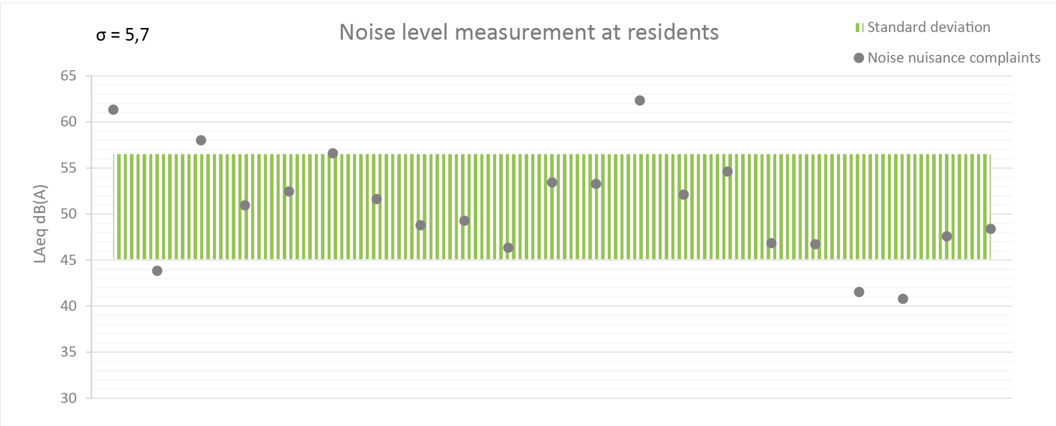


Figure 43: Noise measurements at residential locations in LAeq with standard deviation.

The average dominant frequency at the residents was low. This is expected because higher octave bands are quickly absorbed, reflected and deflected. In 71% of the measurements the dominant frequency was 250 Hertz or lower with a mode of 200 Hertz.

5.2.2 Temporal analysis

To see the effect of the duration of noise, time-frames during the event are chosen that have consisted characteristics. This means the direction and the speed of the wind is consistent and the source power is consistent.
Two time-frames were suitable, namely 30 July 2016 from 18:00-22:00 and 3 September 2016 from 17:00 - 22:00. The complaints during that time are plotted and visualised in Figure 44. The two compatible time-frames had few complaints, but still the most complaints were after 8 hours of noise exposure. In the lowest time-frame all noise complaints that were made during opening hours of the event are placed on a time-line. At events where the meteorological circumstances could influence the noise exposure 9 hours after opening most complaints are made.
The results from the temporal analysis seem to underpin the acoustic analysis. After 8 till 9 hours the noise levels and sound spectra start to fluctuate

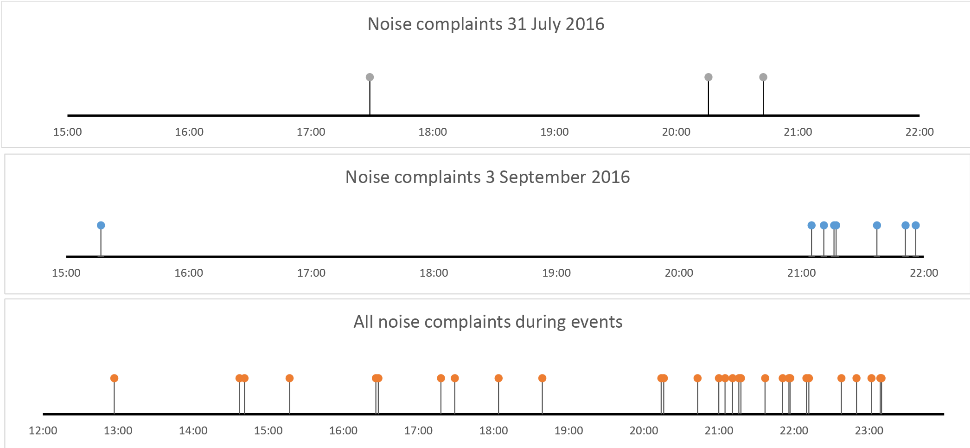


Figure 44: Time-lines with moment of complaint, the two upper time-lines are during constant circumstances, the lowest are all noise complaints.

less. The music from these events became more monotonously. It could be that the residents notice the more repetitive and monotonous noise and start to complain, but this is very unlikely. The chances are more likely that after the long exposure of noise people start to complain and this is coincidently during this change in music.

5.2.3 Spatial analysis

In this subsection the results of the spatial analysis between the noise nuisance complaints and the event will be presented.

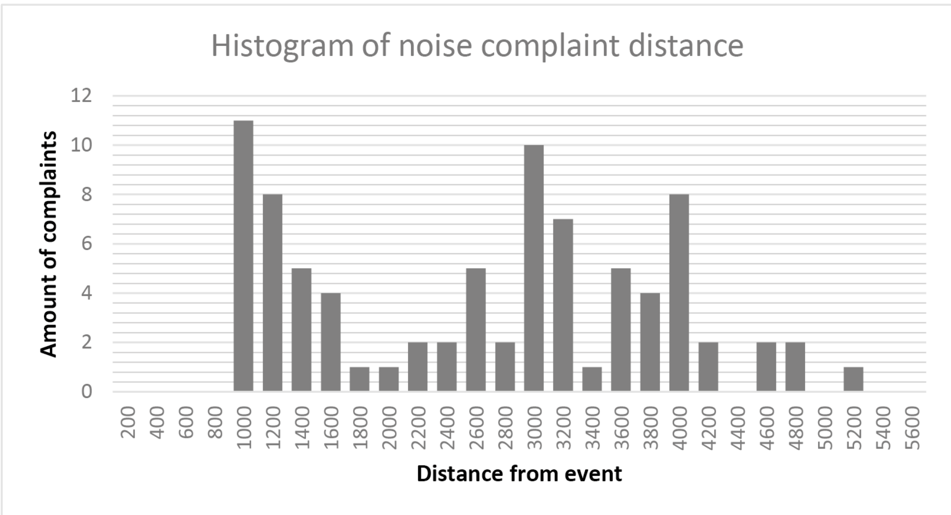


Figure 45: Distance histogram of all noise nuisance complaints.

First the distance to the event is discussed. The assumption is that more complaints are made by residents in closer proximity to the event area. In Figure 45 a distance histogram of the complaints is shown. In this image there is no linear reduction as the distance from the event grows. The reason for this is that the distribution of residential addresses is not homogeneous in every direction or at every distance. To cope with the uneven distribution every residential address in 8 wind directions is indexed into distance categories and the percentage of complainers per distance is calculated. It is done for each wind-direction to eliminate the effect of wind and speaker directivity upon the residential address distribution.

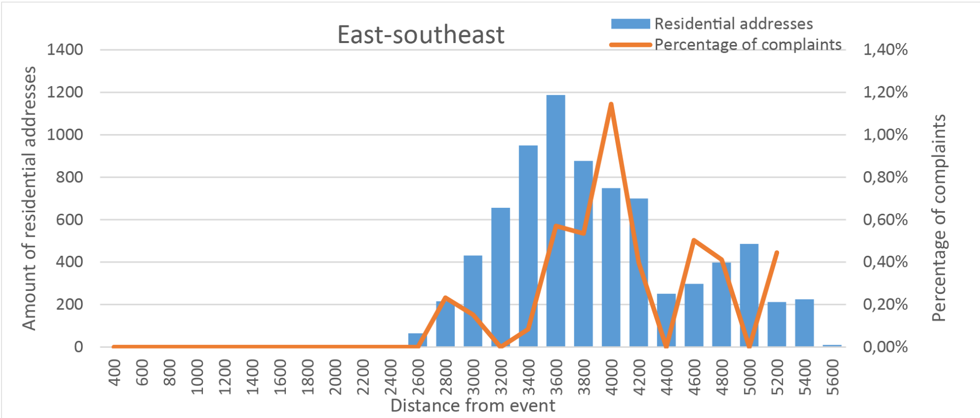


Figure 46: Percentage of complaints and the amount of residential addresses in the direction of east-southeast.

In one direction there were no complaints at all, in five other directions relatively speaking the amount of complaints became less when distance grew, in two directions the amount of complaints did not decrease. The two directions that did not follow up to the expectation are the directions east-southeast and South-southeast. In Figure 46 the percentage of noise complaints per distance is visualised together with the amount of residential addresses at each distance. At first the data did not seem to make sense till the realisation that most of those complaints were made during the days that another event was being held as well as mentioned in Section 4.2.2. The other event was held at the "Gaasperplas". After performing the same spatial analysis with the Gaasperplas event area it is presumed that the anomalies in this region were caused by misplaced complaints. Figure 47 shows both event areas and the noise nuisance complaints that did not fit the expected trend.
The assumption that more residents complain nearby the event matches with the data from this thesis. On average the nearest complaint in a cardinal direction is made when 200 addresses fall within the 45 degrees sight-lines. In every direction the amount of complaints decreases when distances increase, this is in line with the amount of noise that decreases in similar trend.
Meteorological conditions have great influence on the propagation of sound as proofed in Section 5.1.1. In the noise calculation software the weather conditions are utterly important. Therefore it is assumed that this influence can be seen in the distribution of noise nuisance complaints as well. The angle of the wind and the speed in kilometres per hour are plotted on graph. The noise nuisance complaints were added with an extra attribute namely the azimuth angle with the event area. These were added into the graphs as well making it visual possible to see whether the noise nuisance complaints are made in the same direction as the wind.
Figure 48 is one of the graphs that were made to see the relation between the location of the noise nuisance complaints and the meteorological circum-

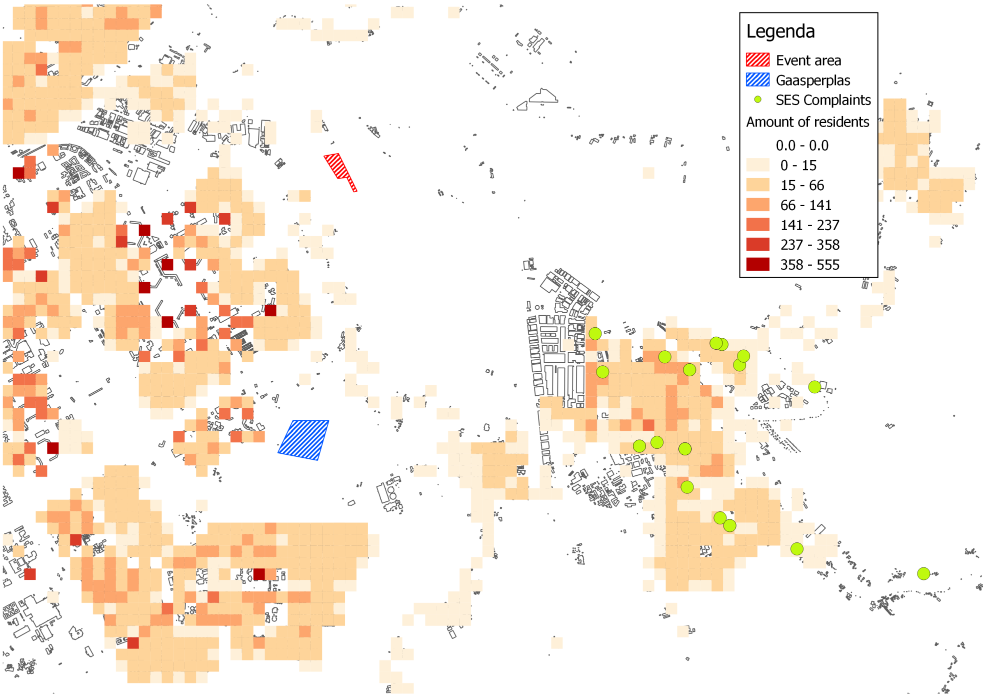


Figure 47: Both event areas and the noise nuisance complaints that were ambiguous.

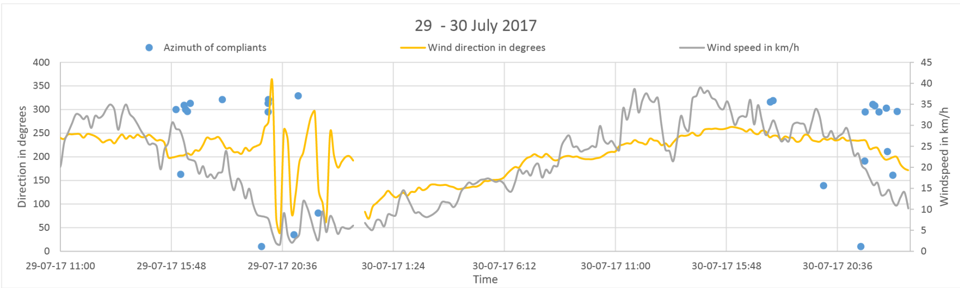


Figure 48: The direction and speed of the wind together with the azimuth of the noise complaints on a time-line.

stances. The yellow line is the wind direction and the grey line is the wind speed. When the yellow line and blue dots are close to one another it means they are in the same azimuth angle in relation to the event.
The results are that the direction of the wind is the dominant factor to influence the location of the complaints at 1500 meters distance or more. At low wind speeds and close by to the event the circular distributions around the event is more evenly spread and depends on the sight-lines of the speaker. But further than 1500 meters from the event and a wind speed above 20 km/h the noise nuisance complaints were always within in 10 degrees deviation of the wind direction.
The effect of the wind should be addressed together with the directivity of the speakers. The sight-lines of the speakers are the leading effect on the location of the nuisance complaint further than 1500 meters when there is no or little wind. Figure 49 visualises the noise nuisance complaints and the sight-lines of the speakers.

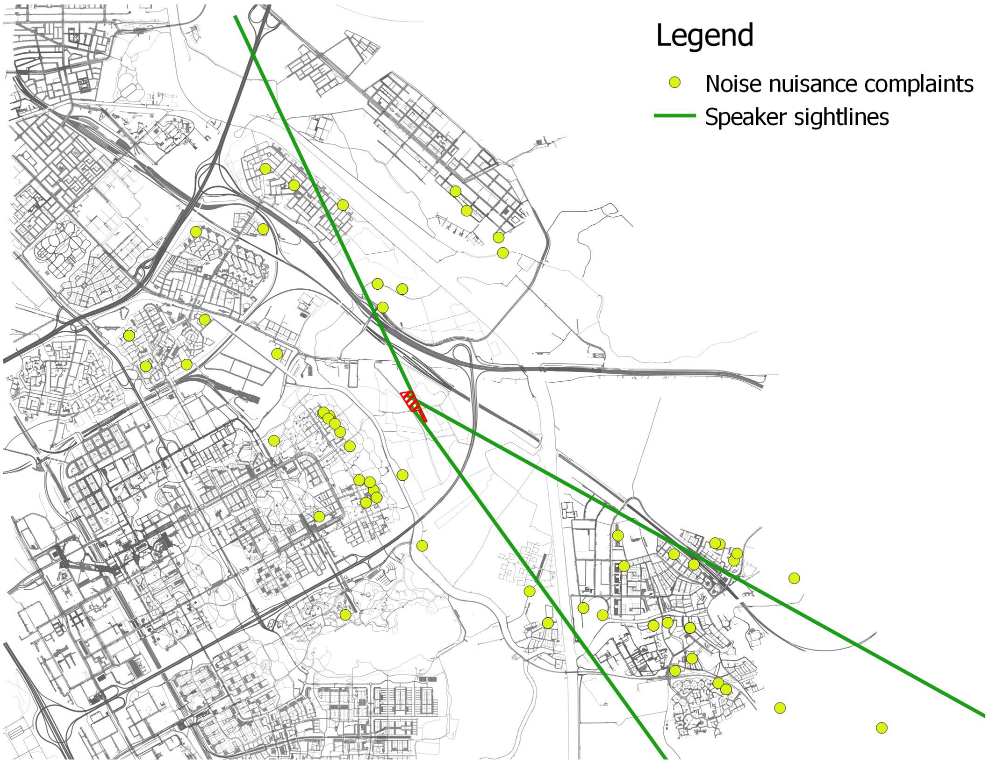


Figure 49: The sight-lines of the speaker and the noise nuisance complaints.

5.2.4 Psychology and social economic influences

The spatial and acoustical analyses can give insight in who can hear the noise and therefore could complain. But why some people decide to complain while others with the same level of noise do not, is another field of research. During the gathering of the noise complaints I heard so many reasons of residents why they are affected by the event, and most of them sounded as valid reasons to be in discontent. This subsection will elaborate more on those reasons that effect residents, although their perception of the event but fell outside of the scope of this research.

In total around 190 emails were received. These emails are from residents that felt the need to send an explanation of their frustration, next to just filling in a complaint through the website. Sometimes highly emotional emails with a cumulation of reasons that led to the anger they felt. Often it seemed they felt betrayed by the municipality and asked the question: Is nothing taken into consideration any longer? ("Wordt nergens meer rekening mee gehouden?") This signals a frustration that is the result of more frequent letdowns than only the outdoor event. Many stories started with complaints about other sources of annoyance like highways, construction noise, neighbours, safety, and now this! When the noise of an event is a reminder of the discontent a resident feels towards policy, the feeling of nuisance is strengthened.

Another common frustration was the incomprehension about why the music needed to be so loud? Why do people like tones that are so loud they are wearing earplugs while dancing? Why do people want to listen to such monotone and loud bass music? It seemed when there was an lack of understanding about how people could have joy from such an event the acceptance of the residents gets less. When it is hard to grasp why people would like an event it gets harder to understand why you should endure nuisance because of it. An example is that during the research another event was held in the neighbourhood of Diemen called 'Kwaku'. This is a well-known multi-cultural family week-long festivity in the Bijlmer (a neighbourhood in Amsterdam). Almost nobody seemed to felt annoyed by this event because it is accepted and loved by the surrounding area. Acceptance and understanding of the purpose and joy the sound source represents, plays a big role. Just like a free concert of a philharmonic orchestra in the canals of Amsterdam would trigger less annoyance than a performance of a gangster rapper.

The protection of the neighbourhood is also a common reasoning residents use. Their park is being destroyed, their streets are being polluted, their neighbours endure hindrance. A need to speak up on behalf of the community makes people complain even if they themselves are not affected. There were several outspoken complaints from people that really went to the location of the event to observe the destruction and to investigate and report their experience. Self pronounced environmental protectors that felt it was up to them to assess the impact of the outdoor music event.

The writers from most of the received messages could be categorised to one or more of the mindsets as mentioned above. There were still many complaints from residents that simply thought the noise was too loud, but the more outspoken, or multiple, or even threatening complaints were from residents that seem to have one of the above characteristics. Their complaints were spatially and acoustically seen often the ones that could not be accounted for. Although probably every neighbourhood includes residents that would react on such a manner toward outdoor music events, it would be interesting to see whether social economic attributes could be linked to these mindsets.

Educational level could influence the need to speak up on behalf of the community. Age and lifestyle could be a measure for acceptance of certain music styles. A bought house could be more reason to actively be concerned about the neighbourhood compared to a rented house. Ethnicity and culture could be related to the willingness to contact authorities. In Figure 50 the percentage of non-western residents is visualised together with the noise nuisance complaints. Is it a coincidence that there were almost no complaints in the Bijlmer, a highly multi-cultural neighbourhood southwest from Diemen?

Residential mindset and social economic influences are related to the reason why people start to complain. The visits I have done were very valuable to understand how to cope with all these different causes of annoyance. But whether somebody does not understand the music or is annoyed by once again a fault of the municipality, their main goal is to be heard, and that their complaint is genuinely dealt with. When residents were correctly informed about the finishing time of the events, and the frequency, and they were visited by me to measure the noise level and listen to their complaints, their grudge against the authorities seemed to reduce and the tolerance towards the noise rose.

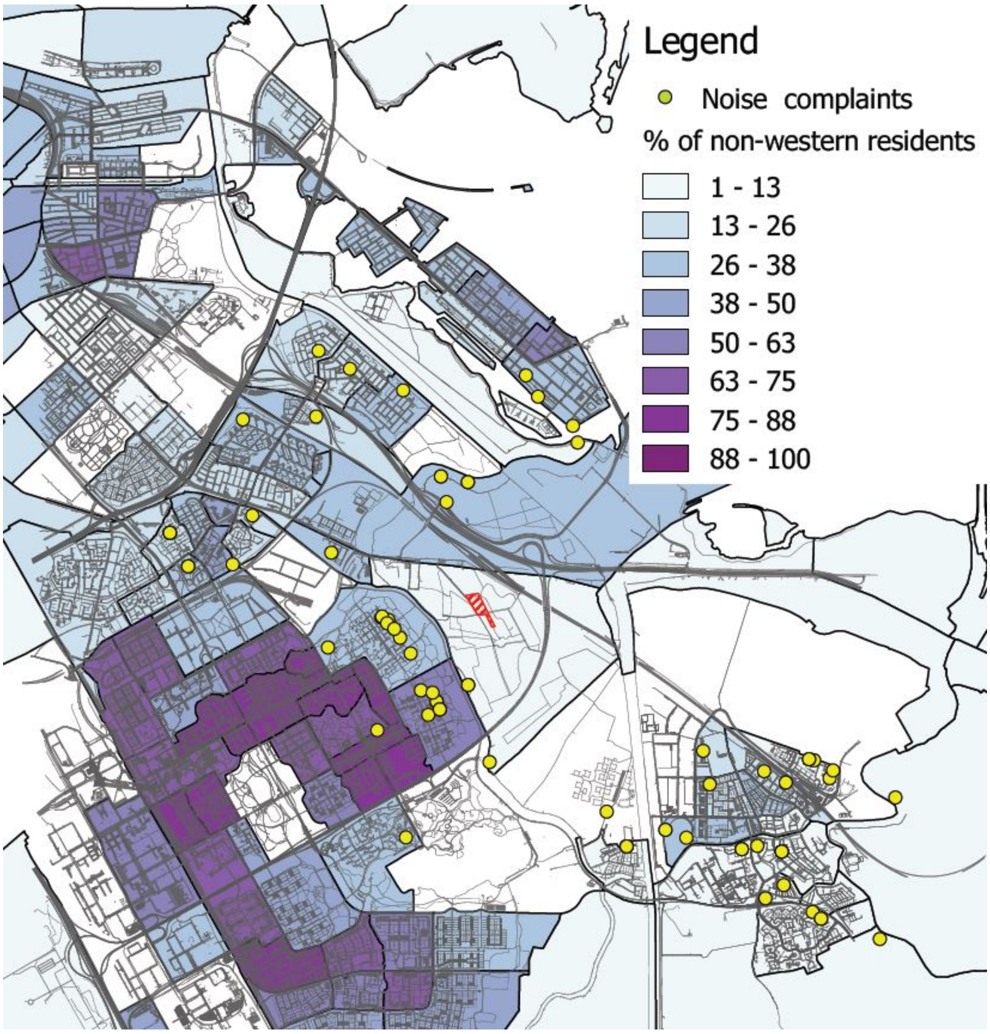


Figure 50: The percentage of non-western residents for each neighbourhood together with the noise nuisance complaints.

5.2.5 Noise level as a predictor for noise nuisance

There is a relation between the location of the nuisance complaint and the noise. The average noise level at the location of the complaint was 50.8 dB(A). This level is loud enough to distinguish the noise from the event above the environmental noise. The variables that direct the spread of noise like the meteorological influences and the directivity of the speakers subsequently influenced the distribution of the complaints. Therefore the spread of noise is a measure to predict the spread of complaints.
The noise level is also a predictor for the location of the noise complaints. Nearby to the event more complaints are made than at a greater distance. This relates to the noise level that reduces in a similar way. The relation between noise levels and nuisance complaints are not as linear that when the noise level goes up a direct reaction is witnessed in the neighbourhood. The relation is as such that the noise level must be high enough for the residents to notice the noise, but when the noise level increases even more, not more people will complain in the same area. Rather when the noise level increases

there is chance that the noise becomes noticeable in more areas, resulting in more complaints.

The music spectrum before the complaints did not appear to differ from the average music spectrum. The fluctuation from the noise level as well as the music spectrum was lower during the complaints than on average, the reason for this is probably the time of day instead of the recognizability of less fluctuating noise. While the evening falls more residents are at home and there is more chance they notice the noise, next to that the temperature drops and this influences the sound rays.

The relevance of the duration of noise exposure is questionable. It could be that residents start to complain in the evening because after 9 hours of noise they are fed up and had enough. But the wind analyses have shown that rather quickly after a change of wind direction residents start to complaint. Especially in the evening hours it appeared that the exposure of noise did not have to be long to cause annoyance. While during the day the tolerance is higher.

The acoustic, spatial and temporal analyses have shown a definite relation between noise and nuisance but it never accounted for all complaints. There were always complaints, up to 70% at one day that were contradictory compared to the expectations. Several reasons for these outliers are mentioned in Section 5.2.4, but there are many more. Therefore a waterproof methodology can not be proposed but a list of focus points concerning the noise could be very valuable to asses the impact of an outdoor music festival.

5.3 ANALYSIS 3: NOISE MAPS AS A TOOL TO PREDICT NOISE NUISANCE

In this section a use of noise maps is proposed to help assess the impact of an outdoor music event. Perfect prediction of the nuisance complaints will not be possible but to make better use of the science of noise propagation and the insight a noise map can give, would benefit all parties. The framework proposed are suggestions on a scientific, social and legal domain.

LOOK AT THE BIGGER PICTURE The focus on the nearest residential building constricts the view to see the what the noise level will be in the whole surrounding area. The focus area should be as big as the 45 dB(A) contour from the noise map. 45 decibels represent the lower quartile noise level value as measured at the location of noise nuisance complaints. To use the nearest residential building as a measure creates ambiguity and could cause opposing effects. For example the speakers are turned away from the nearest residential building and are now facing an entire neighbourhood.

LIMITS AND ENFORCEMENT Noise limits have to be set to not endanger the health of the visitors. A 100 dB(A) and a 110 dB(C) at the FOH is an appropriate limit that will still please the visitor. A maximum level at the building facade of 65 dB(A) and 80 dB(C) have proven to be possible in Amsterdam. No resident should endure louder noise levels than that. The enforcement should be focused on the noise level at the FOH, because these are most accurate. Real-time monitoring of those levels ensures the compliance of the event producer and it makes it impossible for the producer to violate the law. These are the only measurements practically not affected by environmental noise or meteorological influences. It reduces the amount of systems and effort needed to monitor compliance both for the municipality as for the event producer. An idea would be to make the real-time measurements visible on-line. Residents than have the feeling they are in control and are not wondering whether the event producer is breaching limits again. This will probably reduce complaints a lot.

SOUND SPECTRUM The sound spectrum that will be used in the noise model should be as accurate as possible. The chosen sound spectrum has such a great influence on how the noise model propagates sound that using a wrong spectrum makes the whole model invalid. By making the event producer accountable for the spectrum they chose to use in the noise model accuracy is stimulated. Just like the noise levels, the average spectrum could be monitored at the FOH. If at the end of the day the average measured sound spectrum differs too much (there must be room for some artistic freedom) from the sound spectrum as used in the predictions the event producer could be held accountable for this. When the artists are known for a big event it is not difficult to make an estimation of the expected spectrum. A correct spectrum will make the noise model more accurate and thus the predictions better and this benefits the event producer as well. The event producer of the test-cases in this thesis would have benefited a lot if the spectrum was chosen correctly.

ENVIRONMENTAL MODEL The municipality should be responsible to deliver a correct environmental model to be used in the noise model. It will allow them to compare noise maps from different event producers and the municipality can than do test themselves and make correct considerations about the noise in their community. The municipality has the most knowledge about urban planning and changes in the environment that could be important for the propagation of sound. Every man to his own trade, make the event producer accountable for the music they produce and municipality responsible for adequate knowledge about the surroundings.

NOISE PROPAGATION METHOD None of the tested noise propagation methods was made for the purpose of noise prediction from outdoor music events. By lack of better a combination of both the *HMRI* and *Harmonoise* must be used. This is not ideal and research is needed to develop a propagation model, that can cope with coherent sources. In this thesis by using the right sound spectrum and environmental model the *HMRI* on averaged managed to obtain an accuracy of 2.3 decibels. The standard deviation of the noise measurements at the nuisance complaints was 5.7 decibels. Therefore with the correct input the *HMRI* appears to be accurate enough for the purpose of nuisance prediction.

DETERMINE THE AMOUNT OF NUISANCE COMPLAINTS To make an estimation about the amount of affected people a noise model must be made with the right input as mentioned above. The noise level on a horizontal grid of calculation points can be calculated. The grid must be large enough to contain the complete contour of the 45 decibel line. These contours can than be exported to a GIS and placed over a layer that contains all residential addresses. If there are residential addresses within the 65 decibel contour in principle the event should not be held. Figure 51 shows a example made for the Diemerbos. Everyone inside the 45 decibel contour line are the residents that will notice the noise and 42% of the complaints come from these areas. This is 0.5% of the total amount of residential addresses.

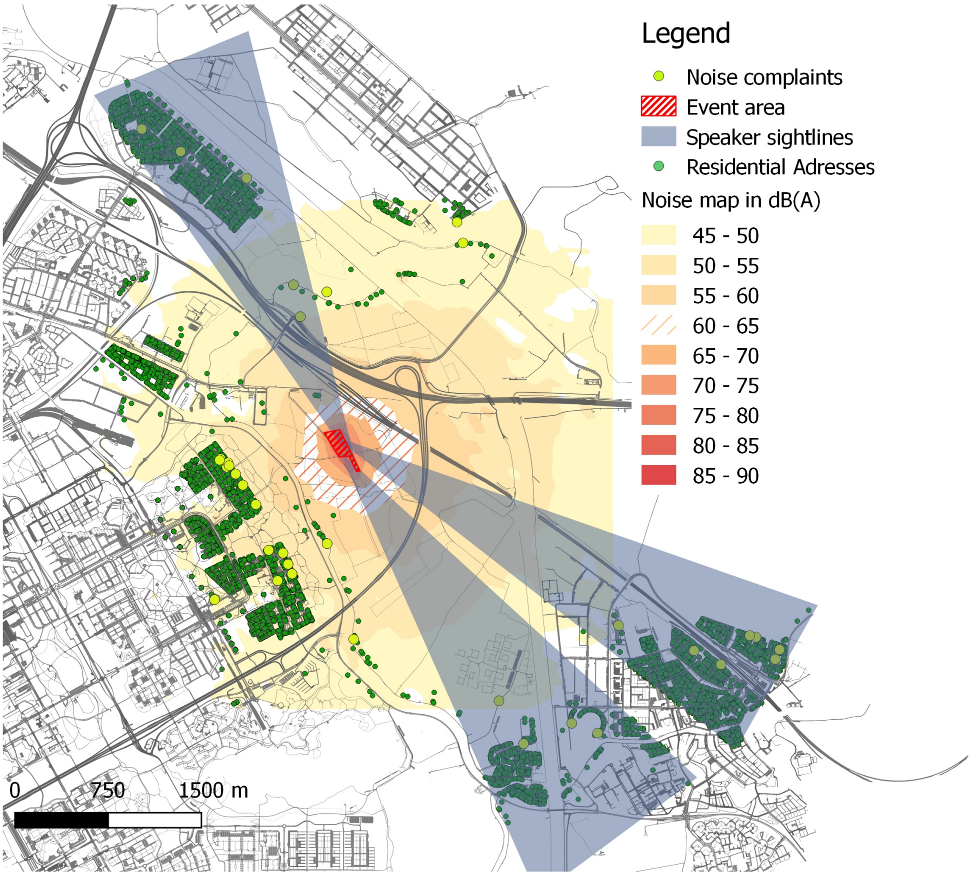


Figure 51: An enhanced noise map displaying the residential addresses that are likely to complain.

Another main predictor of the nuisance complaints are the sight-lines from the speakers. 38% of the noise nuisance complaints felt within a 10 degrees aperture angle of the sight-lines over a distance of 4 kilometres. 0.4% of the residential addresses within these areas complain about noise nuisance. The long distance of 4 kilometres is the result of the coherent sources, this is why the impact reach from the sight-lines of the speakers is much further than than the *HMRI* predicts.
The spread of the noise contours help assess the noise impact of outdoor music event.
The other 20% of the complaints came from residents from who the relation to the noise could not be understood, or from residents during atypical me-

teorological circumstances. To tackle the momentary effects of the weather, multiple different situations should be simulated using Harmonoise. Subsequently the same analyses as above could be done to see how many residents are affected when the weather changes.
When the environmental model is accurate because of the efforts of the municipality, the music spectrum is accurate because of the efforts of the event producers, a noise map can be made that could help predict the noise nuisance related to outdoor music events.

PREVENT NUISANCE Next to noise control a lot can be done to prevent the nuisance. To start with the location of the event area. Preferably the location should have as little emotional connection with the surrounding residents as possible. If it is a well visited park or everyone's favourite picnic spot the noise will cause more annoyance because it reminds residents of the spot that has been taken. Temporary vacant building-sites, empty parking lots, pieces of no-ones lands are examples of suited areas. This will also reduce the amount of resident that fiercely feel the need to protect their neighbourhood. Another focus point must be the acceptance of certain event by the neighbourhood. Probably when asked everyone will say no to an event near their house, but with some generalization an assumption can be made. A party next to student housing is probably better than next to a nursing home.
The municipality should actively inform all possible residents (within the 45 dB contour) about the upcoming events. The information about the frequency and the finishing time should be very clear, those were the most asked questions from the residents, when does it stop? Inform people clearly what the nuisance hotline is, where they can ask questions and that official authorities are monitoring the event. A good addition would be to use a *Harmonoise* noise model to simulate the noise levels prior to the event, when the weather forecast is known. This would still give time to inform those residents. A well informed resident is always better than an angry one.
During the event a nuisance hotline like festivaloverlast.nl can be used to monitor the nuisance. When people complain, reassure them as soon as possible and preferably share a link for people to monitor the noise levels, this will feel as a great reimbursement and creates trust. After a summer season of events the municipality should analyse the nuisance data to see whether the set of boundaries from the noise map expectations still matches the spread of nuisance complaints.

6 CONCLUSION

This thesis does not proof that a noise map can be a valid tool for predicting noise nuisance from outdoor music events. Further research should be done to validate the framework from Section 5.3. Only a different event and another location could proof whether the noise nuisance predictors as identified in this research are correct. The path noise travels, is as incomprehensible and unique as a residents' subjective reaction to it. Whether it is the source, the environment or the receiver, the assumptions that are made are based on averaging, simplification and preconceptions. It could be that the music played during the events in the Diemerbos were like non other, that the unique conditions caused reflections that are unforeseen, and the residents are an extremely irritable bunch of people. All the data from the seven events had to be used to have enough correct data to conduct all the analyses, and every nuisance complaint has shaped the limits from the framework. Therefore the only correct way to validate the framework and to see whether the noise nuisance predictors take similar effect is to test it with another event at a different location.

The main objective to lay the foundation for a map that effectively disseminate noise information and facilitates well-informed decision making concerning the impact and assessment of outdoor music events, is achieved. The essential elements that make up the basis of a correct noise map have been discussed and tested. The misconduct and flaws that are entwined around contemporary noise prediction procedures for outdoor music events, are outlined and explained. The aspects of noise that can annoy residents both physical as psychological have been addressed. All this knowledge combined should help a decision maker better asses the impact of outdoor music events, and hopefully streamlining a more efficient process that benefits all parties.

This thesis has tried to dismantle the complex technical and social challenges that are intertwined during the impact assessment of noise from outdoor music events. The acoustical analysis has shown the noise nuisance complaints are a reaction on the noise that is produced by the event. The spread that causes residents to complain can be wide but the complaints are not unfounded. A threshold of 45 dB(A) has been found from which some residents seem to be annoyed. Higher source power levels do not seem to influence the relative amount of complaints, but the source power does influence how far the sound will reach and thus how many residents are exposed to the noise and are within this 45 dB(A) contour.

Most of the nuisance complaints are related to the noise, therefore it is possible to use an enhanced noise maps to predict the nuisance complaints. To thrive for the highest accuracy of noise level predictions should be an aim but this is not possible with the current noise prediction methodologies, like the *HMRI*. But for the purpose of nuisance predictions the level of accuracy is high enough compared to the high uncertainty of nuisance prediction. Multiple noise maps should be made with different wind directions. The maximum spread of noise in each wind-direction could be used to determine the maximum amount of affected residents. When the spread of noise is laid upon a map with residential density a chance upon complaints could be determined with a factor depending on the distance to the event and the sight-lines of the speakers. In this way a noise map would serve the impact assessment of an outdoor music event.

This thesis strongly recommends to change current practices and legislation, or at least the limitations of current practices should be more widely known. A better collaboration between municipality and event producer is beneficial for both. By making both parties accountable for the quality of the noise map accuracy is stimulated and this will benefit the surrounding area. There is an overall need for more specialist knowledge, software packages and less ambiguity.

For me personally this research revealed how a geomatics engineer can offer an unique view towards a multidisciplinary metropolitan challenge. I had to collaborate a lot to understand al the facets from this thesis. I worked with engineers that knew everything about sound, I met with people from the municipality, and with event producers, and at the end I could show all of those experts a view from their expertise they had not seen before. For me this showed the possibilities the skill to combine and visualise data can bring to the community, and for this I am very grateful.

7 FUTURE WORK

This research only scratched the surface of a very broad and interdisciplinary topic. Further work can be done in a lot of different fields of expertise. In this chapter I will focus most on what a geomatics engineer could do to extent this topic, and what I as geomatics engineer could have done (and maybe could still do).

VALIDATING THE NOISE MAP TO PREDICT NOISE NUISANCE This thesis has only presented what could be a framework how to use a noise map to predict noise nuisance. The fact that it is not tested is the main missing element of this thesis. The validation of this framework would be a very valuable contribution and the results would substantiate all the assumptions and the recommendations made in this thesis.

3D NOISE MODELS In this thesis the 3D aspect is not avoided but definitely underexposed. The research proved that noise levels can differ depending on the height. Although the Netherlands is a rather flat country if would be interesting to visualise better the 3D characteristic of sound. Especially when there are barriers or unexpected result that need a in-depth analyses a 3D visualisation could offer great insight. Figure 52 shows a vertical grid through the event, an insight that could proof very beneficial.

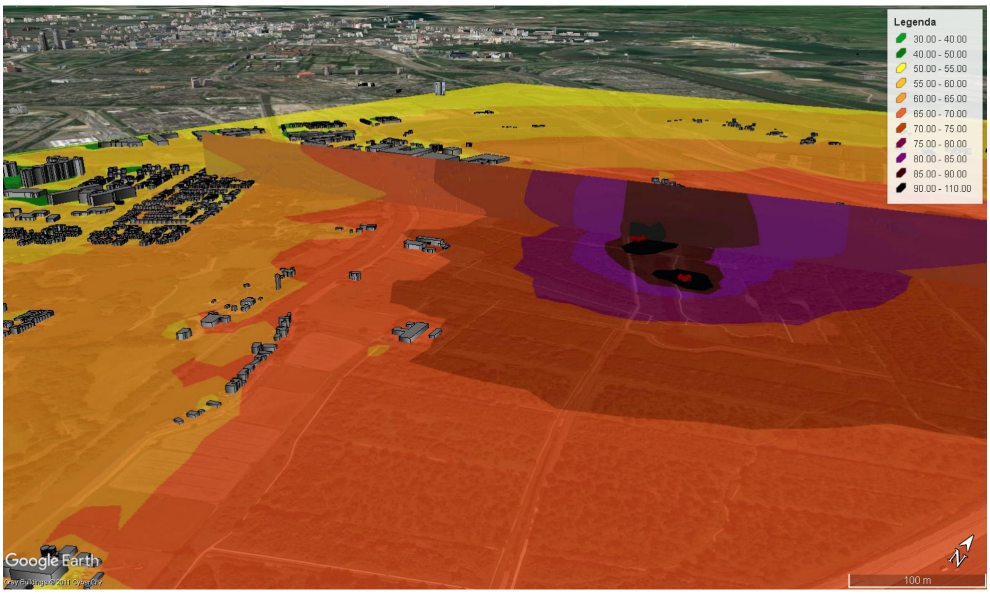


Figure 52: A vertical grid placed through the event area.

NOISE DIFFRACTIONS A diffraction by a building or a wall is definitely one of the biggest influences a noise ray could have. It is known that because of simplification and to save computational power the noise propagation software does not include every possible reflection or diffraction. In this thesis there was a goal to also analyse how much influence the number of diffractions has on the spread of nuisance complaints. The assumption is that without calculating the noise level a Geomatics specialist could make an accurate guess of the location of a complaint by analysing the possible diffractions. This facet of noise propagation is very underexposed in this thesis.

BUILDING CHARACTERISTICS There are all sorts of buildings and they all react different on noise levels. An analysis that focuses on the building characteristics could be very interesting. Buildings have also a natural frequency, and low noise frequencies from outdoor music events can start resonating with the natural frequency of the building. This can result in an amplification of low frequency inside of the house, causing annoyance with the residents. All these kind of phenomena like isolation, amount of windows, gabled roofs, building material, influences the noise attenuation, and it would be very fascinating to see how much they influence noise annoyance.

SOCIAL ECONOMIC ANALYSIS Personally I think with only CBS (Centraal Bureau Statistiek) data combined with nuisance complaint data there are so many interesting relations that could be investigated. How education or income can relate to the manifestation of dissatisfaction is so immensely relevant for municipal decisions. To create greater insight into the mindset of a neighbourhood as a whole is very valuable, and this could be another new field where the qualities to combine and understand spatial data stand out.

ABSTRACT

Noise nuisance caused by outdoor music events has become a heavily discussed issue in metropolitan environments such as Amsterdam. The main objective of this research is to lay the foundation for a map that effectively disseminate noise information and facilitates well-informed decision making concerning the impact and assessment of outdoor music events. A noise map disseminates noise level information and is a common tool for environmental noise caused by roads or industries. The research question is: can a noise map be a valid tool for predicting noise nuisance from outdoor music events in the built environment?

This master thesis is an exploration whether subjective opinions that are the result of a realworld event can be predicted by spatial analysis. Sound is a phenomenon with a spatial attribute and the knowledge of sound propagation is applied frequently in many different industries. In practice noise level prediction is an important instrument to decide by authorities whether an event can take place or not, therefore a study to better understand the relationship between complaints and noise level prediction is valuable.

Noise measurements have been made at several events in the surrounding area of Amsterdam. The noise measurements have been used to investigate the accuracy of the current noise level prediction methodology. Spatial data and noise measurements were gathered from actual noise nuisance complaints to gain insight into the relation between the noise levels and nuisance complaints. Finally recommendations are made to help the municipality and event-producers better assess the possible impact of an outdoor music event.

8 APPENDICES

8.1 APPENDIX 1: WWW.FESTIVALOVERLAST.NL SURVEY

Vragenlijst festivaloverlast.nl 14-04-2016

Dit zijn de vragen die volgen na het knopje “Meld nu” ingedrukt te hebben. Rode vragen zijn vragen waar de gebruiker zelf de input er na kan invoeren. Blauwe woorden zijn opties van om op te drukken voor de gebruiker. Groen knoppen zijn meerdere opties om aan te geven.

1. *Denkt u overlast te ondervinden van evenement bij u in de buurt?*
   Ja (ga door naar vraag 3)
   Nee (ga door naar vraag 2)

   Ik heb niks te melden (terug naar Home screen)

2. *Dit is goed nieuws! Om een beter te beeld te krijgen waar mensen wel of niet overlast ondervinden willen wij u vragen om uw adres. Deze gegevens zullen niet worden opgeslagen maar enkel gebruikt worden om te transformeren naar een geo-locatie die gelinkt is met uw melding, niet met verdere persoonsgegevens.*

   Straat:

   Huisnummer:

   Toevoeging:

   Plaats:

   Vorige vraag (ga terug naar vraag 1)

   Volgende (ga door naar vraag 4)

3. *Wat onpretting voor u! Graag vragen wij uw klacht verder te specificeren. Wat voor overlast ondervindt u? (Meerdere opties mogelijk)*

   Mobiliteitshinder

   Geluidsoverlast

   Vuilnis

   Visuele-overlast (lichten, lasers, overkappingen)

   Anders, namelijk:

   Vorige vraag (ga terug naar vraag 1)

   Volgende (ga door naar vraag 5 bij het niet aanvinken van “geluidsoverlast” , anders naar vraag 6)

4. *Dank u wel voor uw geluid! Wij zullen deze informatie gebruiken om de communicatie tussen buurtbewoners, evenementen en de gemeente te bevorderen. Om uw stem te laten gelden vragen wij om uw emailadres.*

   Emailadres:

   Vorige vraag (ga terug naar vraag 2, of 8)

   Volgende (ga door naar vraag 9)

5 *Om een beter te beeld te krijgen waar mensen wel of niet overlast ondervinden willen wij u vragen om uw adres. Deze gegevens zullen niet worden opgeslagen maar enkel gebruikt worden om te transformeren naar een geo-locatie die gelinkt is met uw melding, niet met verdere persoonsgegevens.*

Straat:

Huisnummer:

Toevoeging:

Plaats:

Vorige vraag (ga terug naar vraag 3, of 7)

Volgende (ga door naar vraag 8)

6 *U heeft aangegeven geluidsoverlast te ondervinden. Wat voor geluid stoort u? (meerdere opties mogelijk)*

Muziekinstallaties

Publieksgleuid (gejoel)

Voorbijgangers/verkeer

Anders, namelijk:

Vorige vraag (ga terug naar vraag 3)

Volgende (ga door naar vraag 7)

7 Ondervindt u deze geluidsoverlast binnen, buiten of beide? (meerdere opties mogelijk)

Binnen

Buiten

Anders, namelijk:

Vorige vraag (ga terug naar vraag 6)

Volgende (ga door naar vraag 5)

8 Wanneer ondervind/ondervond u dit ongemak?

Nu

Anders, namelijk:

Vorige vraag (ga terug naar vraag 5)

Volgende (ga door naar vraag 4)

9 Uw melding is gemaakt!
Tonen van kaart met dichtsbijzijnde evenementen plus basis info

Vorige vraag (ga terug naar vraag 4)

Klaar (Terug naar Home screen)

8.2 APPENDIX 2: PREVAILING ACOUSTICAL REPORT, SOURCES AND RESULTS

Model: Chasing The Hihat
Groep: (hoofdgroep)
Lijst van Puntbronnen, voor rekenmethode Industrielawaai - IL

Groep	Naam	Omschr.	X	Y	Hoogte	Rel.H	Maaiveld	Type	Richt.	Hoek	Cb(u)(D)	Cb(u)(A)	Cb(u)(N)	Cb(D)
Podium A	03	Subwoofers, 0gr	128252,36	482500,82	1,00	1,00	-1,00	Normale puntbron	110,00	45,00	12,000	4,000	--	0,00
Podium A	03	Subwoofers, 45gr	128252,36	482500,82	1,00	1,00	-1,00	Normale puntbron	155,00	45,00	12,000	4,000	--	0,00
Podium A	03	Subwoofers, 90gr	128252,36	482500,82	1,00	1,00	-1,00	Normale puntbron	200,00	45,00	12,000	4,000	--	0,00
Podium A	03	Subwoofers, 135gr	128252,36	482500,82	1,00	1,00	-1,00	Normale puntbron	245,00	45,00	12,000	4,000	--	0,00
Podium A	03	Subwoofers, 180gr	128252,36	482500,82	1,00	1,00	-1,00	Normale puntbron	290,00	45,00	12,000	4,000	--	0,00
Podium A	03	Subwoofers, 225gr	128252,36	482500,82	1,00	1,00	-1,00	Normale puntbron	335,00	45,00	12,000	4,000	--	0,00
Podium A	03	Subwoofers, 270gr	128252,36	482500,82	1,00	1,00	-1,00	Normale puntbron	20,00	45,00	12,000	4,000	--	0,00
Podium A	03	Subwoofers, 315gr	128252,36	482500,82	1,00	1,00	-1,00	Normale puntbron	65,00	45,00	12,000	4,000	--	0,00
Podium A	01	Line array, 0gr	128247,45	482492,11	5,00	5,00	-1,00	Normale puntbron	110,00	45,00	12,000	4,000	--	0,00
Podium A	01	Line array, 45gr	128247,45	482492,11	5,00	5,00	-1,00	Normale puntbron	155,00	45,00	12,000	4,000	--	0,00
Podium A	01	Line array, 90gr	128247,45	482492,11	5,00	5,00	-1,00	Normale puntbron	200,00	45,00	12,000	4,000	--	0,00
Podium A	01	Line array, 135gr	128247,45	482492,11	5,00	5,00	-1,00	Normale puntbron	245,00	45,00	12,000	4,000	--	0,00
Podium A	01	Line array, 180gr	128247,45	482492,11	5,00	5,00	-1,00	Normale puntbron	290,00	45,00	12,000	4,000	--	0,00
Podium A	01	Line array, 225gr	128247,45	482492,11	5,00	5,00	-1,00	Normale puntbron	335,00	45,00	12,000	4,000	--	0,00
Podium A	01	Line array, 270gr	128247,45	482492,11	5,00	5,00	-1,00	Normale puntbron	20,00	45,00	12,000	4,000	--	0,00
Podium A	01	Line array, 315gr	128247,45	482492,11	5,00	5,00	-1,00	Normale puntbron	65,00	45,00	12,000	4,000	--	0,00
Podium A	02	Line array, 0gr	128256,31	482509,51	5,00	5,00	-1,00	Normale puntbron	110,00	45,00	12,000	4,000	--	0,00
Podium A	02	Line array, 45gr	128256,31	482509,51	5,00	5,00	-1,00	Normale puntbron	155,00	45,00	12,000	4,000	--	0,00
Podium A	02	Line array, 90gr	128256,31	482509,51	5,00	5,00	-1,00	Normale puntbron	200,00	45,00	12,000	4,000	--	0,00
Podium A	02	Line array, 135gr	128256,31	482509,51	5,00	5,00	-1,00	Normale puntbron	245,00	45,00	12,000	4,000	--	0,00
Podium A	02	Line array, 180gr	128256,31	482509,51	5,00	5,00	-1,00	Normale puntbron	290,00	45,00	12,000	4,000	--	0,00
Podium A	02	Line array, 225gr	128256,31	482509,51	5,00	5,00	-1,00	Normale puntbron	335,00	45,00	12,000	4,000	--	0,00
Podium A	02	Line array, 270gr	128256,31	482509,51	5,00	5,00	-1,00	Normale puntbron	20,00	45,00	12,000	4,000	--	0,00
Podium A	02	Line array, 315gr	128256,31	482509,51	5,00	5,00	-1,00	Normale puntbron	65,00	45,00	12,000	4,000	--	0,00
Podium B	06	Subwoofers, 0gr	128291,00	482385,18	1,00	1,00	-1,00	Normale puntbron	140,00	45,00	12,000	4,000	--	0,00
Podium B	06	Subwoofers, 45gr	128291,00	482385,18	1,00	1,00	-1,00	Normale puntbron	185,00	45,00	12,000	4,000	--	0,00
Podium B	06	Subwoofers, 90gr	128291,00	482385,18	1,00	1,00	-1,00	Normale puntbron	230,00	45,00	12,000	4,000	--	0,00
Podium B	06	Subwoofers, 135gr	128291,00	482385,18	1,00	1,00	-1,00	Normale puntbron	275,00	45,00	12,000	4,000	--	0,00
Podium B	06	Subwoofers, 180gr	128291,00	482385,18	1,00	1,00	-1,00	Normale puntbron	320,00	45,00	12,000	4,000	--	0,00
Podium B	06	Subwoofers, 225gr	128291,00	482385,18	1,00	1,00	-1,00	Normale puntbron	5,00	45,00	12,000	4,000	--	0,00
Podium B	06	Subwoofers, 270gr	128291,00	482385,18	1,00	1,00	-1,00	Normale puntbron	50,00	45,00	12,000	4,000	--	0,00
Podium B	06	Subwoofers, 315gr	128291,00	482385,18	1,00	1,00	-1,00	Normale puntbron	95,00	45,00	12,000	4,000	--	0,00
Podium B	04	Stacked p.a., 0gr	128284,26	482380,88	3,00	3,00	-1,00	Normale puntbron	140,00	45,00	12,000	4,000	--	0,00
Podium B	04	Stacked p.a., 45gr	128284,26	482380,88	3,00	3,00	-1,00	Normale puntbron	185,00	45,00	12,000	4,000	--	0,00
Podium B	04	Stacked p.a., 90gr	128284,26	482380,88	3,00	3,00	-1,00	Normale puntbron	230,00	45,00	12,000	4,000	--	0,00
Podium B	04	Stacked p.a., 135gr	128284,26	482380,88	3,00	3,00	-1,00	Normale puntbron	275,00	45,00	12,000	4,000	--	0,00

Model: Chasing The Hihat
Groep: (hoofdgroep)
Lijst van Puntbronnen, voor rekenmethode Industrielawaai - IL

Groep	Cb(A)	Cb(N)	Lwr 31	Lwr 63	Lwr 125	Lwr 250	Lwr 500	Lwr 1k	Lwr 2k	Lwr 4k	Lwr 8k	Lwr Totaal
Podium A	0,00	--	--	115,95	--	--	--	--	--	--	--	115,95
Podium A	0,00	--	--	112,95	--	--	--	--	--	--	--	112,95
Podium A	0,00	--	--	113,95	--	--	--	--	--	--	--	113,95
Podium A	0,00	--	--	109,95	--	--	--	--	--	--	--	109,95
Podium A	0,00	--	--	108,95	--	--	--	--	--	--	--	108,95
Podium A	0,00	--	--	109,95	--	--	--	--	--	--	--	109,95
Podium A	0,00	--	--	113,95	--	--	--	--	--	--	--	113,95
Podium A	0,00	--	--	112,95	--	--	--	--	--	--	--	112,95
Podium A	0,00	--	--	--	118,96	118,97	119,99	120,02	118,11	117,43	--	126,79
Podium A	0,00	--	--	--	118,96	118,97	118,99	119,02	115,11	111,43	--	125,60
Podium A	0,00	--	--	--	112,96	111,97	112,99	111,02	108,11	102,43	--	118,82
Podium A	0,00	--	--	--	110,96	106,97	105,99	106,02	105,11	101,43	--	114,78
Podium A	0,00	--	--	--	108,96	105,97	103,99	105,02	105,11	100,43	--	113,40
Podium A	0,00	--	--	--	110,96	106,97	105,99	106,02	105,11	101,43	--	114,78
Podium A	0,00	--	--	--	112,96	111,97	112,99	111,02	108,11	104,43	--	118,88
Podium A	0,00	--	--	--	118,96	118,97	118,99	119,02	115,11	111,43	--	125,60
Podium A	0,00	--	--	--	118,96	118,97	119,99	120,02	118,11	117,43	--	126,79
Podium A	0,00	--	--	--	118,96	118,97	118,99	119,02	115,11	111,43	--	125,60
Podium A	0,00	--	--	--	112,96	111,97	112,99	111,02	108,11	102,43	--	118,82
Podium A	0,00	--	--	--	110,96	106,97	105,99	106,02	105,11	101,43	--	114,78
Podium A	0,00	--	--	--	108,96	105,97	103,99	105,02	105,11	100,43	--	113,40
Podium A	0,00	--	--	--	110,96	106,97	105,99	106,02	105,11	101,43	--	114,78
Podium A	0,00	--	--	--	112,96	111,97	112,99	111,02	108,11	104,43	--	118,88
Podium A	0,00	--	--	--	118,96	118,97	118,99	119,02	115,11	111,43	--	125,60
Podium B	0,00	--	--	113,95	--	--	--	--	--	--	--	113,95
Podium B	0,00	--	--	110,95	--	--	--	--	--	--	--	110,95
Podium B	0,00	--	--	111,95	--	--	--	--	--	--	--	111,95
Podium B	0,00	--	--	107,95	--	--	--	--	--	--	--	107,95
Podium B	0,00	--	--	106,95	--	--	--	--	--	--	--	106,95
Podium B	0,00	--	--	107,95	--	--	--	--	--	--	--	107,95
Podium B	0,00	--	--	111,95	--	--	--	--	--	--	--	111,95
Podium B	0,00	--	--	110,95	--	--	--	--	--	--	--	110,95
Podium B	0,00	--	--	--	116,96	116,97	117,99	118,02	116,11	115,43	--	124,79
Podium B	0,00	--	--	--	116,96	116,97	116,99	117,02	113,11	109,43	--	123,60
Podium B	0,00	--	--	--	110,96	109,97	110,99	109,02	106,11	100,43	--	116,82
Podium B	0,00	--	--	--	108,96	104,97	103,99	104,02	103,11	99,43	--	112,78

Model: Chasing The Hihat
Groep: (hoofdgroep)
Lijst van Puntbronnen, voor rekenmethode Industrielawaai - IL

Groep	Naam	Omschr.	X	Y	Hoogte	Rel.H	Maaiveld	Type	Richt.	Hoek	Cb(u)(D)	Cb(u)(A)	Cb(u)(N)	Cb(D)
Podium B	04	Stacked p.a., 180gr	128284,26	482380,88	3,00	3,00	-1,00	Normale puntbron	320,00	45,00	12,000	4,000	--	0,00
Podium B	04	Stacked p.a., 225gr	128284,26	482380,88	3,00	3,00	-1,00	Normale puntbron	5,00	45,00	12,000	4,000	--	0,00
Podium B	04	Stacked p.a., 270gr	128284,26	482380,88	3,00	3,00	-1,00	Normale puntbron	50,00	45,00	12,000	4,000	--	0,00
Podium B	04	Stacked p.a., 315gr	128284,26	482380,88	3,00	3,00	-1,00	Normale puntbron	95,00	45,00	12,000	4,000	--	0,00
Podium B	05	Stacked p.a., 0gr	128297,22	482390,17	3,00	3,00	-1,00	Normale puntbron	140,00	45,00	12,000	4,000	--	0,00
Podium B	05	Stacked p.a., 45gr	128297,22	482390,17	3,00	3,00	-1,00	Normale puntbron	185,00	45,00	12,000	4,000	--	0,00
Podium B	05	Stacked p.a., 90gr	128297,22	482390,17	3,00	3,00	-1,00	Normale puntbron	230,00	45,00	12,000	4,000	--	0,00
Podium B	05	Stacked p.a., 135gr	128297,22	482390,17	3,00	3,00	-1,00	Normale puntbron	275,00	45,00	12,000	4,000	--	0,00
Podium B	05	Stacked p.a., 180gr	128297,22	482390,17	3,00	3,00	-1,00	Normale puntbron	320,00	45,00	12,000	4,000	--	0,00
Podium B	05	Stacked p.a., 225gr	128297,22	482390,17	3,00	3,00	-1,00	Normale puntbron	5,00	45,00	12,000	4,000	--	0,00
Podium B	05	Stacked p.a., 270gr	128297,22	482390,17	3,00	3,00	-1,00	Normale puntbron	50,00	45,00	12,000	4,000	--	0,00
Podium B	05	Stacked p.a., 315gr	128297,22	482390,17	3,00	3,00	-1,00	Normale puntbron	95,00	45,00	12,000	4,000	--	0,00
Podium C	09	Subwoofers, 0gr	128440,23	482240,12	1,00	1,00	-1,00	Normale puntbron	330,00	45,00	12,000	4,000	--	0,00
Podium C	09	Subwoofers, 45gr	128440,23	482240,12	1,00	1,00	-1,00	Normale puntbron	15,00	45,00	12,000	4,000	--	0,00
Podium C	09	Subwoofers, 90gr	128440,23	482240,12	1,00	1,00	-1,00	Normale puntbron	60,00	45,00	12,000	4,000	--	0,00
Podium C	09	Subwoofers, 135gr	128440,23	482240,12	1,00	1,00	-1,00	Normale puntbron	105,00	45,00	12,000	4,000	--	0,00
Podium C	09	Subwoofers, 180gr	128440,23	482240,12	1,00	1,00	-1,00	Normale puntbron	150,00	45,00	12,000	4,000	--	0,00
Podium C	09	Subwoofers, 225gr	128440,23	482240,12	1,00	1,00	-1,00	Normale puntbron	195,00	45,00	12,000	4,000	--	0,00
Podium C	09	Subwoofers, 270gr	128440,23	482240,12	1,00	1,00	-1,00	Normale puntbron	240,00	45,00	12,000	4,000	--	0,00
Podium C	09	Subwoofers, 315gr	128440,23	482240,12	1,00	1,00	-1,00	Normale puntbron	285,00	45,00	12,000	4,000	--	0,00
Podium C	07	Stacked p.a., 0gr	128445,07	482243,01	3,00	3,00	-1,00	Normale puntbron	330,00	45,00	12,000	4,000	--	0,00
Podium C	07	Stacked p.a., 45gr	128445,07	482243,01	3,00	3,00	-1,00	Normale puntbron	15,00	45,00	12,000	4,000	--	0,00
Podium C	07	Stacked p.a., 90gr	128445,07	482243,01	3,00	3,00	-1,00	Normale puntbron	60,00	45,00	12,000	4,000	--	0,00
Podium C	07	Stacked p.a., 135gr	128445,07	482243,01	3,00	3,00	-1,00	Normale puntbron	105,00	45,00	12,000	4,000	--	0,00
Podium C	07	Stacked p.a., 180gr	128445,07	482243,01	3,00	3,00	-1,00	Normale puntbron	150,00	45,00	12,000	4,000	--	0,00
Podium C	07	Stacked p.a., 225gr	128445,07	482243,01	3,00	3,00	-1,00	Normale puntbron	195,00	45,00	12,000	4,000	--	0,00
Podium C	07	Stacked p.a., 270gr	128445,07	482243,01	3,00	3,00	-1,00	Normale puntbron	240,00	45,00	12,000	4,000	--	0,00
Podium C	07	Stacked p.a., 315gr	128445,07	482243,01	3,00	3,00	-1,00	Normale puntbron	285,00	45,00	12,000	4,000	--	0,00
Podium C	08	Stacked p.a., 0gr	128434,90	482238,31	3,00	3,00	-1,00	Normale puntbron	330,00	45,00	12,000	4,000	--	0,00
Podium C	08	Stacked p.a., 45gr	128434,90	482238,31	3,00	3,00	-1,00	Normale puntbron	15,00	45,00	12,000	4,000	--	0,00
Podium C	08	Stacked p.a., 90gr	128434,90	482238,31	3,00	3,00	-1,00	Normale puntbron	60,00	45,00	12,000	4,000	--	0,00
Podium C	08	Stacked p.a., 135gr	128434,90	482238,31	3,00	3,00	-1,00	Normale puntbron	105,00	45,00	12,000	4,000	--	0,00
Podium C	08	Stacked p.a., 180gr	128434,90	482238,31	3,00	3,00	-1,00	Normale puntbron	150,00	45,00	12,000	4,000	--	0,00
Podium C	08	Stacked p.a., 225gr	128434,90	482238,31	3,00	3,00	-1,00	Normale puntbron	195,00	45,00	12,000	4,000	--	0,00
Podium C	08	Stacked p.a., 270gr	128434,90	482238,31	3,00	3,00	-1,00	Normale puntbron	240,00	45,00	12,000	4,000	--	0,00
Podium C	08	Stacked p.a., 315gr	128434,90	482238,31	3,00	3,00	-1,00	Normale puntbron	285,00	45,00	12,000	4,000	--	0,00

Model: Chasing The Hihat
Groep: (hoofdgroep)
Lijst van Puntbronnen, voor rekenmethode Industrielawaai - IL

Groep	Cb(A)	Cb(N)	Lwr 31	Lwr 63	Lwr 125	Lwr 250	Lwr 500	Lwr 1k	Lwr 2k	Lwr 4k	Lwr 8k	Lwr Totaal
Podium B	0,00	--	--	--	106,96	103,97	101,99	103,02	103,11	98,43	--	111,40
Podium B	0,00	--	--	--	108,96	104,97	103,99	104,02	103,11	99,43	--	112,78
Podium B	0,00	--	--	--	110,96	109,97	110,99	109,02	106,11	102,43	--	116,88
Podium B	0,00	--	--	--	116,96	116,97	116,99	117,02	113,11	109,43	--	123,60
Podium B	0,00	--	--	--	116,96	116,97	117,99	118,02	116,11	115,43	--	124,79
Podium B	0,00	--	--	--	116,96	116,97	116,99	117,02	113,11	109,43	--	123,60
Podium B	0,00	--	--	--	110,96	109,97	110,99	109,02	106,11	100,43	--	116,82
Podium B	0,00	--	--	--	108,96	104,97	103,99	104,02	103,11	99,43	--	112,78
Podium B	0,00	--	--	--	106,96	103,97	101,99	103,02	103,11	98,43	--	111,40
Podium B	0,00	--	--	--	108,96	104,97	103,99	104,02	103,11	99,43	--	112,78
Podium B	0,00	--	--	--	110,96	109,97	110,99	109,02	106,11	102,43	--	116,88
Podium B	0,00	--	--	--	116,96	116,97	116,99	117,02	113,11	109,43	--	123,60
Podium C	0,00	--	--	112,95	--	--	--	--	--	--	--	112,95
Podium C	0,00	--	--	109,95	--	--	--	--	--	--	--	109,95
Podium C	0,00	--	--	110,95	--	--	--	--	--	--	--	110,95
Podium C	0,00	--	--	106,95	--	--	--	--	--	--	--	106,95
Podium C	0,00	--	--	105,95	--	--	--	--	--	--	--	105,95
Podium C	0,00	--	--	106,95	--	--	--	--	--	--	--	106,95
Podium C	0,00	--	--	110,95	--	--	--	--	--	--	--	110,95
Podium C	0,00	--	--	109,95	--	--	--	--	--	--	--	109,95
Podium C	0,00	--	--	--	115,96	115,97	116,99	117,02	115,11	114,43	--	123,79
Podium C	0,00	--	--	--	115,96	115,97	115,99	116,02	112,11	108,43	--	122,60
Podium C	0,00	--	--	--	109,96	108,97	109,99	108,02	105,11	99,43	--	115,82
Podium C	0,00	--	--	--	107,96	103,97	102,99	103,02	102,11	98,43	--	111,78
Podium C	0,00	--	--	--	105,96	102,97	100,99	102,02	102,11	97,43	--	110,40
Podium C	0,00	--	--	--	107,96	103,97	102,99	103,02	102,11	98,43	--	111,78
Podium C	0,00	--	--	--	109,96	108,97	109,99	108,02	105,11	101,43	--	115,88
Podium C	0,00	--	--	--	115,96	115,97	115,99	116,02	112,11	108,43	--	122,60
Podium C	0,00	--	--	--	115,96	115,97	116,99	117,02	115,11	114,43	--	123,79
Podium C	0,00	--	--	--	115,96	115,97	115,99	116,02	112,11	108,43	--	122,60
Podium C	0,00	--	--	--	109,96	108,97	109,99	108,02	105,11	99,43	--	115,82
Podium C	0,00	--	--	--	107,96	103,97	102,99	103,02	102,11	98,43	--	111,78
Podium C	0,00	--	--	--	105,96	102,97	100,99	102,02	102,11	97,43	--	110,40
Podium C	0,00	--	--	--	107,96	103,97	102,99	103,02	102,11	98,43	--	111,78
Podium C	0,00	--	--	--	109,96	108,97	109,99	108,02	105,11	101,43	--	115,88
Podium C	0,00	--	--	--	115,96	115,97	115,99	116,02	112,11	108,43	--	122,60

Model: Chasing The Hihat
Groep: (hoofdgroep)
Lijst van Puntbronnen, voor rekenmethode Industrielawaai - IL

Groep	Naam	Omschr.	X	Y	Hoogte	Rel.H	Maaiveld	Type	Richt.	Hoek	Cb(u)(D)	Cb(u)(A)	Cb(u)(N)	Cb(D)
Podium D	12	Subwoofers, 0gr	128299,40	482540,29	1,00	1,00	-1,00	Normale puntbron	130,00	45,00	12,000	4,000	--	0,00
Podium D	12	Subwoofers, 45gr	128299,40	482540,29	1,00	1,00	-1,00	Normale puntbron	175,00	45,00	12,000	4,000	--	0,00
Podium D	12	Subwoofers, 90gr	128299,40	482540,29	1,00	1,00	-1,00	Normale puntbron	220,00	45,00	12,000	4,000	--	0,00
Podium D	12	Subwoofers, 135gr	128299,40	482540,29	1,00	1,00	-1,00	Normale puntbron	265,00	45,00	12,000	4,000	--	0,00
Podium D	12	Subwoofers, 180gr	128299,40	482540,29	1,00	1,00	-1,00	Normale puntbron	310,00	45,00	12,000	4,000	--	0,00
Podium D	12	Subwoofers, 225gr	128299,40	482540,29	1,00	1,00	-1,00	Normale puntbron	355,00	45,00	12,000	4,000	--	0,00
Podium D	12	Subwoofers, 270gr	128299,40	482540,29	1,00	1,00	-1,00	Normale puntbron	40,00	45,00	12,000	4,000	--	0,00
Podium D	12	Subwoofers, 315gr	128299,40	482540,29	1,00	1,00	-1,00	Normale puntbron	85,00	45,00	12,000	4,000	--	0,00
Podium D	10	Stacked p.a., 0gr	128296,99	482538,28	2,00	2,00	-1,00	Normale puntbron	130,00	45,00	12,000	4,000	--	0,00
Podium D	10	Stacked p.a., 45gr	128296,99	482538,28	2,00	2,00	-1,00	Normale puntbron	175,00	45,00	12,000	4,000	--	0,00
Podium D	10	Stacked p.a., 90gr	128296,99	482538,28	2,00	2,00	-1,00	Normale puntbron	220,00	45,00	12,000	4,000	--	0,00
Podium D	10	Stacked p.a., 135gr	128296,99	482538,28	2,00	2,00	-1,00	Normale puntbron	265,00	45,00	12,000	4,000	--	0,00
Podium D	10	Stacked p.a., 180gr	128296,99	482538,28	2,00	2,00	-1,00	Normale puntbron	310,00	45,00	12,000	4,000	--	0,00
Podium D	10	Stacked p.a., 225gr	128296,99	482538,28	2,00	2,00	-1,00	Normale puntbron	355,00	45,00	12,000	4,000	--	0,00
Podium D	10	Stacked p.a., 270gr	128296,99	482538,28	2,00	2,00	-1,00	Normale puntbron	40,00	45,00	12,000	4,000	--	0,00
Podium D	10	Stacked p.a., 315gr	128296,99	482538,28	2,00	2,00	-1,00	Normale puntbron	85,00	45,00	12,000	4,000	--	0,00
Podium D	11	Stacked p.a., 0gr	128301,52	482542,11	2,00	2,00	-1,00	Normale puntbron	130,00	45,00	12,000	4,000	--	0,00
Podium D	11	Stacked p.a., 45gr	128301,52	482542,11	2,00	2,00	-1,00	Normale puntbron	175,00	45,00	12,000	4,000	--	0,00
Podium D	11	Stacked p.a., 90gr	128301,52	482542,11	2,00	2,00	-1,00	Normale puntbron	220,00	45,00	12,000	4,000	--	0,00
Podium D	11	Stacked p.a., 135gr	128301,52	482542,11	2,00	2,00	-1,00	Normale puntbron	265,00	45,00	12,000	4,000	--	0,00
Podium D	11	Stacked p.a., 180gr	128301,52	482542,11	2,00	2,00	-1,00	Normale puntbron	310,00	45,00	12,000	4,000	--	0,00
Podium D	11	Stacked p.a., 225gr	128301,52	482542,11	2,00	2,00	-1,00	Normale puntbron	355,00	45,00	12,000	4,000	--	0,00
Podium D	11	Stacked p.a., 270gr	128301,52	482542,11	2,00	2,00	-1,00	Normale puntbron	40,00	45,00	12,000	4,000	--	0,00
Podium D	11	Stacked p.a., 315gr	128301,52	482542,11	2,00	2,00	-1,00	Normale puntbron	85,00	45,00	12,000	4,000	--	0,00

Model: Chasing The Hihat
Groep: (hoofdgroep)
Lijst van Puntbronnen, voor rekenmethode Industrielawaai - IL

Groep	Cb(A)	Cb(N)	Lwr 31	Lwr 63	Lwr 125	Lwr 250	Lwr 500	Lwr 1k	Lwr 2k	Lwr 4k	Lwr 8k	Lwr Totaal
Podium D	0,00	--	--	109,95	--	--	--	--	--	--	--	109,95
Podium D	0,00	--	--	106,95	--	--	--	--	--	--	--	106,95
Podium D	0,00	--	--	107,95	--	--	--	--	--	--	--	107,95
Podium D	0,00	--	--	103,95	--	--	--	--	--	--	--	103,95
Podium D	0,00	--	--	102,95	--	--	--	--	--	--	--	102,95
Podium D	0,00	--	--	103,95	--	--	--	--	--	--	--	103,95
Podium D	0,00	--	--	107,95	--	--	--	--	--	--	--	107,95
Podium D	0,00	--	--	106,95	--	--	--	--	--	--	--	106,95
Podium D	0,00	--	--	--	112,96	112,97	113,99	114,02	112,11	111,43	--	120,79
Podium D	0,00	--	--	--	112,96	112,97	112,99	113,02	109,11	105,43	--	119,60
Podium D	0,00	--	--	--	106,96	105,97	106,99	105,02	102,11	96,43	--	112,82
Podium D	0,00	--	--	--	104,96	100,97	99,99	100,02	99,11	95,43	--	108,78
Podium D	0,00	--	--	--	102,96	99,97	97,99	99,02	99,11	94,43	--	107,40
Podium D	0,00	--	--	--	104,96	100,97	99,99	100,02	99,11	95,43	--	108,78
Podium D	0,00	--	--	--	106,96	105,97	106,99	105,02	102,11	98,43	--	112,88
Podium D	0,00	--	--	--	112,96	112,97	112,99	113,02	109,11	105,43	--	119,60
Podium D	0,00	--	--	--	112,96	112,97	113,99	114,02	112,11	111,43	--	120,79
Podium D	0,00	--	--	--	112,96	112,97	112,99	113,02	109,11	105,43	--	119,60
Podium D	0,00	--	--	--	106,96	105,97	106,99	105,02	102,11	96,43	--	112,82
Podium D	0,00	--	--	--	104,96	100,97	99,99	100,02	99,11	95,43	--	108,78
Podium D	0,00	--	--	--	102,96	99,97	97,99	99,02	99,11	94,43	--	107,40
Podium D	0,00	--	--	--	104,96	100,97	99,99	100,02	99,11	95,43	--	108,78
Podium D	0,00	--	--	--	106,96	105,97	106,99	105,02	102,11	98,43	--	112,88
Podium D	0,00	--	--	--	112,96	112,97	112,99	113,02	109,11	105,43	--	119,60

Model: Chasing The Hihat
Groep: (hoofdgroep)
Lijst van Rekenpunten, voor rekenmethode Industrielawaai - IL

Groep	Naam	Omschr.	X	Y	Maaiveld	Hdef.	Hoogte A	Hoogte B	Hoogte C	Hoogte D	Hoogte E	Hoogte F	Gevel
	01	Muiderstraatweg 61-63	128102,59	482823,35	-1,58	Eigen waarde	5,00	--	--	--	--	--	Ja
	02	Stammerdijk 23	127784,28	482414,00	-1,66	Eigen waarde	5,00	--	--	--	--	--	Ja
	03	Stammerdijk 24-25	128020,65	482153,29	-1,94	Eigen waarde	5,00	--	--	--	--	--	Ja
	04	Stammerdijk 29	128241,72	481888,94	-1,94	Eigen waarde	5,00	--	--	--	--	--	Ja
	05	Frankendael, volkstuinvereniging	129336,52	480824,11	-1,94	Eigen waarde	1,50	--	--	--	--	--	Ja
	06	Geerdinkhof	127601,01	482007,79	-1,94	Eigen waarde	5,00	--	--	--	--	--	Ja

Rapport:	Resultatentabel
Model:	Chasing The Hihat
LAeq per oktaaf bij Bron/Groep voor toetspunt:	01_A - Muiderstraatweg 61-63
Groep:	(hoofdgroep)
Groepsreductie:	Nee

Naam Bron/Groep	Omschrijving	Hoogte	Li Totaal	31	63	125	250	500	1000	2000	4000	8000
01_A	Muiderstraatweg 61-63	5,00	59,9	--	58,1	47,9	48,1	49,9	48,9	45,9	36,8	--
Groep	Podium A		57,3	--	55,4	45,5	45,9	46,4	46,0	43,9	35,7	--
Groep	Podium C		54,1	--	51,7	41,7	42,9	46,5	44,2	37,9	26,2	--
Groep	Podium B		51,7	--	50,2	39,3	37,7	39,6	40,3	38,7	28,0	--
Groep	Podium D		46,5	--	45,9	34,8	28,7	29,2	29,0	25,4	13,5	--

Alle getoonde dB-waarden zijn A-gewogen

Rapport:	Resultatentabel
Model:	Chasing The Hihat
LAeq per oktaaf bij Bron/Groep voor toetspunt:	02_A - Stammerdijk 23
Groep:	(hoofdgroep)
Groepsreductie:	Nee

Naam Bron/Groep	Omschrijving	Hoogte	Li Totaal	31	63	125	250	500	1000	2000	4000	8000
02_A	Stammerdijk 23	5,00	61,6	--	59,1	50,3	50,7	52,6	52,1	47,7	36,9	--
Groep	Podium A		57,5	--	55,8	46,2	46,2	46,4	45,9	43,4	33,6	--
Groep	Podium C		56,7	--	50,9	46,0	48,0	50,6	49,9	43,7	31,4	--
Groep	Podium B		54,7	--	53,5	42,6	40,1	42,5	42,1	39,5	29,3	--
Groep	Podium D		50,2	--	48,9	38,6	33,9	37,2	38,6	36,1	25,6	--

Alle getoonde dB-waarden zijn A-gewogen

Rapport:	Resultatentabel
Model:	Chasing The Hihat
LAeq per oktaaf bij Bron/Groep voor toetspunt:	03_A - Stammerdijk 24-25
Groep:	(hoofdgroep)
Groepsreductie:	Nee

Naam Bron/Groep	Omschrijving	Hoogte	Li Totaal	31	63	125	250	500	1000	2000	4000	8000
03_A	Stammerdijk 24-25	5,00	63,7	--	61,2	50,3	52,6	56,0	53,8	49,5	39,2	--
Groep	Podium A		59,4	--	56,4	44,6	50,0	52,2	49,7	45,4	34,4	--
Groep	Podium B		59,1	--	56,6	46,5	46,8	51,5	49,3	45,1	34,9	--
Groep	Podium C		57,1	--	55,0	44,4	44,9	48,9	46,5	42,2	33,0	--
Groep	Podium D		51,5	--	49,5	37,1	37,3	42,6	42,2	37,8	26,0	--

Alle getoonde dB-waarden zijn A-gewogen

Rapport:	Resultatentabel
Model:	Chasing The Hihat
LAeq per oktaaf bij Bron/Groep voor toetspunt:	04_A - Stammerdijk 29
Groep:	(hoofdgroep)
Groepsreductie:	Nee

Naam Bron/Groep	Omschrijving	Hoogte	Li Totaal	31	63	125	250	500	1000	2000	4000	8000
04_A	Stammerdijk 29	5,00	63,2	--	58,9	52,3	53,5	56,2	55,6	50,3	39,9	--
Groep	Podium B		60,5	--	53,9	50,3	51,7	54,5	54,1	48,5	38,4	--
Groep	Podium A		57,3	--	55,3	43,9	46,7	48,7	45,9	41,0	27,5	--
Groep	Podium C		53,5	--	51,5	43,8	41,1	42,6	42,3	40,0	31,2	--
Groep	Podium D		52,9	--	47,8	42,1	41,8	45,9	47,2	41,2	29,2	--

Alle getoonde dB-waarden zijn A-gewogen

8.3 APPENDIX 3: NOISE MAP WITH EXTENDED ENVIRONMENTAL MODEL

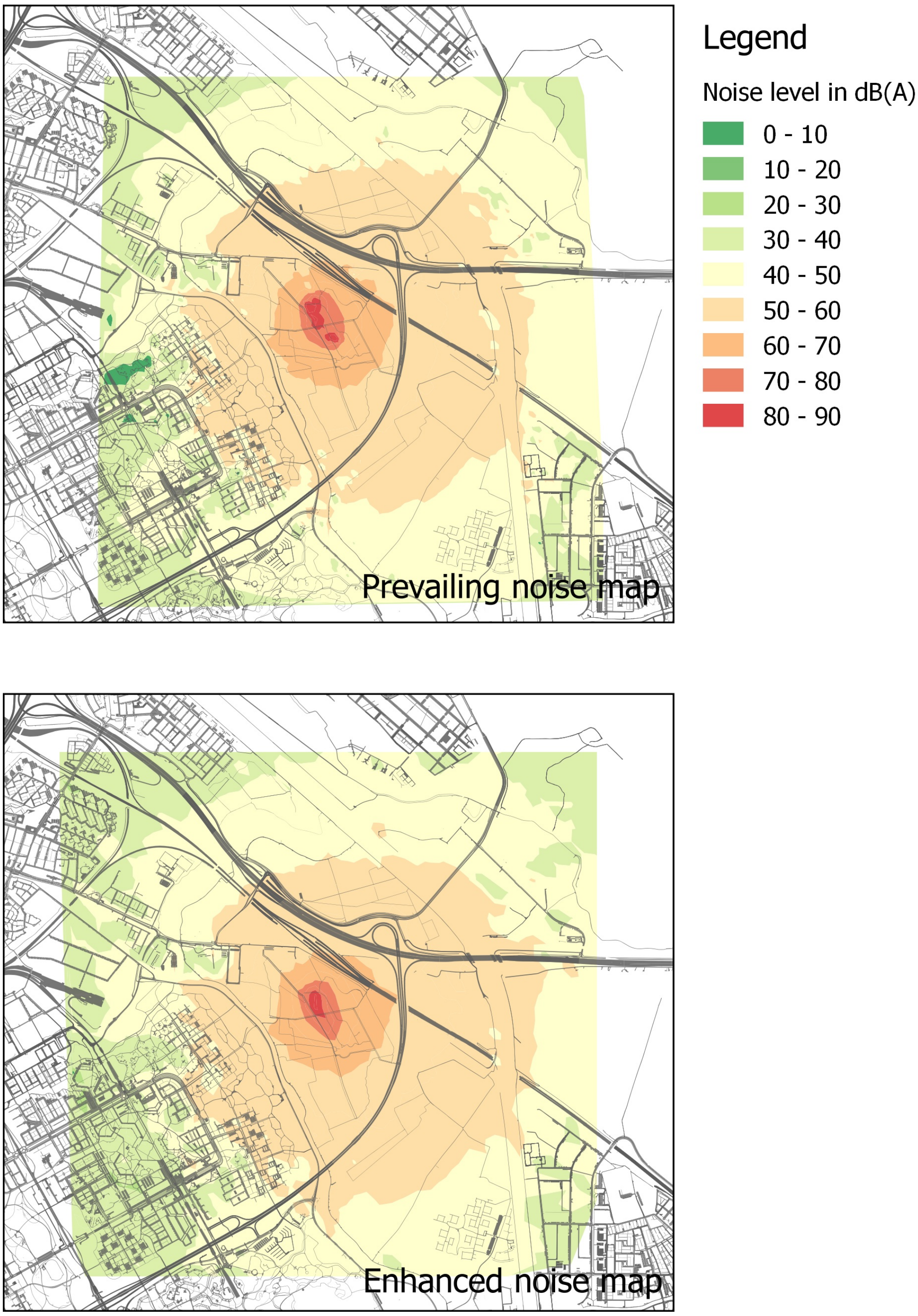


Figure 53: The prevailing noise map and the noise map with an enhanced environmental model

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