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The practicalities of soundscape data collection by systematic approach according to ISO 12913-2

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ABSTRACT

Arup has developed, formalised and digitised an approach to performing soundscape data collection. The approach is centred on the ISO 12913-2:2018 Technical Standard which proposes a standardised method for soundscape data collection that includes 3D sound recordings, measurements of acoustic and psychoacoustic parameters and provides example questionnaires for subjective perception. While ISO 12913-2 describes procedures for how recordings, measurements, and interviews are to be carried out, much of the Standard is informative only. A structured format has specifically been developed to further standardise an approach and understand how it may be implemented effectively within a corporate acoustic consulting environment.

This study discusses findings and conclusions gathered from undertaking soundscape surveys using the structured approach at seven purposely selected urban centres across the world. Further development has been made on how to interpret and implement the ISO 12913-2 Standard to facilitate and make accessible for use within the

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corporate consulting environment. Conclusions have been drawn from the issues faced and recommendations for further consideration provided that are based on correlations in the data set obtained through the surveys.

Keywords: Soundscape, ISO12913, Recording, Psychoacoustics, Auralization, Ambisonics, Binaural

I-INCE Classification of Subject Number: 72

1. INTRODUCTION

While the concept of 'soundscape' seeks to address the contextual nature of perception and broaden the focus to positive outcomes, environmental planning and assessment of the acoustic environment is traditionally focused on mitigating the harmful effects of sounds, by minimising environmental impact through noise abatement. While potential health impacts are of great importance, research has shown that reducing sound levels does not necessarily lead to better acoustic comfort in urban and rural areas [e.g. 1-3].

The soundscape approach has been given special attention in legislation, standards, and guidance related to environmental issues with regards to sound and noise [4-9]. In a planning context, there is a clear aspiration to balance activation of the public realm with the protection of amenity for sensitive receivers. In order to support this balance, a more granular understanding of how soundscapes are perceived in context is required.

Due to the holistic nature of the soundscape approach, various assessment methodologies and tools have been developed ranging from non-participatory observational methods, to interviews and structured questionnaires. There is a consensus that due to this diversity, the comparability of studies is impeded [10].

Within the past decade, there has been considerable effort to standardise the soundscape approach and to establish protocols [11-12]. The recently published ISO/TS 12913-2 proposes how methods and tools can be applied to study the perception of acoustic environments in context [13].

The soundscape approach has gained increasing importance in recent years with research and applications extending across a multitude of built environment disciplines such as planning, architecture, public health, social studies and acoustics. For the successful application of the soundscape approach within the built environment, survey methodologies need to be further refined and distilled to what is essential in order to make them accessible to the wider built environment community comprising policy makers, planners, developers, engineers and designers.

Implementing the recommended format and structure of the surveys as detailed in ISO 12913-2, including both subjective responses and objective recordings, a measurement methodology and questionnaire was devised that allowed Arup to test validity and applicability to the acoustic consulting environment.

In the process of developing and executing the various surveys, a number of limiting factors and complications were discovered when attempting to follow the Standard as a prescriptive text.

In order to promote inclusiveness and accessibility to the methodology, recommendations are made for a hierarchy of soundscape survey to accommodate differing levels of detailed assessment commensurate with consulting firms' resources. This tiered approach will hopefully allow and encourage more consultancies to begin to

adopt a revised supplementary approach to the traditional acoustic survey methodology which is considered comparatively limited in its application.

2. SURVEY EQUIPMENT AND METHODOLOGY

The following sections summarise the structured soundscape assessment methodology and equipment developed and tested to inform applicability to the built environment consultancy.

3.1. Site Selection

A total of six cities across the world were selected for implementation of the standardised soundscape survey format. Within each selected city, the targeted soundscape survey site was intended to be an urban, iconic, public square or place.

The sites and respective locations selected were:

- Times Square – New York City, USA
- Trafalgar Square – London, United Kingdom
- Dam Square – Amsterdam, The Netherlands
- Merlion Park – Singapore, Singapore
- Circular Quay – Sydney, Australia
- Federation Square – Melbourne, Australia

In addition to the geographical spread, the sites were selected for their expected diversity of socioeconomic and cultural demographics as well as the wish to have even distribution of participants based on their exposure to the site (i.e. tourist, resident and visitor).

Surveys were also conducted during the same season (summer) in each location to allow for reasonably comparable meteorological conditions.

3.2. Objective Measurements

Simultaneous audio, video and weather recordings were made throughout the surveys at each location. The availability and access to specific equipment as defined in ISO 12913-2:2018 was not always possible which resulted in slight variances in equipment used for each site. Preference was given to ambisonic over binaural recording techniques so as to utilise the in-house Arup SoundLab™ multi-loudspeaker array for playback as is the intended purpose of the study. ISO 12913-2:2018 states “is acknowledged that [ambisonic] recording technologies can offer some advantages. In particular, such technologies strive for a later playback based on multi-loudspeaker arrays providing a certain level of immersion. However, in contrast to binaural measurement technology these technological approaches lack standardization and make it difficult to perform aurally accurate analyses to compute psychoacoustic parameters and indicators [14]. It should be noted that over the past 15 years of capturing data using ambisonic microphones, Arup has developed its own standardised approach to measurements and playback, allowing a degree of uniformity across the globe.

The minimum setup for each measurement site consisted of the following:

- An ambisonic measurement rig consisting of an ST450 MKII SoundField microphone including control unit with Rycoet wind shield and shock mount and a Sound Devices 744T 4-channel field data recorder.
- A Brüel & Kjær 2250 Sound Level Meter with Type 1 calibrated transducer.
- 360-degree video recorder using either a Ricoh Theta V or Garmin VIRB 360.
- A weather station logging temperature, wind speed, wind direction and relative humidity.

The typical setup involved the ambisonic microphone and camera being arranged vertically on a tripod at 1.5 and 1.7m respectively as to not create a discrepancy between the origins of video and audio. This was important in ensuring sound sources within close proximity to the setup were able to be localised correctly. The Sound Level Meter was mounted on an independent tripod at a height of 1.5m within close proximity to the ambisonic microphone to ensure accurate calibration. The weather station was located at a height of 1.5m and at least 1m from the microphones to ensure noise generated by the wind speed indicator fan was not picked up in the recordings. A typical setup is shown in Figure 1 below.

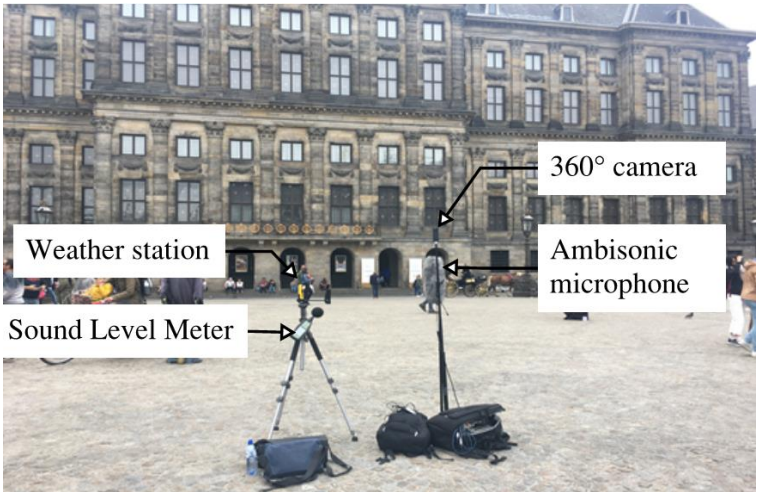

Figure 1 - Typical configuration of ambisonic microphone, Sound Level Meter, 360 camera and weather station.

In addition to the equipment listed above, a Neumann KU 100 binaural head was used for the Federation Square and Circular Quay surveys in Australia. Difficulties were encountered in obtaining a calibrated binaural dummy head to be used for the surveys, this resulted in the use of an uncalibrated head for testing and validation of procedures only.

Four channel ambisonic B-format audio (W, X, Y, Z) was recorded using a sample rate of 48kHz, 24 bit depth. Mono calibrated audio from the Sound Level Meter was recorded using a sampling rate of 44.1kHz and 16 bit depth.

The audio and video equipment were placed in the approximate centre of each survey location (where possible) with the video and ambisonic audio ‘front’ orientated towards the primary landmark of significant interest, both aurally and visually.

The survey included two people at each site and the format consisted of a minimum of 15 minutes of audio and video recordings during which an appraisal of the soundscape was undertaken by the investigator followed by approximately 1-2 hours of subjective survey questionnaires to interviewees comprising a cross-section of passers-by. The two activities of objective and subjective surveys were not able to be undertaken concurrently as noise spill from the conversations associated with the subjective questionnaire had the potential to influence the recordings. A further 15 minute recording was then undertaken to capture any significant changes to the soundscape environment. Overall, each survey typically took in the order of 4-6 hours to complete, including equipment setup and pack down (but excluding travel to and from site).

3.3. Subjective Surveys

Two standalone subjective surveys were compiled, developed and translated into an app-based questionnaire delivered by means of a tablet computer. The surveys were designed to be completed by the person undertaking the survey (Investigator) and by people experiencing the soundscape in context (Interviewees). By utilising tablet-based survey procedures, it was possible to pinpoint the precise location of each soundscape survey (accurate to 3m). This enabled a finer resolution of soundscape perception within the bounds of the site.

Questions and format of the surveys were predominantly derived from ISO 12913-2:2018 and implemented into the questionnaires.

3.3.1 Interviewee survey

Participants of the Interviewee survey were selected at random across each survey location.

The Interviewee survey was comprised of the following general structure:

- Participant Information – Questions on age, residential status, perceived hearing ability, relation to expertise in the study of acoustics and participants frequency at survey location.
- Subjective evaluation of site – Questions on the participants perception of the environment including weather, brightness, visual engagement, neuropsychologic observations and likelihood to revisit.
- Perception of the sound environment – Questions on the appropriateness of soundscape, subjectively assessed qualities (eventful, pleasant, chaotic etc).

The above structure reflects the intent of ISO12913-1:2014 which defines a soundscape as *"acoustic environment as perceived or experienced and/or understood by a person or people, in context"*, the three main components of which being the acoustic environment, people, and context.

In total, the survey was comprised of 27 questions and 2 optional long format questions. Figure 2 below shows extracts of the developed Interviewee survey as presented on the tablet computer.

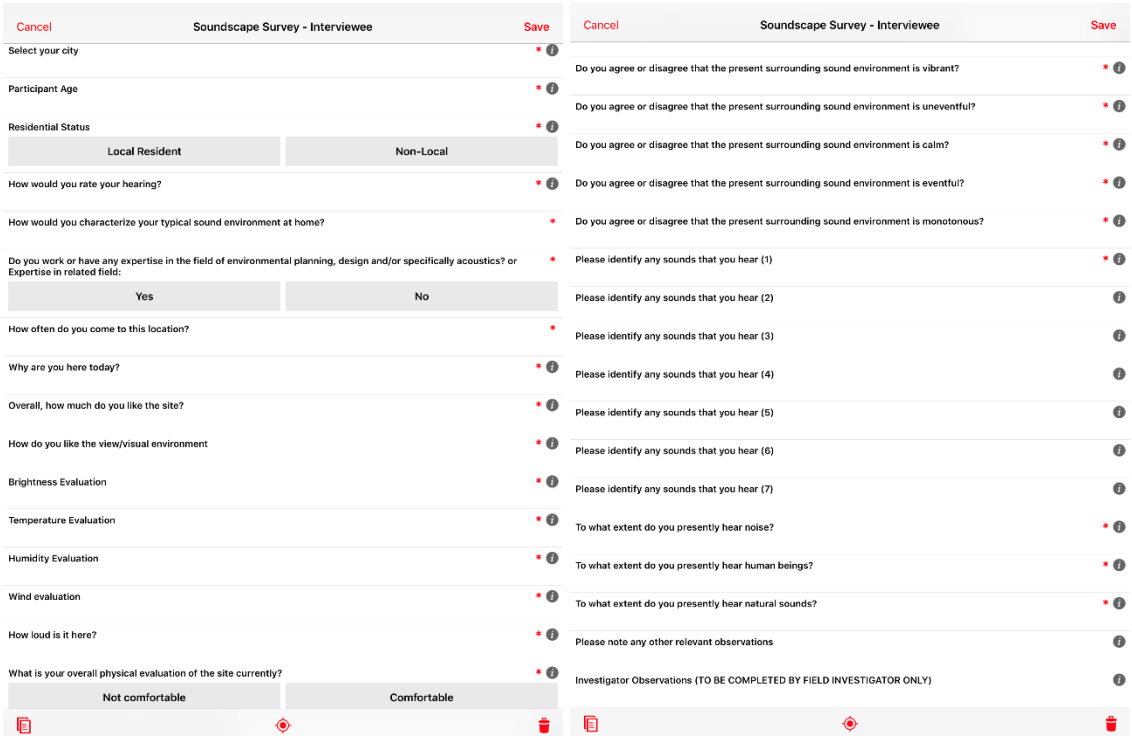

Figure 2 - Screenshots of interviewee tablet survey

3.3.2 Investigator survey

The Investigator survey was devised to supplement the Interviewee survey and was only completed by Arup staff with a background in acoustics at the commencement and completion of objective measurements per survey location. The survey was divided into two components, pre-survey and post-survey to be undertaken before and after the questionnaires were completed. Additional questions and input were also included as relating to descriptions of soundscape ecology, neuropsychological observations, sound signals, keynote sounds, sound marks and graphic representations of the study area as proposed by R Murray Schafer [15] and reflected in the soundscape taxonomy provided in ISO12913-2:2018. In addition, comments pertaining to equipment were also noted (e.g. calibration levels, serial numbers, mounting heights etc.).

Figure 3 below shows extracts of the developed Investigator survey as delivered via computer tablets.

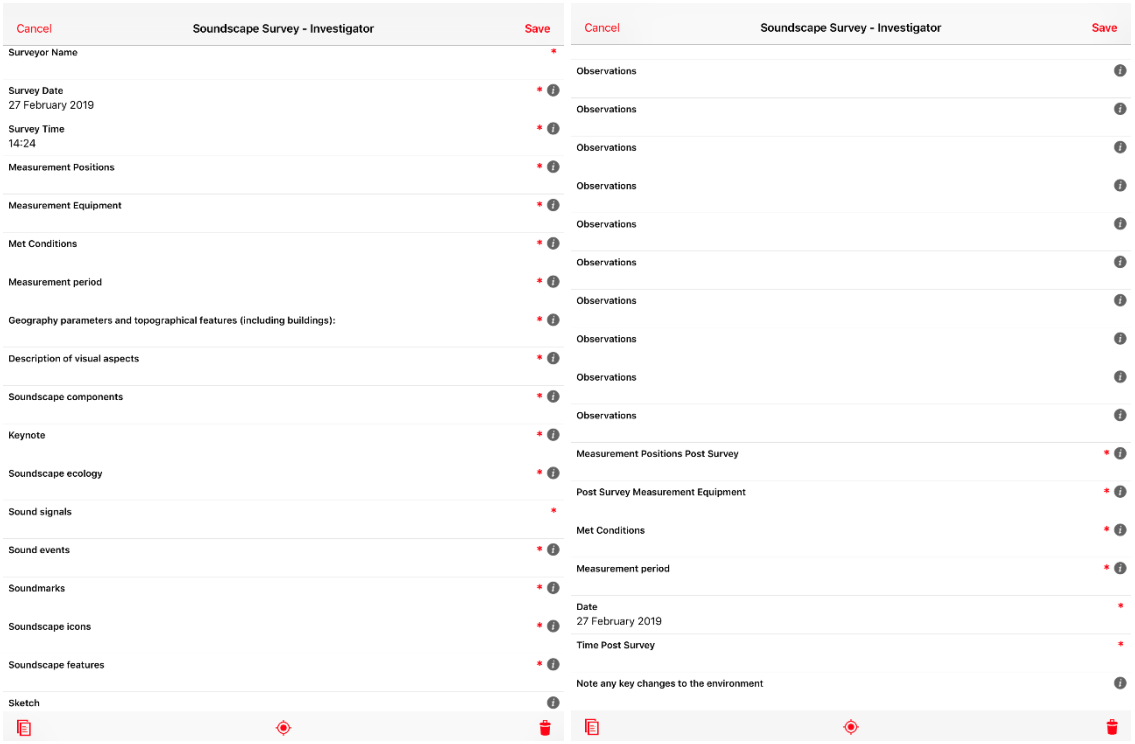

Figure 3 - Screenshot of investigator tablet survey

3. RESULTS AND DISCUSSION

The following sections summarise key findings and recommendations with respect to both objective and subjective survey procedures based on experience of implementation.

4.1. Evaluation of Objective Survey

The objective survey, which included the preparation, deployment, calibration, recording, documentation, post-processing and analysis of the data acquired using the equipment noted in Section 3.2 was a reasonably onerous process as compared with traditional acoustic survey methodologies.

For well-established academic and government institutions, the equipment list as proposed in ISO 12913-2:2018 may already be part of the existing catalogue, however, the requirements were regarded prohibitive for consulting firms. The process of recoding in ambisonic format and mixing down to binaural is believed to be a more cost effective and versatile alternative that should be considered by those wishing to accurately reproduce measured soundscapes. Further advancements in standardisation of multi-loudspeaker ambisonic array for calibrated soundscape reproduction may be considered beneficial and allow for wider application of the soundscape methodology.

For the purpose of soundscape reproduction within the Arup SoundLab™ multi-loudspeaker array, use of a 360-degree camera and VR reproduction has proven to be a valuable tool for employing immersive playback to support further analysis and exploration of the measured Soundscapes. Numerous studies, namely the ‘Urban Soundscapes of the World Project’ [16-17] have used similar hardware configurations to reproduce measured Soundscapes within a controlled VR/binaural environment to obtain subjective responses. The continuing development of video recording devices and

immersive playback suites will make possible the capability to supplement audio recordings to create a hyper-realistic auditory and visual experience.

The equipment required to undertake surveys is significant and generally requires a minimum of two people to transport and set up. Given the practical constraints associated with frequent soundscape surveying in a consulting context, standardization of measurement equipment across the practice is critical. Minimising the number of separate tripods required to support multiple pieces of equipment saves time on site and reduces impact to pedestrian traffic flow.

For surveys undertaken in Sydney and Melbourne, for which measurement equipment included the Neumann KU100 dummy head, a compact single tripod array was developed that involved mounting the camera above the binaural head with the Sound Level Meter and ambisonic microphone attached to the same tripod. A typical setup is shown in Figure 4 below.

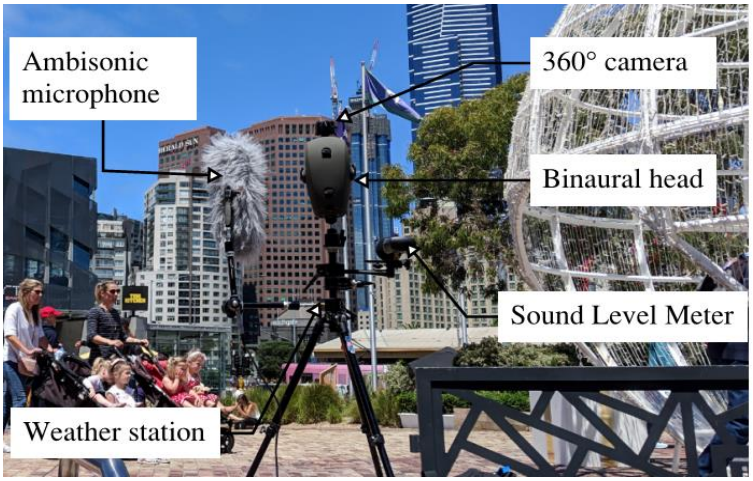

Figure 4 - Typical configuration of Ambisonic microphone, Binaural head, Sound Level Meter, camera and weather station

The standard recommends that subjective surveys are bookended by objective measurements and recordings. Is adds considerable time and effort both during measurement but also post processing. In practice, a preferred example from each survey site forms the main playback content. On site, it is recommended that a subjective evaluation of whether the soundscape and conditions have changed significantly enough to warrant additional measurements subsequent to subjective surveys being undertaken.

The influence of local climate on the subjective perception of a soundscape is still widely unknown, however it is expected that the level of detail used to assess weather within the survey area can be obtained through professional services (i.e. web or application based meteorological platforms) rather than an on-site weather logger measuring only the immediate surrounds.

When released, it is expected that ISO 12913 Part 3 will contain procedures and identify an approach to the psychoacoustic analysis of Soundscape recordings. Until then, assumptions have to be made when collecting, evaluating and reporting on survey information pertaining to psychoacoustic qualification. A standardised approach, particularly when comparing psychoacoustic attributes between different Soundscapes is therefore required. Further discussion and development, both from the Arup survey team and the wider Soundscape community is necessary in order to develop common guidelines and processes to ensure collective agreement, as disparity in objective techniques can result in unclear and incomparable survey datasets.

4.2. Evaluation of Subjective Surveys

4.2.1 Evaluation of Interviewee Survey

As ISO 12913-2:2018 is informative only, the subjective questionnaire was comprised of only questions that were deemed appropriate to the requirements of the study, which was to create a database of various global locations and respective subjective impressions that can be used as a reference in future soundscape design work. The questions were formatted into an app-based questionnaire and delivered via a tablet computer to volunteering participants. Whilst every attempt was made to rationalise and efficiently structure the contents of the questionnaire, a number of observations were made that will be used to further standardise the approach for use in the context of a consulting business setting.

To obtain a dataset considered appropriate for analysis, an aspirational target of minimum twenty participants was set per survey location. This value was taken from the minimum reporting requirements outlined in Section C.2.3 of ISO 12913-2:2018. The minimum reporting requirements proved difficult to obtain considering the survey location was within a highly trafficked and populated urban setting, the question is then posed as to how this target may be achieved ‘under similar conditions' in less accessible areas. The average time taken to achieve the target overall survey locations was 4.5 hours, the target of twenty people was not able to be met in two survey locations within the allocated timeframe.

Within the setting of an urban square, the demographic range of volunteers willing to undertake the survey was not as diverse as initially expected. Subjective observations supported by demographic analysis from all surveys noted that the individuals that were more willing to complete the questionnaire were those who had the time to spare. Non-Local participants (in the case of Singapore, 100% of those surveyed) made up the majority of the participants in all locations with the exception of Melbourne.

Common observations from those overseeing the surveys and feedback from interviewees undertaking the survey included:

- Participants quickly lost interest in the survey, primarily due to the overall length of time required for completion. It was important to explain the length of time required to achieve a thoughtful outcome. This was on average ten minutes. When stating this, the majority of potential participants declined to commit.
- For committed participants, the question of validity of responses was raised as it was observed some participants tended to rush through the survey, particularly towards the end, potentially without providing much thought or consideration to the responses due to frustration.
- Further questions are subsequently raised regarding the size of the data set. Issues of contaminated data are typically overcome with large datasets, however using the minimum required 20 participants, disregard to the answering of questions may be identifiable within the processed results. It is noted that a larger data set may be interrogated once the survey methodology is made more accessible and more surveys are undertaken globally.
- Due to numerous reasons (e.g. eyesight, language engagement etc.), it was concluded that participants preferred to be asked the questions in an interview format whilst the interviewer filled out the questionnaire rather than providing the tablet computer for the participant to complete their own answers. Careful

attention was required to ensure the participant was not guided into answering questions that did not reflect their own observations.

- For many participants, English was not their native language. Subjective descriptors of the sound environment within the questionnaire had to be communicated in English. The variance of the description may not match the participants subjective experience. It is therefore recommended that further investment be made into adequately translating the contents of a refined methodology to improve relevance in context.
- Due to the nature of the sampling size and survey methodology, results are potentially biased toward specific social groups that were available during the survey hours and were likely to be in the survey locations. With a larger data set obtained from a global pool of soundscape surveys, the demographic spread of experience in context of various soundscape environments and features may lead to more meaningful overarching observations.

4.2.2 Evaluation of Investigator Survey

The Investigator Survey proved valuable in providing complementary data to the Interviewee Survey by participants educated in soundscapes, acoustic survey methodologies and data collection. This resulted in more formalised questions pertaining to the description of soundscape which subsequently led to a greater detail of understating the survey locations to those tasked with interpreting and analysing the measurement data. The investigator survey further allowed for specifically homogenised inputs and descriptions beyond individual subjective perceptions.

Particular attention should be given to the part of the investigator survey that included the soundscape descriptors relating to concepts such as key note, sound signals and soundmarks. Given the highly subjective nature of this section of investigator survey, responses to this section of the survey were highly variable and feedback was that further guidance on how to interpret these soundscape concepts would be required in order to meaningfully retain. Beyond reading the background information available in R Murray Schafer's text, additional description of the intention for this component of the investigator survey may be required.

4. PROPOSED REVISIONS

Following the discussion of limitations and challenges identified through pilot studies, in-house testing and global preliminary surveys, a tiered soundscape data collection methodology based on the suggested procedures within ISO 12913-2:2018 which supports the needs of an acoustic consulting practice has been identified and is outlined below.

The proposed objective methodology seeks to work within practical and logistical constraints for varying size of consultancy and technical demands of each project while still achieving minimum data collection requirements identified in the standard in a consistent and refined approach.

The proposed subjective methodology aims to gather data regarding people, acoustic environment, and context as explicitly required in the standard, with the additional goal of reducing survey length, achieving greater participant engagement and improving question clarity.

Minimum proposed standard equipment to include for various types of survey are provided in Table 1 below for small, medium and large (e.g. scientific) application. This

information is provided for reference and application in response to project and consultancy limitations and requirements.

Survey Methodology	**Estimated duration**	**Objective survey requirements**	**Subjective survey requirements**
A (least onerous)	1-2 hrs	Sound Level Meter	Investigator survey
B (mid-tier)	4-6 hrs	Sound Level Meter Ambisonic microphone and multichannel recorder 360 Camera	Investigator survey Interviewee survey
C (most onerous)	6-8 hrs	Sound Level Meter Ambisonic microphone and multichannel recorder 360 Camera Weather station Binaural dummy head	Investigator survey Interviewee survey (min 20 participants)

Table 1 - Tiered objective measurement requirements

Measurements with all listed equipment should be recorded for a 15-minute duration at the beginning of the soundscape survey. After the relevant amount of subjective surveys, appraisal should be made as to whether an additional set of 15-minute measurements will be required to capture significant changes to soundscape.

As a guide, the following matrix presented in is provided to assist with selection of appropriate level of detail for soundscape survey depending on size of consultancy size and project complexity.

Size of consultancy	**Complexity of project**		
	Simple	Medium	Complex
Small	A	A	B
Medium	A	B	B
Large	B	B	C

Table 2 - Survey application matrix

The accompanying interviewee and investigator surveys will be amended as per the discussion provided in Section 4.2.1 to primarily feature questions from Section C3.1 Questionnaire (Method A) within ISO 12913-2:2018. The presentation format will also be revisited with a view to maintain the intentions of the research that supports the development of questionnaires. Further opportunities will be sought to minimise the length and complexity of the survey with a view to maximise engagement and therefore relevance of the data set obtained.

CONCLUSION

A standardized soundscape survey methodology has been compiled based on information provided in ISO12913-2:2018 for testing within the acoustic consulting environment. Observations and recommendations have been made to refine and improve practical application of both the objective and subjective survey components of the Standard. A summary has been provided to promote accessibility to the wider

acoustic consulting community in order to promote a soundscape approach to assessment and design.

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