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Factors that Influence Community's Acceptance of Noise: An Introduction for Urban Air Mobility

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Table of Contents

Factors that Influence Community's Acceptance of Noise: An Introduction for Urban Air Mobility

Mary M. Connors[1]

Abstract

Noise has been identified as a major challenge to community acceptance of Urban Air Mobility Systems. The purpose of this paper is to assist designers, developers, and implementers in understanding the various factors—from the noise source itself to the conditions of the community—that influence how the community is likely to respond to the introduction of a new noise source. Particular consideration is given to the role of non-acoustical factors and suggestions are offered as to how future research could help advance the understanding of community acceptance of Urban Air Mobility and other emergent vehicle systems..

1. Introduction

Whenever a new technology is planned for a residential community, questions must be addressed as to how that community is likely to respond. When the new technology involves adding noise to the environment (as occurs with a new transportation system) it is even more important to assess community response. In order to anticipate how the new sound environment will be greeted, the developers and implementers of the technology must fully understand the soundscape being created. What kind and level of noise is being added to the background that currently exists? The industry surrounding Urban Air Mobility (UAM) has clearly recognized noise as a potential obstacle to UAM implementation and has listed it as a major challenge to the growth of the industry (Uber Elevate, 2016).

Determining both the nature and level of noise anticipated and the response expected is a highly complex endeavor and largely context dependent. In establishing the noise acceptance of a system, the level of "annoyance" is the measure most often employed, although many other measures (sleep disruption, lessening of cognitive capabilities such as attention or memory, hearing loss, and general health problems) can also play a role. Adding to the difficulty in this inquiry is the pressure from industry and its regulators to establish a standard—a magic number—that will define what level of noise is acceptable and what is not.

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1.1 Purpose

With reference to transportation, it is generally concluded that rail and road noise are less disturbing to communities than aircraft noise, with fixed-wing aircraft less disturbing than helicopter noise. From this, and unless other factors intervene, it can reasonably be assumed that UAMs, especially in large numbers, could result in a significant level of annoyance to impacted communities.

The purpose of this brief treatise is not to provide a simple answer to the question of community acceptance—since the only accurate answer is "it all depends". The purpose here is to help designers, engineers, and others involved in developing and implementing a new transportation system such as UAM to be aware of the range of factors that contribute to the acceptance or rejection of a new noise source. Community acceptance or rejection of noise goes well beyond the noise source itself, as will be described below. The hope is that greater awareness of the various issues that could affect acceptance will lead to a broader approach in considering and addressing the "noise problem".

Although this report is intended for the UAM community, it may also be helpful to UTM implementation or to any effort where noise management is an essential element of community acceptance.

1.2 Definitions

In this publication, terms will be used in the following way:

- *Sound source:* The physical element generating the sound waves.
- *Sound level*: The Magnitude of the sound.
- *Decibels:* A logarithmic measure of sound level.
- *DNL:* An expression (day/night level) commonly used to refer to the physical energy or "dosage" of a sound source expressed in decibels.
- *Audibility:* The detectability of noise against its background.
- *Loudness:* A human judgment that may not directly reflect the physical source. (Two sources of equal energy may be perceived as of different loudness.)
- *Weighting:* A method of analyzing data to reflect loudness as a fuction of frequency. A commonly used weighting approach is the "A" weighting that reflects the response of loudness judgements of listeners and captures reduced sensitivity to high and low frequencies. (Weighting is also used below in the conventional sense to describe how data can be adjusted to reflect known conditions.)
- *Spectral characteristics:* The wavelengths constituting the noise source.
- *Frequency:* The number of noise events.
- *Duration:* The length of time the noise source is audible.
- *Noisiness:* A description of a noise stimulus that leans in the direction of a negative evaluation.
- *Annoyance:* A global description of a stimulus that is clearly perceived as negative but without further analysis of the cause of the negativity.

2. Aural Factors

The first step in understanding the acceptance/rejection of community noise is to understand the source of the noise—i.e., the noise stimulus. The noise stimulus and its impact have been a subject of scientific investigation for many decades. The physical source can be described in terms of its spectral distribution, its frequency, its duration, its smoothness or impulsiveness, etc. If the interest is specifically in understanding the human response, the investigator may prefer to consider not just the energy components of the source but its perceptual correlates such as loudness or audibility. In either case, most noise measurements are eventually expressed in DNL decibels and generally follow an A-weighted protocol. When determining a standard for community noise, a 10dB penalty is usually applied to nighttime levels. This has the effect both of accommodating nighttime activities, especially sleep, and of limiting the noise footprint, since noise from a particular source can be perceived further at night where there is low background noise. Most researchers base annoyance findings on the level at which 50% of respondents are highly annoyed. High annoyance represents an area on the response curve where responses are stable. However, between and among studies there is a significant variability in highly annoying noise levels—sometimes covering multiple (log) decibel units.

Aural factors lend themselves to direct measurement techniques. While it may be extremely challenging to duplicate the essential qualities of a particular noise source (either by recording or modeling), once this is accomplished the evaluation of human response can follow from well-designed and analyzed empirical studies. Such studies, performed in labs or simulation facilities, can capture the relatively direct relationship between the source and the human response. The determination of the impact of aural factors under particular circumstances is, of course, only one factor in how the noise will be perceived in the community of interest, and it is these other factors that make community acceptance so difficult to predict. Estimates of how well aural factors predict acceptance vary widely, with some authors reporting the contribution of aural factors as low as 13–15% (NAL, 1982; Sheridan et al, 2010). However, most investigators conclude that aural factors are able to account for more, and perhaps as much as half of the variance found in real-world community settings. Whatever the numbers, a significant amount of variability remains to be explained.

3. Environmental Factors

Beyond the sound source itself are the physical structures of the community that affect the way sound reaches the listener. Hills, mountains, flatlands, etc. may shift the path of the noise source on a relatively predictable basis. Time of the year may also influence how the source is received, while local weather may result in dynamic changes. Similarly, the materials used in the construction of residences may influence the sounds reaching the residents. Background noise is a major contributor to how an added noise source is perceived. Against a high noise background, a new noise may be barely audible or may be masked and not even be detected, while against a low noise background a new source may be perceived to dominate the sound environment.

4. Non-Acoustic Factors

Exactly what is included under "non-acoustic" factors differs among researchers. Here we include as "non-acoustic" all those factors that impact community acceptance that are not directly related to the sound source and do not represent error in measurement.

Evaluating non-acoustic factors associated with noise is an attempt to understand the black box of the community acceptance question. It requires looking behind the responses and determining what are the contextual factors influencing the responses. At one extreme are factors that have some indirect relationship to the sound source. At the other extreme are factors that are embedded in the fabric of the particular community. But since non-acoustic factors play such a large role in the acceptance/rejection question, they must be considered to whatever extent they can be revealed. Although important in all cases, non-acoustic factors are particularly important in the case of a totally new noise source, such as that associated with emergent vehicles.

Here we will consider factors not directly related to the sound source or the environment under three headings: demographic, psychological, and social.

4.1 Demographic Factors

One of the few non-acoustic areas that has shown consistent results across studies and communities is demographic factors. Most researchers who have investigated demographics such as age, gender, race, ethnicity, etc. have concluded that no differences in annoyance response can be attributed to these groupings. However, there are marked differences in response between average respondents and those who are "super-sensitive" and between normals and those who are "oblivious" to noise. But these categories do not follow a demographic distinction. The percentage of the population of "super-sensitives" seems to cluster around 15%. Since sensitivity to noise has been assumed to be normally distributed, we can assume an equal percentage of the population to be "oblivious" (although larger percentages have been reported [Sobotova et al, 2006]). Individual sensitivity to noise has been found to be a stable individual characteristic nd can be easily measured (e.g., the Noise Sensitivity Questionnaire, described in Shepherd et al, 2010). This stability for an individual across sources and conditions renders sensitivity to noise an important hook in the conduct of noise acceptance investigations.

The one population descriptor that does show a significant difference in acceptance or rejection of noise is the income of the respondents. Lower income residents tend to be less annoyed, or at least express their annoyance less, than higher income residents.

4.2 Psychological Factors

Some of the most elusive non-acoustic factors are those buried in the psyche of those exposed to noise. Control plays an important role in reactions to noise. It is reasonable to assume that fear of losing control and the resulting feeling of helplessness are central to an individual's response to noise. People closely guard the control they have over their lives, including their environment. Being exposed to noise they cannot control can result in a high level of stress. If the exposure is regular and can be anticipated, it is likely to have less impact than if it is random and surprises the receiver. This may be one element in why the noise one generates him/herself offends less than similar noise made by others.

Beyond control, response to noise is affected by the meaning of the noise to the receiver. The cry of a child taking his first breath is welcome, while the cry of a person in pain causes stress. Similarly, a helicopter delivering a dangerously ill patient to medical care would be expected to be better tolerated than one transporting a wealthy individual to or from his weekend get-away.

Another concern for some individuals is noise-triggered fear. Such fear could be associated with an earlier event, such as a previous accident, or another perceived threat to safety, and in some cases the fear could be shared among residents of the community. For example, an increased number of vehicles overhead could trigger in some a fear that something bad is about to happen.

4.3 Social Factors

Noise can contribute to how community members interact with each other. If noise is seen as unnecessary or is ascribed to someone who is ignoring the well-being of others, it will result in annoyance, and, if possible, in the elimination of the noise source. Many vehicles flying at low altitudes could also raise concerns about privacy. More generally, the anticipated response to noise such as that generated by UAMs will reflect how the society views the system as benefitting or disadvantaging their group interactions.

5. Impact of Noise

The major categories ordinarily used to describe the impact of noise on communities are: general annoyance, task interference, and sleep. “Annoyance” is a global concept that implies a common and recognizable response but makes no claim to understanding what contributes to the annoyance. “Interference” captures the disruption to normal activities with exposure to noise. Noise can interfere with conversation and can lead to lessening of cognitive abilities, poor judgment, bad decisions, and generally reduced performance. It has also been found to increase aggression and lessen helping behavior (Page, 1977; Cohen and Spacapan, 1984). Confrontational behaviors associated with noise have been found not only during the noise exposure itself but even after the noise ceases. “Sleep” is a particular category of interference but is usually distinguished due to its assumed importance to overall health. A number of stress-related impacts, such as those affecting blood pressure or gastrointestinal disturbances have been associated with noise (see review by Stansfeld, 2003).

6. Community-Specific Responses

In every community there is a mixture of noise sources that constitutes the overall noisiness experienced by the community residents. Predicting community response to changes in this overall soundscape must take into account both the aural and non-acoustic factors affecting that community. High noise levels are found in neighborhoods with high populations, often the populations of low income. Fidell (1982) found that when a new noise level is introduced into a community it can take two months or more for a stable level of annoyance to be reached, i.e. to achieve the annoyance plateau. It follows that measurements taken within two months of the initiation of a noise source can potentially underestimate the actual annoyance level. Once the stable level has been reaced, it does not appear to matter how long community members have been exposed (Vallet et al, 1978).

6.1 Measuring Community Responses to Noise

There are two basic measures that historically have been used to evaluate the response to noise in a particular community: complaints lodged by community members and surveys of community members. Complaints concerning noise associated with a single source, such a factory or an airport, will exceed those arising from multiple sources or from a source that is difficult to identify. Noise complaints in and around airports have been gathered both by the Federal Aviation Administration (FAA) and often by the airport management. Complaints are considered a reliable measure of the extent of the noise problem but are available only late in the process when change options are limited.

Survey data have been the pro-active method-of-choice in evaluating annoyance based on noise, but these too have significant limitations. Like complaints, they provide data only after the fact. They also tend to present many obstacles to achieving their goal of accurately measuring acceptance (ACRP, Report 183, 2017). Also, surveys today are more difficult to conduct than in former times. For one thing, fewer and fewer people now respond to surveys. And, telephone surveys, a favored method of conducting community surveys, have lost some of their advantages in recent years. The use of cell phones, along with or in lieu of land lines, makes the objective of random selection difficult to achieve. In addition, surveys represent a point in time—a snapshot of community reaction that could change with circumstances. Overall, community surveys are very expensive to conduct with scientific precision, and, most importantly, few results on noise acceptance gathered in one community can be generalized to other communities.

For a variety of reasons, only a very small number of noise surveys have been conducted in the United States in the last few decades, although surveys have been used recently in European and Asian nations. However, the legacy of community noise surveys conducted decades ago in the U.S., and more recently in other nations, when viewed together, continue to provide measurable benefit. For instance, findings from surveys, taken over many years demonstrate that more recent respondents are less tolerant of noise than their earlier counterparts—i.e. annoyance responses have moved over time in the direction of being more annoyed (Sobotova et al; 2006; Basner, 2018). There may be several explanations for this shift, but it appears that annoyance is greater today than in the past even with similar sound levels (as reported in van Kamp and Schreckenberg, 2018.)

As a result of the difficulties in capturing reliable reactions to noise, the emphasis today has shifted from measuring annoyance responses to trying to develop better methods for predicting responses (Basner, 2018).

6.2 Predicting Community Responses to Noise

There are essentially two paths in attempting to predict response to noise at the community level. One relies on weighting factors that influence acceptance that are known or believed to be present in the community; the other, more recent, takes a computational approach based on data from a very large number of community noise surveys conducted over the last half century.

The weighting method, early proposed by Stevens et al (1955), begins with results found for aural factors and imposes credits or penalties based on specific community factors. This is a straight-forward approach relying on observation and intuition to account for the influence of non-acoustic factors. Though promising, this method has not been validated or widely used.

The computational approach, termed Community Tolerance Level or CTL, depends on an empirically-derived relationship between effective loudness (loudness adjusted for duration) and community annoyance. The authors of this approach (Fidell et al, 2011) report that the rate of change of effective loudness correlates with the rate of change of community annoyance. Effective loudness, based on DNL levels reported in a large number of surveys, uses the established relationship of 10dB as akin to doubling perceived loudness and 3dB as equating to a doubling of duration. The focus of the CTL method is to predict annoyance by extending the results of aural measures taken from the combined surveys evaluated. These authors estimate that this approach, when combined with the uncertainty accounted for by aural factors (~47%), can account for an additional 25% of the variance, and result in the ability to predict about three-quarters of the uncertainty in a community's response to noise. The authors have extended their findings, originally based on aircraft noise, to other transportation modes (Schomer et al, 2012). Additional modification of the CTL method to improve precision has been offered by Taraldsen et al (2016). The CTL approach relies on correlational data and does not reveal the underlying elements contributing to the annoyance. This latter area, i.e., identifying causes of annoyance, would seem to offer the most promise for further understanding, and therefore predicting, community response to noise.

7. Interacting with and Preparing the Community

Whenever a significant sound source is added to the soundscape of a community, it is important to consider how this change should be introduced. The community needs to be informed and prepared. Members of the community may have numerous concerns (as outlined in Section 4). Introducing a new transportation mode requires addressing which of these concerns apply to the particular community.

One common concern to be anticipated at the community level is a potential loss of property values. Property values should be part of any initial discussion with community members. Another likely concern needing to be addressed involves future development. Although a community may be willing to experiment with a certain noise increase if the benefits gained offset their immediate concerns, they may be unwilling to take that first step without assurances regarding future developments. One approach here is to outline the steps of the potential growth process and how the community will be included at each step.

There is substantial literature on best practices for interacting with communities affected by noise (for one review, see ACRP Research Report 15, 2017). Chapter Four of this volume (Community Engagement Strategies and Techniques) contains detailed guidance on every aspect of interacting with communities in support of successful outcomes. But the overall message can be briefly summarized as: Listen. Be transparent. Build trust. Start early.

It takes dedication to enssure that the community is fully and accurately prepared, but it is essential to do so. The community is the final arbiter of what is or is not to be allowed. Through ordinances or other community action, their voices will be heard. How the community interaction is addressed could prove to be the determining factor in the acceptance or rejection of new transportation systems including UAM.

8. Conclusions

A significant difference between emergent vehicles systems such as UAM and earlier aviation systems is that, for the former, the ultimate success of the industry is highly dependent on those who do not buy a ticket or pay a bill as well as on those who do. Those on the ground will have a major voice in how the industry develops, and noise management and acceptability will be a critical element in community decisions.

Even a relatively limited examination of noise, how it impacts communities, and how communities are likely to respond to new and emergent transportation systems reveals certain facts. Noise in natural settings is difficult to limit and to manage. Noise is an amorphous concept, multi-dimensional and multi-variable, as well as highly situation- and context-dependent. Understanding how noise impacts a community must involve consideration of environmental and non-acoustic factors as well as aural factors.

While investigating the “bottom-up” factors affecting annoyance, it is also suggested that the “top-down” predictors of Community Tolerance Levels and Weighting non-acoustic factors could also contribute to the overall understanding of noise acceptance. The CTL method has been empirically demonstrated, although predicting non-acoustic results from aural findings seems counter-intuitive. Alternately, the Weighting method is intuitive, but needs to be extended to include what is currently known or learned of non-acoustic factors.

It is possible that a combination of the research on causes—particularly if they can be generalized—combined with a new and improved CTL or Weighting approach could lead to a fuller understanding of how to predict community response to noise as opposed to measuring acceptance or rejection after the fact.

Before concluding, it should be noted that resolving noise issues for emerging vehicle systems such as UAM, is necessary but not sufficient to resolve all community concerns. If vehicles are deployed in the numbers now being projected, there will be additional demands to ensure safety, to protect privacy, to limit emissions and to guard against blocking visual access to free and open air space.

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