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Ambient noise inside airport terminals: a detailed survey of the background noise at Amsterdam Airport Schiphol

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ABSTRACT

Airport terminals tend to be busy, with high ambient noise levels as a consequence. The level and spectrum of background noise form a determining factor for the intelligibility of Public Address and Voice Alarm messages. Previously reported data on background noise at airports vary between surveys, raising the question whether ambient noise information can be applied generically across different terminals, as is often done. For this reason, Amsterdam Airport Schiphol carried out a survey of the background noise throughout its extensive terminal complex. Longitudinal measurements were carried out at 21 locations (for a combined duration of more than 500 hours), as well as grid-based short-term measurements at more than 900 positions. Focus was on the worst-case situations occurring during rush hours. Short noise bursts (e.g. passing of retail supply carts) that are not considered detrimental to the effectiveness of Public Address and Voice Alarm messages (since these are normally repeated a few times) were excluded from further consideration. The remaining background noise levels were somewhat lower than previously assumed even at the busiest times, ranging from 61 dB(A) in pedestrian traffic areas to 68 dB(A) for the security filters. The spectrum was similar in shape across all locations.

1. INTRODUCTION

Amsterdam Airport Schiphol, which serves as a major transportation hub in north-western Europe, receives about 72 million passengers annually [1]. The buildings and infrastructure that make up the terminal complex are designed to deal with this massive flow of people through a (comparatively) small space. Factors that have an impact on comfort and safety of passengers are of prime interest to those who manage and operate the airport. One such factor is the ambient noise throughout the terminal complex.

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While elevated levels of background noise are unavoidable in busy public spaces, a direct impact of the level and spectrum of noise on comfort and well-being of travellers has previously been established [2]. Background noise also has an impact on the intelligibility of service announcements, which are intended to support the traveller's travel experience. Reduced intelligibility of those messages also translates into negative impact on the on-time performance and the experience of the traveller. Perhaps more importantly, noise also affects the intelligibility of messages produced by the voice alarm (VA) system. Since the VA system plays a pivotal role in the complex system of regulations and infrastructure surrounding terminal safety, it is important to have an accurate quantitative insight into the background noise. VA systems can then be designed to cope with the expected level of background noise effectively, thus ensuring that evacuation messages are intelligible.

Intelligibility is estimated by means of the Speech Transmission Index or STI [2,3] as required by the applicable standards relating to VA systems in the Netherlands [5]. The impact of background noise with a given level and spectrum on speech intelligibility can be predicted very accurately, at least in terms the average intelligibility observed over a larger group of listeners, and over time. Once the background spectra and levels are known throughout a venue, it is straightforward to predict "hotspots" in terms of intelligibility issues. STI predictions can also be used to suggest modifications of the VA system needed to (continue to) meet intelligibility requirements. The same applies to public announcements provided as a service to passengers at gates and in waiting areas; in some situations these are played through a separate PA system, in some cases through a combined PAVA system. Either way, intelligibility requirements also apply to these service announcements, which means that background noise is also to be considered.

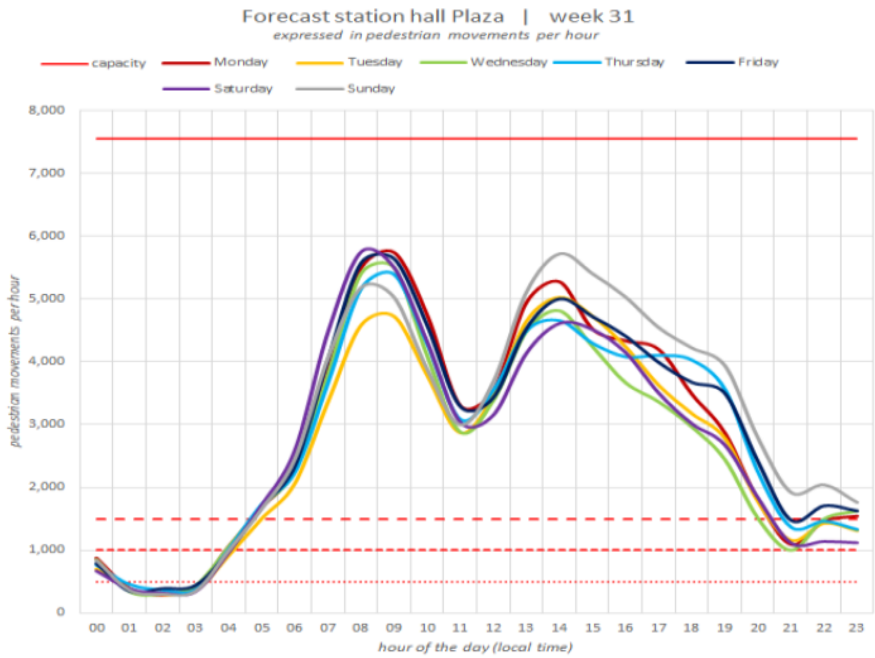

Figure 1: Forecast people flow - Plaza Station at Schiphol (week 31-2020).

Standards require that a "representative noise spectrum" is determined for each space [4,5], or if multiple spaces are similar in terms of their acoustic characteristics, for each type of space. This representative spectrum is then applied when measuring and predicting speech intelligibility of VA systems. Ideally, to simplify the analysis, the background noise at a venue is summarized through a small number of space categories (with corresponding spectra) rather than determining a representative noise spectrum for each specific position. However, for a venue as big and complex as Amsterdam Airport, arriving at a table of reliable and commonly accepted background noise spectra is more difficult than it may appear. The total area of the terminal complex is nearly 200 acres in size [1] (800.000 m^2 gross floor area), ranging from relatively quiet lounges to bustling shopping areas. The crowd density (and by association the background noise) fluctuates with the time of day. This is illustrated by Figure 1; this is a typical forecast for the people flow as a function of the time of day. These forecasts vary from day to day. Traffic in any corridor may be very dense at one moment, e.g. after a wave of incoming flights debarked simultaneously, while the corridor may be nearly deserted shortly after.

2. METHODS

2.1. Definitions

To come to an operational definition of a "representative background noise spectrum," we have to consider that we are applying the spectrum in the context of VA system intelligibility. This means that:

- We are not concerned about any peaks in the background noise that are short in duration (e.g. shouting children, motorized carts passing through, the sound of a luggage trolley when exiting a moving walkway). These sounds are transient enough that they will not mask evacuation messages, especially when taking into account that each message is repeated multiple times.
- We are also not interested in the *average* sound spectrum. The VA system has to be intelligible even (or maybe especially) during rush hours when the ambient noise level peaks. If we were to take the average spectrum across a long time (possibly the 24h or 7 day average), the background noise would be underestimated right when most people are in the terminal.

For the purposes of this study, we define the representative spectrum as the average spectrum during "rush hour conditions" in normal business situations. We define rush hour conditions through the measured short-term average spectrum; if this background noise averaged across a 15-minute time span falls into the top 20% measured across a long duration (>24h), we consider it to be representative. In order to determine this short-term average, we exclude short peaks/bursts of up to 30 seconds. These are normally due to PA announcements or transient noise sources that we defined as irrelevant to the performance of the VA system. Measurements were done on days during which the airport was operating at at least 85% of its capacity to ensure rush hour conditions.

2.2. Scope of the survey and downselection of data

An extensive survey was held to measure the ambient noise throughout the terminal. Longitudinal level and spectrum measurements were done at 21 locations throughout the terminal, for a total of more than 500 hours. From these recordings, we determined the levels and spectra corresponding to our rush hour criteria. Based on our recordings, we were able to predict where and when peak conditions can be expected throughout the terminal complex. We then measured spectra throughout the terminal complex on a grid of approx. 900 individual measuring points, during times with expected rush hour conditions. We verified that the spectra indeed matched rush hour criteria by comparing grid measurements to longitudinal measurements for the approximate same measuring position. Between the longitudinal measurements and grid measurements, we were able to obtain a comprehensive overview of ambient noise throughout the terminal in space as well as time. In order to make the outcome of the study manageable, we categorized all spaces within the terminal according to function and approximate ambient noise level. Each category comprises spaces with the same kind of use (e.g. lounge, reclaim and corridor) and the same approximate background noise environment.

2.3. Methods and equipment

For the longitudinal tests, we used two Bedrock SM30 sound level meters compliant to IEC-61672:2013 [6]. The sound level meters logged L_{AEQ} levels and 1/3 octave spectra continuously and simultaneously stored calibrated audio recordings of the audio signal for further post-hoc analysis.

Figure 2: Example of a longitudinal test setup

The grid measurements were performed with two Class 1 Bedrock SM90 sound levels meters. All equipment was calibrated with a B&K4231 field calibrator, which was in turn calibrated to a traceable laboratory standard. In addition to measured level and spectra, further processing of audio was done in Matlab, based on recorded (calibrated) audio. Short-term L_{EQ} calculations were performed across 1-second timeframes. These 1-second L_{EQ} values were obtained as a basis to calculate L_{EQ} over timeframes of varying lengths.

3. RESULTS

3.1. Natural fluctuation patterns

As expected, the ambient noise varies with the measuring position and the time of day and also shows pronounced peaks of short duration when PA messages are played or due to transient events (shouting, carts, etc). The influence of these transient events in the signal analysis is reduced when observing (moving) L_{EQ} results over longer averaging times. In order to observe the natural fluctuation patterns of the ambient noise over time without taking the impact of transient noises into account, we found that a 15-minute integration interval was suitable. Below, we present the equivalent continuous A-weighted sound pressure level as a function of time of day, with integration times of 1 second and 15 minutes, for two different locations.

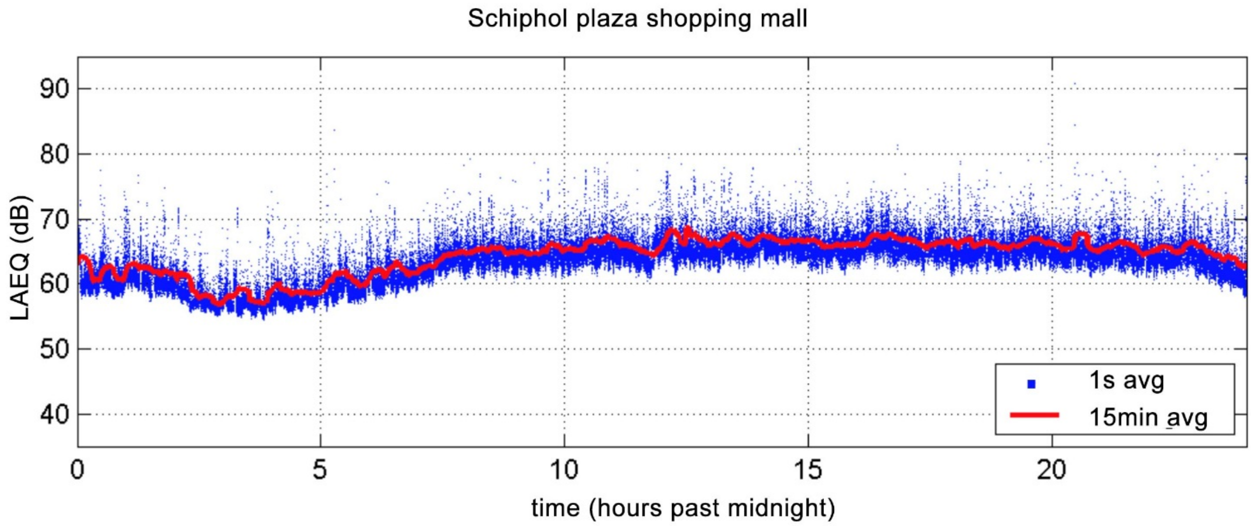

Figure 3: The equivalent continuous A-weighted sound pressure level (LA_{EQ}), with integration times of 1 second and 15 minutes, for a central location within the Schiphol plaza shopping mall.

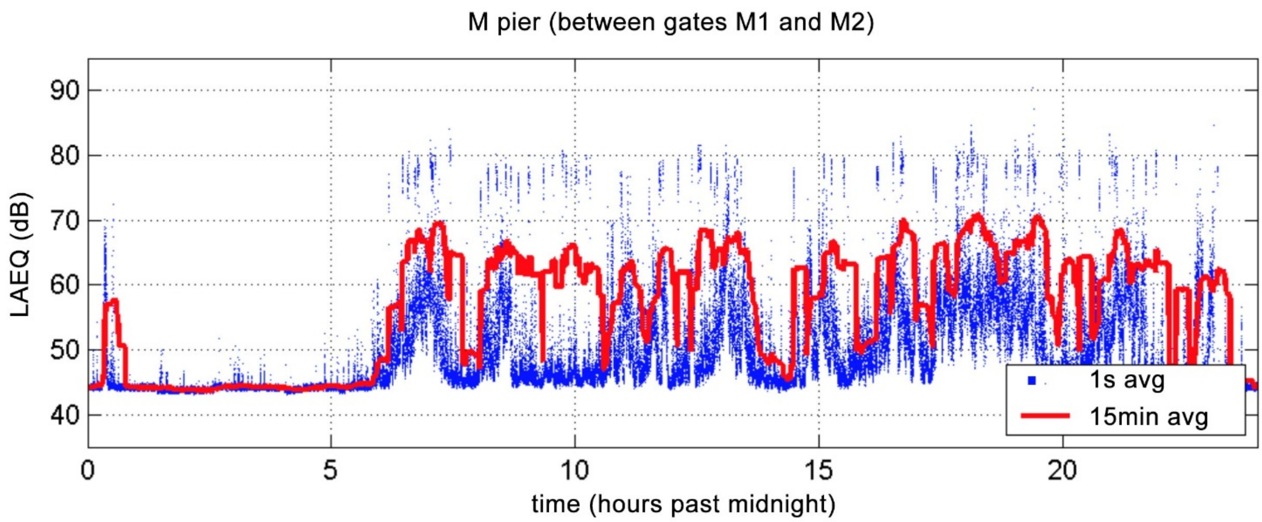

Figure 4: The equivalent continuous A-weighted sound pressure level (LA_{EQ}), with integration times of 1 second and 15 minutes, for a position in the corridor between gates M1 and M2.

Figures 3 and 4 show distinctly different patterns. At Schiphol Plaza, which is a shopping mall that connects the Schiphol train station to the rest of the terminal complex, the ambient noise level fluctuates with the time of day, but the 15 min average falls within a consistent trend between approx. 55 and 70 dB(A). The background noise level is lower during the nightly hours, but otherwise there are little variations.

Figure 4 was measured in a corridor at the beginning of the M pier, between gates M1 and M2. This is a generally quiet corridor, which is nearly empty during the night. The occupation range bandwidth (difference in high and low) is large, due to arrival and departure peaks. The natural ambient noise (mostly due to HVAC) is around 45 dB(A). The 15-minute average level is raised up to 70 dB(A) during peaks, and the instantaneous level (1-second average) goes up to 80 dB(A) due to PA messages.

In both cases, representative times (when it comes to the impact of background noise on VA systems) is during daytime, at moments when the respective areas are filled with passengers and crew. Our grid measurements were timed to take place under those ‘peak’-conditions.

3.2. Representative spectra for each category of spaces

Our 900+ grid measurements were translated into mean values for 24 individual spaces (zones) within the terminal complex. Spaces with similar functions and background noise levels were grouped into 7 categories. The mean A-weighted sound pressure level for each of these categories is given below in table 1.

Table 1: Average sound pressure level, per category of spaces

Category	**A-weighted sound pressure level** (dB(A))
Piers	61
Lounges (with nearby shops)	63
Departure/arrival - halls	62
Shopping malls	66
Busy areas around food and beverage outlets	66
Reclaim area	62
Security filters / immigrations	68
Baggage handling system	68

The average octave band spectrum per category was also calculated, leading to remarkably similar spectra. The difference between octave bands after normalization in terms of A-weighted sound pressure level was less than 1 dB per octave band. We therefore decided to summarize the octave band spectra as on normalized spectrum, which is given in table 2.

Table 2: Relative octave band spectrum of ambient noise

octave band level	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**dB(A)**
Normalized spectrum	0	-2	-2	-5	-9	-13	-17	0

In order to arrive at the spectrum for any given category, the normalized spectrum is added to the A-weighted level that applies to that category.

The complex and fluctuation ambient noise situation is captured quite well in just the two tables above, at least for the purpose of designing and evaluation voice evacuation systems (and any other use for which the focus is on persistent noises during peak hours, and not on transient sounds or quiet times). However, upon revisiting the total body of measurement data by comparing individual measurements to the above average, a few notable situations were found where the average tables underestimate the background noise that was observed. These are given in table 3.

Table 3: Specific situations with elevated background noise levels.

Location / Area	*A-weighted sound pressure level in dB(A)*
Murphy's Irish Pub	77
Security filter departures 3	70
Corridor between B en C (noisy moving walkways)	71
M/H pier gatehouses and stairwells during boarding	70

These exceptions to the general ambient noise situation occurred in exceptionally crowded spaces, such as the pub. These data were snapshots of worst-case situations; the noise in the stairwells on the M/H pier was observed when these were packed with passengers travelling in groups and in stairwells with high reverberation times.

4. CONCLUSIONS

The ambient noise at Amsterdam Airport Schiphol varies with the time of day and between different spaces within the terminal complex. The ambient noise level varies over a range of more than 25 dB between the quietest and busiest time and locations.

Spaces can categorized into 7 space categories. Representative noise levels for these categories range between 61 to 68 dB(A). These are the equivalent-continuous noise levels representative for times when the airport is at busy operating hours during normal business operations. The average background level (normalized for the overall A-weighted level) is the same within 1 dB per octave band for each type of airport space. Exceptions where the ambient noise level is elevated (for a shorter or longer period) occur in crowded spaces such as pubs and stairwells filled with waiting people.

Gaining insight into ambient noise conditions around a venue as large and complex as a major international airport is challenging. For most purposes, the overall database of measurement data that was collected is too large to be manageable. The overall dataset could be summarized into tables 1 and 2 of this paper by clearly defining what noise conditions are considered representative given our interests (i.e. intelligibility of PA/VA messages). By densely sampling the noise spectrum as a function as time as well as position within the terminal complex, it could be verified that the summarized noise data are indeed representative across all spaces within each space category.

5. REFERENCES

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