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The sound perceptions of urban pavements by sighted and visually impaired people – a case study in Surabaya, Indonesia

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ABSTRACT

The valuation of pavements using sound aspects is crucial for a country with poor pavement conditions and a large population of visually impaired people. This study recruited sighted and visually impaired participants to conduct a "soundwalk" to appraise the urban pavements. It was held *in-situ* on nine renovated pavement segments in Surabaya, Indonesia. Data were collected using a questionnaire comprising open and closed-ended questions in the format of a semantic scale. The SPL was also measured to describe the sound level concerning participants' sonic perception. The semantic data were then extracted using varimax-rotated principal component analysis with a polychoric correlation. The sighted group elicits two solid soundscape dimensions; pleasantness and eventfulness. The visually impaired group evokes four soundscape dimensions; pleasantness-direction-safety, space, eventfulness, and contour. The soundscape dimensions reflect the pavements' critical factors and show that visually impaired participants appraise the pavements in more detail than the sighted.

KEYWORDS
Urban pavement; soundscape; soundwalk; sighted people; visually impaired people

1. Introduction

Similar to the American English term "sidewalk", "pavement" is a British English term for a paved walk for pedestrians at the side of a street. In urban life, pavements are critical and integral components of roadway systems and become the main public places of a city (Jacobs 1961). Besides the primary function for pedestrians, pavements have many other features, such as accommodating street vendors and merchants (Loukaitou-Sideris and Ehrenfeucht 2009). In developing countries, street vendors have become a significant informal sector that dominates the area of pavements (Timothy and Wall 1997; Cross 2000). The blockage significantly reduces walkability on pavements (Blomley 2010). The ideal width of a 2-lane walkway is 2.2 m, with a minimum of 1.4 m, which increases gradually with the number of lanes to be accommodated (Buchmueller and Weidmann 2006).

The interrelationship between walking trajectories and pedestrians' perception of the pavement environmental design is often neglected (Nasir et al. 2014). Many studies about

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users' satisfaction based on physical characteristics of pavements have been conducted, such as about the width (Kim, Choi, and Kim 2011), the effect of trees (Schroeder and Cannon 1987; Williams 2002) and flowers (Todorova, Asakawa, and Aikoh 2004), urban signscapes (Nasar and Hong 1999), lighting conditions (Fujiyama et al. 2005), pavement surface conditions (Øvstedal and Ryeng 2004), pavement connectivity (Randall and Baetz Q3 2001), and aesthetic aspects (Ball et al. 2001; D'Acci 2019). Other studies focused on users' preference, such as about distance and route (Agrawal, Schlossberg, and Irvin 2008), path choice (Kim at al. 2016), route choice and behaviour (Xi and Son 2012), pedestrians' behaviour (Zacharias 2001) and spatial orientation and angularity (Montello 1991). Wang et al. (2012) said that satisfaction judgement about pavements does not depend solely on the physical dimension of the environment, but also the emotional perception associated with it. Therefore, the typical visual assessment of pavements needs to be complemented by users' emotional perception, such as using sound perception. There is sensitive information in almost any kind of sound received by humans every day (Weninger et al. 2013). Aletta et al. (2016) underpinned that both visual and aural elements build people's perceptual construct.

1.1. Pavements and the potency of sonic assessment

CABE (2008) stated that most streets are noisy, polluted, hazardous, and unpleasant. It describes precisely the streets of Indonesian cities, which might affect the satisfactory and safety levels while walking on the pavement alongside. The noisy and uncomfortable streets can also create unsafe pavements. Therefore, it is essential to assess typical pavements using an aural method for a more comprehensive evaluation. A well-known concept for the aural appraisal is "soundscape"; a theory popularised by Schafer (1977) that later is identified by ISO as "an acoustic environment as perceived or experienced and/or understood by people; in context" (ISO 2014). Schafer also devised a method called soundwalking;an empirical method for identifying a soundscape and components of a soundscape in various locations. Over a large area that is not possible to perceive the acoustic environment in one spot, a soundwalk is required to understand the acoustic environment fully. By the International Organization for Standardization (ISO 2018), a soundwalk is defined as "participatory group sound, and listening walks across an investigated environment".

The concept of soundscape and soundwalk has been widely adopted to assess the acoustic conditions of the built environment. Most surveys assess the soundscape of urban open public spaces in general (Yang and Kang 2005; Zhang and Kang 2007; Kang and Zhang 2010) or to appraise specific urban parks (Nilsson and Berglund 2006; Payne 2008; Szeremeta and Zannin 2009; Liu et al. 2013; Brambilla et al. 2013; Jeon and Hong 2015; Aletta et al. 2016); however, soundscape studies that focus on pavements are minimal. Among them are about how to conduct proper pedestrian soundwalking (Drever 2013), modelling of soundscape pleasantness of urban paths (Aumond et al. 2017), characteristics of pedestrian tourist routes (Aletta et al. 2017) and investigation of pedestrian preference towards route shapes (D'Acci 2019). All those studies were conducted in developed countries with temperate climates, which differs from the built environment found in developing countries with warmer climates. All studies were also undertaken by sighted people; thus, the perception taken might not be purely aural.

1.2. The sense of sight and hearing of visually impaired people

The sense of sight is believed to be the most important sense for humans. It acts to integrate the role of other senses. It helps to put tastes, sounds, aromas, tactile impressions, objects, and people in perspective (Ward 2000). Studies of soundscape have shown that there is a correlation between the aural and visual aspects of the assessment. It means that the perception of the sound is not purely auditory but also visual (Carles, Bernáldez, and Lucio 1992; Viollon, Lavandier, and Drake 2002; Tse et al. 2012; D'Alessandro et al. 2018). Even the International Organization for Standardization describes how the interpretation of auditory sensation may be influenced by many factors, including sensory elements such as visual impression and odour (ISO 12913-2 2018). There is a great deal of ignorance about hearing, probably more than there is regarding vision. Many people are aware of how the eye works in general, but very few people know about sound in the ear (Plack 2018). Therefore, it is interesting to study pavements by using the soundscape appreciated by visually impaired people, as the judgment thereof would be borne by the hearing sense alone.

Blind people are more sensitive to sound than sighted people (González-Mora et al. 1999). They are also typically able to process acoustic information better (Lessard et al. 1998). Blind people localise sounds and assimilate them with the sound from the environment more accurately than sighted people (Dunai et al. 2015). Because visually impaired people are good at engaging with the surrounding sound, soundscape assessments undertaken by this community may offer a more detailed evaluation of the built environment. Soundscape conducted by visually impaired people is a relatively new subject and is being investigated by Mediastika et al. (2019) and Mediastika et al. (2020). The two studies, which were conducted in parks, elaborate that visually impaired people have unique soundscape dimensions of danger and direction. It could be more critical when they walk on pavements.

The study aimed to investigate the perception of visually impaired people about pavements being compared to the perception of sighted people. The valuation of pavements by the visually impaired is crucial in a country with poor pavement conditions and a significant population of blind people. About 4 million Indonesians are blind; 1.5% of the population. (Pusdatin 2010). The ultimate goal of the study is to learn whether walking independently on pavements is doable for the visually impaired. Also, it is to look for initial references to improve pavement design if recommended by the respondents.

2. Methods

2.1. Case study: pavements in Surabaya, Indonesia

Walking is a strategic mobility mode that provides health benefits, social capital, relieves traffic congestion, preserves resources, and vitalises communities (Leyden 2003; Blanco et al. 2009). However, Wang et al. (2016) declared four physical built environment barriers to walking: opportunity, access and distance, safety, and physical setting. With the unfavourable pavement conditions (narrow, damaged, contoured, obstructed, etc.) and the warm outdoor temperature, Indonesians prefer to ride motorised vehicles even to reach a place as close in the distance as 200 m (Susantono 2014; Setianto and Joewono 2016). It is easy to spot the low quality and poor walkability pavements in Indonesian

Figure 1. Snapshots of the improper pavements' use at Malioboro Street Yogyakarta and Tanah Abang Jakarta, Indonesia (https://jogja.tribunnews.com/and https://finance.detik.com/berita-ekonomi-bisnis/).

Figure 2. A snapshot of a non-accessible segment of pavements due to obstructions, a non-standard coloured and non-embossed guiding blocks of Surabaya's pavements.

cities (Qodrilia and Widodo 2016; Figure 1). Many such segments are also inaccessible by people with disabilities (Figure 2).

Surabaya, the second-largest city of Indonesia, has witnessed vast improvements over the last ten years. This includes the development of pavements, especially in and around the city centre where heritage buildings and heritage districts are located. The Siola area 130
in Surabaya, for example, has the best pavements compared with other pavements around the city (Figure 3). They are 3–5 m in width, and some spots are equipped with benches and trees. A few studies could be found about pavements in Indonesia and Surabaya in particular, and most are in Bahasa Indonesia. Among those limited few,

Figure 3. A view of Jalan Tunjungan (Siola area of segments 1, 2, and 3), where the pavement's width and pavement materials were revitalised.

a survey indicated that the refurbished pavements of Surabaya are classified "B" (Rendy 2011). The "B" classification is given, when pavements provide a 3.7–5.6 m2/person space and flow rate of 16–22 persons/min/m. At this category, a sufficient area for pedestrians to pass other pedestrians is available (Bloomberg and Burden 2006). The Surabaya municipality has also made efforts to accommodate people with a visual disability, such as by installing guiding blocks and sounded-signage. Even so, there are conditions where the installed elements hardly accommodate the disabled community (Vianto and Maruf 2018, Figure 2). Combined with the warm outdoor temperature, all these lower the motivation of the downtown community to walk outdoors, especially those with a disability.

2.2. *The participant*

In East Java Province of which Surabaya is the capital, live nearly 850 thousand people with a visual impairment (Pusdatin 2010). However, their existence is not easy to spot. They mostly stay at home due to dependency and less orientation and mobility skills. A group of junior and senior high school students of the Foundation of Education for Blind Children (YPAB) of Surabaya was invited to participate. The YPAB students are sufficiently educated and can live their lives quite independently. There are approximately 40 students in YPAB, but most do not have proper orientation and mobility to walk on their own on pavements alongside heavy traffic.

The study involved 10 visually impaired students that met the study criteria for sufficient orientation and mobility. They were 4 females and 6 males between 16 to 21 years of age. Their age is slightly older than the average junior and senior high school students because they are students with special needs. This age range matches coincidentally with the age of the sighted participants. Ethical approval of the study to partnering with YPAB was granted by the Body of National Unity, Politics and Community Protection (Bakesbangpol), a body under the Surabaya City Government with license number 070/6619/436.85/2017 dated 19 July 2017. Also, granted by an official approval letter from the Headmaster of YPAB dated 1 August 2017, to include publishing images taken during the project.

The sighted participants were 24 Petra Christian University (PCU) undergraduate students consisting of 13 females and 11 males between 19 to 21 years of age, which is within a similar range to that of the YPAB students' ages. They are all categorised as "adolescent" or "early adult" by the World Health Organization. The age range between the two groups of participants was considered acceptable. The survey would only collect their instant appraisal of the studied pavements, which does not require advanced knowledge or experience. Ma, Wong, and Mak (2018) showed that many studies of soundscape involving extensive age ranges and various backgrounds elicited quite identical responses.

Different gender of the respondents is deemed to contribute insignificantly to their sonic perception (Fields 1993; Miedema and Vos 1998; Kang and Zhang 2010; Xiao and Du 2011; Zhang et al. 2016). Meanwhile, the aspect of different educational backgrounds contributes to different acoustic perception is arguable. Some studies stipulated a relationship (Kang and Zhang 2010; Meng, Kang, and Jin 2013; Zhang et al. 2016), but some also said the alliance is insignificant (Xiao and Du 2011; Liu et al. 2018). In the study, participants' educational backgrounds are within a tight gap – i.e., between secondary schools and the early stage of university levels. Thus, the difference is expected to contribute to insignificant acoustic perceptions. Moreover, they are within a considerably identical age range. The participants in both groups have resided in Surabaya for quite some time, either as locals or as students. Thus, all are considered to have local experience.

2.3. The location and questionnaire

The study was conducted empirically, with data collected *in-situ* on nine pavement segments of Surabaya. The pavement segments were selected according to the following considerations: (1) the location is within the city centre; (2) the segment serves as the optimum or most improved pavement compared with other pavement segments in Surabaya; (3) the location is along a major arterial road with sufficient variation of the pavement conditions. The selected segments were varied in their width (2.5–5 m), their materials (smooth tiles and slightly coarse tiles), equipped with and without guiding blocks, provided with and without canopies, and equipped with two crossing types (pelican crossing and pedestrian bridge). The selected pavements are Siola (3 segments), Bambu Runcing (2 segments), Raya Darmo (4 segments) (Figure 4). Each segment is approximately 200 m long. The typical pavement under study of this paper is portrayed in Figure 5.

The questionnaire consists of two parts. The first part comprises two open-ended questions, which were intended to collect participants' willingness and preferences. For the visually impaired participants, it asks about (1) respondents' perception if they have to walk the pavement by themselves without accompanying persons; (2) what do they like/dislike about the pavement segments. For the sighted respondents, it asks about (1) their willingness to walk down the pavements; (2) what do they like/dislike about the pavement segments. The second part was designed as bipolar semantic questions in which the attributes used to build it were elicited from a focus group discussion (FGD) held in the

Figure 4. The map of the segments. It consists of 9 segments, each of approximately 200 m long.

Figure 5. Typical pavements in the study (a) the Siola segment (the most improved pavement; 5 m width); (b) the Bambu runcing segment (4 m width); (c) the Darmo segment (2.5 m width).

Q4 previous study about soundscape in urban parks (Mediastika et al. 2000). In the FGD of parks, they were also asked of their opinion about pavements. The visually impaired described pavements with 19 terminologies and the sighted with 8 only. However, the 19 terminologies were all used to build the questionnaire for both groups. Later, the data collected from the sighted, somehow, showed that some terminologies are irrelevant.

Of the 19 attributes, some attributes (rough, natural, unclear direction, far, slow, know the location, scary, spacious, slippery, near traffic, and flat) were excluded for the sighted participants as the communality test below 0.4 (Table 1). The exclusion of some terminologies verifies that from the early stage, visually impaired people describe their

Table 1. Attributes that were developed from a focused group discussion of the previous study to build the questionnaire (– et al. 2020).

	Attributes			
	Sighted	Visually impaired	Context	Communality
1	(−1) crowded – (0) – (1) uncrowded	(−1) crowded – (0) – (1) uncrowded	soundscape	0.738
2	(−1) comfortable – (0) – (1) uncomfortable	(−1) comfortable – (0) – (1) uncomfortable	soundscape	0.792
3	(−1) noisy – (0) – (1) quiet	(−1) noisy – (0) – (1) quiet	soundscape	0.501
4	(−1) fun – (0) – (1) boring	(−1) fun – (0) – (1) boring	soundscape	0.613
5	-	(−1) rough – (0) – (1) smooth	soundscape	0.069
6	-	(−1)natural – (0) – (1) unnaural	soundscape	0.037
7	(−1) safe – (0) – (1) unsafe	(−1) safe – (0) – (1) unsafe	soundscape	0.757
8	-	(−1) unclear – (0) – (1) clear direction	soundscape	0.170
9	-	(−1) far – (0) – (1) near	soundscape	0.017
10	-	(−1) slow – (0) – (1) fast	soundscape	0.066
11	-	(−1) know – (0) – (1) don't know the location	soundscape	0.019
12	(−1) full – (0) – (1) empty	(−1) full – (0) – (1) empty	soundscape	0.518
13	-	(−1) scary – (0) – (1) normal	soundscape	0.034
14	-	(−1) spacious – (0) – (1) tight	soundscape	0.045
15	(−1) easy – (0) – (1) uneasy	(−1) easy – (0) – (1) uneasy	access	0.668
16	-	(−1) slippery – (0) – (1) stable	access	0.069
17	(−1) clear – (0) – (1) unclear route	(−1) clear – (0) – (1) unclear route	access	0.694
18	-	(−1) near – (0) – (1) far traffic	access	0.288
19	-	(−1) flat – (0) – (1) contoured	access	0.013

environment in more details than the sighted do. By the communality test, it was confirmed as irrelevant to ask sighted participants filling a questionnaire using attributes which have not emerged from their perception. The use of attributes to construct the semantic questionnaire is adopted from a direct elicitation method, that is, individual vocabulary techniques determined by Bech and Zacharov (2007). According to them, the individual attributes could be collected from a mixture of interviews and personal experiences. It is typically acceptable to use semantic adjectives or attributes based on expert judgement or previous research relating to urban soundscape (Kang and Zhang 2010). In the study, the semantic adjectives were derived from attributes that emerged in the earlier stage. The communality test of the semantic attributes by visually impaired participants showed that the attributes are all validated, but some of them had to be excluded for the sighted participants. At this point, we learn that it is not possible to compare the two groups' perceptions with identical attributes precisely. Both groups have different opinions of the surrounding sound from the first stage of data collection.

The second part of the closed-ended semantic bipolar questions was constructed with 3 scales of −1, 0, and 1. Scale −1 was for the attributes elicited by participants, 0 for a neutral response, and 1 for the antonym of the attributes (Table 1). Some might say that the 3-point scale might not provide an adequate in-depth analysis such as Lehmann and Hulbert (1972). On the other side, Jacoby and Matell (1971) said that using a 3-point scale is good enough. Without the intention to ignore the debate, the 3-point scale was used to avoid the communication barrier between participants and the accompanying persons. It was confirmed after a trial interview using a 5-point scale caused a miscommunication between the visually impaired participants and the interviewers (Mediastika et al. 2000). Simplification of the scale – from the commonly used 5 or 7 points to only 3 – was intended to allow a quick grasp of the question by the interviewee, who would then be able to answer the items instantly and accurately. After all, this method has also been validated by comparing the soundscape dimensions of sighted participants in the earlier study with the soundscape dimensions of sighted participants from the other studies (Mediastika et al. 2000).

2.4. The soundwalk

The soundwalks were carried out over four Saturdays (each at 9–11 am) under similar conditions. That is when a regular traffic flow with no congestion occurred almost identical in each specified pavement segment. Saturday was selected because it is weekend time for students, who typically use their time to enjoy the city. The skepticism that different days and periods have different conditions is unwarranted. The chosen pavements are alongside vital main roads, where irregular events that create different traffic flows and pedestrian flows on the pavement are rarely held. Data collection of the visually impaired participants was held on the 1st Saturday (5 segments of Siola and Bambu Runcing) and the 2nd Saturday (4 segments of Darmo). Then, the 3rd and 4th Saturdays were for the sighted participants at the same segments, accordingly. It was deliberately designed that the nine segments for two groups of participants (18 segments of 3.6 km in total) were not carried out simultaneously in one day. The unfavourable warm outdoor temperature was the primary consideration in dividing the survey in four Saturdays, so as participants could walk the route as relaxing as possible. Also, the accompanying persons of the visually impaired participants are the sighted participants, which means they will have to go along the routes twice at a later time if conducted in one day. An exhaustive survey might result in bias data.

The details of the design elements included and the primary sound sources that emerged in each segment are compiled in Table 2. The soundwalk of visually impaired people was done in pairs of the visually impaired and the accompanying person. The visually impaired survey was held in silence to allow participants to listen to the surrounding sound fully. The participants used walking sticks to guide them tactically (Figure 6). To control the natural quietness during the survey, each pair departed the starting point in 5 minutes time-lag. The accompanying persons paid attention only when the participants were about to encounter a dangerous situation, such as towards a quite deep hole, a massive obstruction, or about to cross the street. After each segment, both the participant and the accompanying person stopped for a break to conduct the questionnaire session. Each segment took approximately 13 minutes, consisting of 8 minutes of walking and 5 minutes of questionnaire completion. With 34 participants of both groups, a total of 306 data were collected from 9 segments. This figure is sufficient for principal component analysis (PCA) that will be utilised to analyse the semantic data (Kang and Zhang 2010).

2.5. The sound pressure level

The sound pressure level (SPL) measurement on the chosen pavements is deemed significant based on arguments that (1) the study focuses on the use of a sonic method; (2) both groups of participants elicited a "noisy" attribute when they were asked to describe pavements during the FGD. Thus, the SPL measurement was intended to confirm

Table 2. Pavements' design elements involved in each segment.

Segments	Spots	Design elements*	Typical sound sources
1	Siola 1	Canopied-pavements, walls and columns alongside, 2.0 to 2.5 m width, guiding blocks, crossing bridge and signed pelican-crossing.	Heavy traffic and crossing-sign.
2	Siola 2	Open-pavements, walls and short tress alongside, 5.0 m width, guiding blocks.	Heavy traffic.
3	Siola 3	Open-pavements, walls and short tress alongside, 5.0 m width, guiding blocks, musical-signed pelican crossing.	Heavy traffic and crossing-sign.
4	Bambu Runcing 1	Open-pavements, fences and tall trees alongside, 2.0 to 4.0 m width, signed pelican crossing, unsigned pelican crossing.	Heavy traffic.
5	Bambu Runcing 2	Open-pavements, fences and tall trees alongside, 2.0 to 4.0 m width.	Heavy traffic.
6	Darmo 1	Open-pavements, fences and tall trees alongside, 2.5 to 3 m width, guiding blocks, crossing bridge	Heavy traffic.
7	Darmo 2	Open-pavements, fences and tall trees alongside, 2.5 to 3 m width, guiding blocks, signed pelican-crossing.	Heavy traffic and crossing-sign.
8	Darmo 3	Open-pavements, fences and tall trees alongside, 5 m width, guiding blocks.	Ordinary traffic.
9	Darmo 4	Open-pavements, fences and tall trees alongside, 5 m width, guiding blocks.	Ordinary traffic.

*All the surveyed pavement segments are within very close proximity to the adjacent streets. It ranges form 0 (for those walking by the edge of the pavements) to 5 m (for those walking on the deepest side of the widest pavement segments).

Figure 6. Snapshot of soundwalks at (a) Siola: segment 1; (b) Siola: segments 2 and 3; (c) Darmo: segment 7 (Permission to use these images was given by YPAB's headmaster).

the semantic data found earlier and to give a general description of the acoustic environment. The SPL at each segment was measured using a calibrated NTi-SL2 with M2211 microphone Class 1 frequency response under IEC 61672 and ANSI S1.4. It was recorded in LAeq(10 minutes), LAFmax, and LAFmin. The sound level metre was placed on a tripod positioned in the middle of the pavements. The proximity to the adjacent streets 285
depended on the segment width – i.e., 1 m for the 2 m width, 1.5 m for the 3 m width, etc.

The study uses noise level standards of 65 dBA stipulated for the trade and office areas (Ministry of Environment 1996) to verify the "noisy" semantic found by the FGD.

Participants have considered the pavements as “noisy” without a time reference. As such, it is not relevant to question whether the noise structure is identical throughout the week or different for each day. The measured LAeq(10 minutes), LAFmax, and LAFmin are deemed adequate to describe the global acoustic environment. The traffic noise might fluctuate on different days and periods, but most of the time is typical (BPS Surabaya 2019). Structures of the measured noise would not have a significant effect on the judgement of the pavements because participants have rated them as “noisy”.

3. Results and discussion

The main results are explained and discussed in the following sub-sections according to the data and analysis used.

3.1. The acoustic environment and participants' preference

Data collected from the open-ended questions showed that sighted (100%) and visually impaired (80%) participants did not like the studied pavements for various reasons. Four unfavourable aspects were identified during the soundwalk. The unfavourable perceptions of the visually impaired are grouped into “guiding blocks”, “pavements”, “signposts”, and “the environment”. These are also arranged in four categories for the sighted, but “signposts” is exchanged with “crossing”. The sighted mostly did not mention anything about the need for a sign or guidance. However, the sighted participants also appraised the pavements due to the guiding blocks for the visually impaired people. The sighted participants' perception about pavements might be triggered by their prior assignment to accompany the visually impaired. Figure 7 describes in details those unfavourable aspects perceived by both groups. The charts clearly show that the sighted participants appraised the pavements and the surrounding primarily based on physical issues, which elicited many indices regarding the pavement condition.

The structure of the pavements dominates the unfavourable perception. Meanwhile, warmth and noise are two additional environmental factors that influence all their unfavourable opinions. As most of the pavement segments are unshaded, it is reasonable that the participants perceive warmth when walking on the pavements. Only the first segment of Siola (segment 1) is covered with a canopy (Figure 6(a)). During the survey period, the upper-level temperatures of Surabaya were recorded at 37–39°C. It was the typical upper-level temperature that mostly occurs in Surabaya (BPS Surabaya 2019). Warmth may cause other perceptions to appear in the survey because thermal comfort is the most important factor when people carry out outdoor activities (Lai et al. 2014).

The visually impaired participants perceived that the pavements were damaged, missing, narrow, contoured, obstructed by massive objects, and holey. A missing pavement is a term when it is suddenly unavailable due to a significant obstruction that blocks almost all pavement areas, such as trees, plant containers, or other objects (Figure 2). Meanwhile, a contoured pavement is a term used to describe uneven surfaces, including when there are too many steps on the pavement. They also noticed that there were different width of pavements; some segments are not equipped with guiding blocks; the guiding blocks are thin, narrow, unstraight, and disconnected in some points. Signs on the path are also considered inadequate, unclear, and offer too little time to cross the road. All

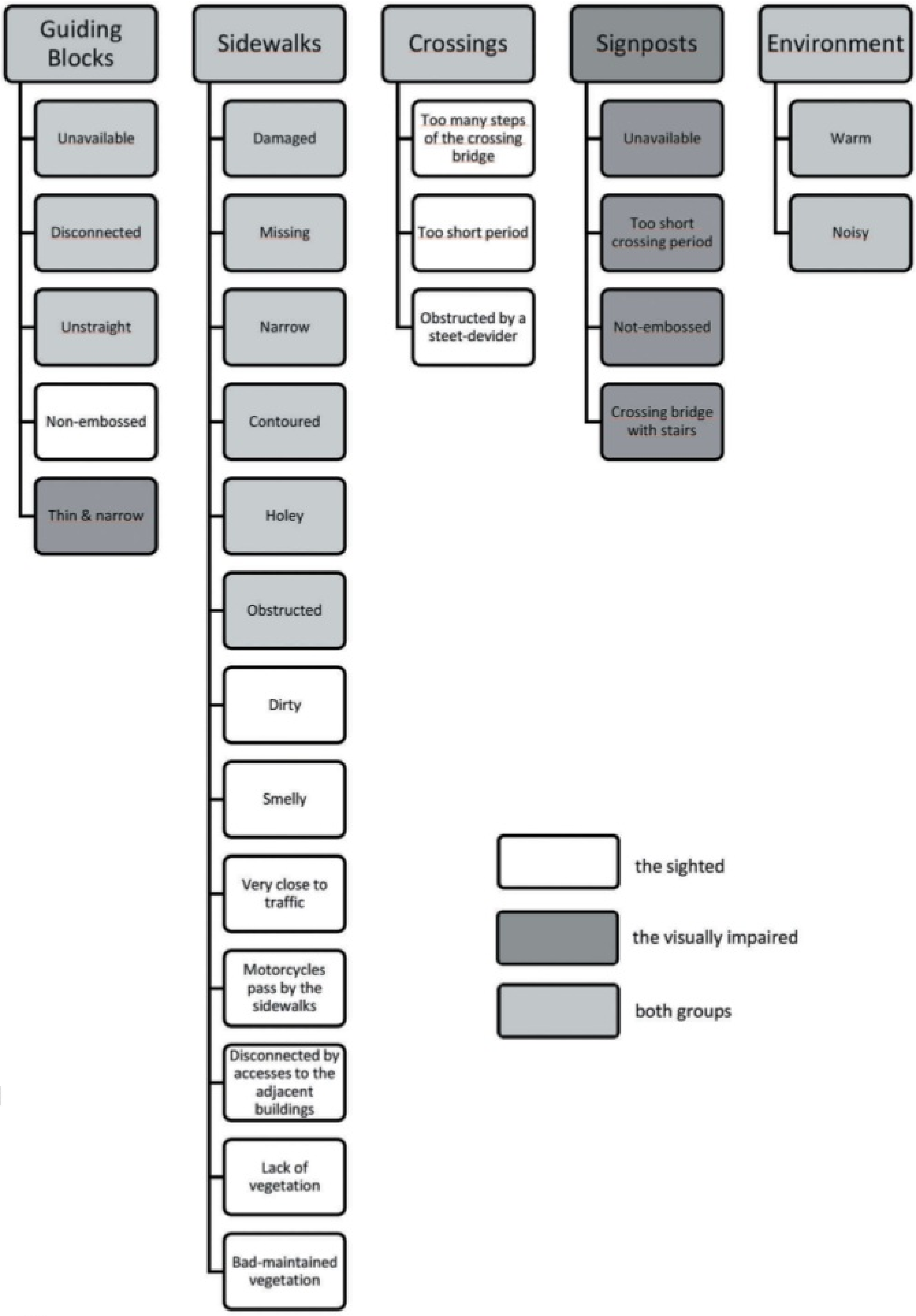

Figure 7. The unfavourable pavement elements, according to both groups of participants.

indices, which are grouped and presented in Figure 7, are related to the pavement's net width. Generally speaking, 3 to 5 m widths of pavement is sufficient. However, as Figures

2, 3, 5, and 6, it is not the net width available for pedestrians. There are trees, cars, commercial signs, holes, and damaged spots that cause people to use the remaining narrow space. For pedestrians, the degree of lateral clearance is far more important than other factors (Kim, Choi, and Kim 2011). Pedestrians experience significant discomfort at obstacles in their moving paths (Muraleetharan and Hagiwara 2007). Once it is deemed uncomfortable by the sighted, it is readily uncomfortable by the visually impaired because they need clearer and broader space than the sighted.

Regarding the short time crossing signage, when it was installed, the creator may have considered the signage period was adequate. However, it is only proper for sighted people as they have visually observed the surroundings before crossing the road. Meanwhile, the visually impaired requires a longer time to experience the environment before crossing the road. They spent half of the given crossing time only to learn the surroundings. Even the sighted group also noticed that the crossing sign was too short. It is in line with Guth et al. (2013), who found that visually impaired people were slower when crossing a street than sighted people. Once they start to cross the road, they might lose the intended route because the pelican crossing is not embossed, which is an essential key to guiding them so far.

Regarding the sound environment, both groups perceived that the pavements are noisy. It correlates with the semantical finding by the FGD. Their perception is confirmed with the result of SPL measurement (Table 3). We see that of the nine segments, it was only segment 9, which LAeq(10 minutes) is slightly below the 65 dBA standard (Ministry of Environment 1996). The traffic noise might fluctuate on different days and periods, but they are as typical as those shown in Table 3. During the daytime, the noise level never lower than those recorded in the survey (BPS Surabaya 2019). In the case when the SPL rises, it might change participants' perception from "noisy" to "very noisy." However, it will not greatly affect participants' opinions about the structure of the pavements. After all, the "noisy" rate has placed the pavements as unfavourable.

3.2. *The soundscape dimension*

The data collected from the semantic attributes were analysed using principal component analysis (PCA) with a change of coordinates known as varimax rotation (Field 2000). By this, each variable can be associated with, at most, one factor. The PCA analysis uses a polychoric correlation instead of Pearson's correlation given that the ordinal data

Table 3. The SPL is measured in each segment, most of which exceed the noise level for the 65 dBA trade and office area (Ministry of Environment 1996).

	Segments	Primary sound source	LA_{eq} (dBA)	LAF_{max} (dBA)	LAF_{min} (dBA)
1	Siola 1	Traffic and crossing signage	78.4	90.7	66.4
2	Siola 2	Traffic	72.2	90.3	62.3
3	Siola 3	Traffic and crossing signage	76.3	90.4	57.7
4	Bambu Runcing 1	Traffic and crossing signage	78.9	98.9	64.4
5	Bambu Runcing 2	Traffic	72.5	94.6	62.9
6	Darmo 1	Traffic	76.5	98.4	61.9
7	Darmo 2	Traffic and crossing signage	77.2	94.0	64.6
8	Darmo 3	Traffic	67.3	86.4	50.9
9	Darmo 4	Traffic	63.3	77.4	51.7

gathered is 3-scale bipolar data, which tends to have strong skewness or kurtosis (Muth`en and Kaplan 1985; Gilley and Uhlig 1993 in Basto and Pereira 2012). The analysis was run separately for the sighted and the visually impaired. The soundscape dimensions were set based on the eigenvalue of the PCA (eigenvalue > 1). By PCA, the terminologies used were grouped into dimensions that were named relative to the word that could explain or represent the dimension in general. They were based on the attributes that appeared in the group. The naming is a subjective judgement, as was Kang and Zhang (2010) and Axelsson, Nilsson, and Berglund (2010). The nomenclature here refers to those of the earlier studies, with a little modification to adjust to the variation of used attributes.

Because the number of attributes between groups is not identical, a comparison of feature-by-feature between the two groups could not be made. The PCA extraction was further to confirm whether each group had consistency with the data they provided for the questionnaire given. The variation in the number of attributes to be analysed reflects a significant difference in subjective responses between the two groups. From the initial stage of attributes collection, we found that the visually impaired assessed pavements in more detail using physical (as if they could see) and psychological attributes, such as "safe" and "scary". Meanwhile, the sighted focused on physical attributes alone, using the senses of sight and hearing.

Substantial dimensions were elicited from sighted participants with two main factors only (Table 4). Here, all 8 attributes of the sighted significantly determine the two main factors. The dominant soundscape dimension is related to the perception of pleasantness, which is associated with the semantic scale of "comfort", "fun", "safe", "easy", and "clear route". It explains 42% of the variance. The second dominant dimension, which explains 26% of the variance, is the perception of eventfulness related to the semantic scale of "crowded", "noisy", and "full". The two major soundscape dimensions of pleasantness and eventfulness extracted from the sighted participants are in line with previous studies of the soundscape in urban public areas by Axelsson, Nilsson, and Berglund (2010) and Kang and Zhang (2010). The related attributes of the two dominant soundscape dimensions indicate that the sighted predominantly uses the visual sense over the hearing to appraise the pavements. The lesser soundscape dimensions of sighted people than those of the visually impaired are following the lesser attributes.

The visually impaired produced four soundscape dimensions quite evenly except for factor #1, which explains 25% of the variance (Table 5). It indicates that visually impaired

Table 4. PCA of sighted participants (KMO Measure Sampling of Adequacy = 0.7106 and Bartlett's Test of Sphericity Sig. = 0.000, $N = 216$).

	Attributes	Factors 1 (42%)	Factors 2 (26%)
1	crowded – uncrowded	0.389	0.724
2	comfortable – not comfortable	0.837	–0.120
3	noisy – quiet	–0.110	0.898
4	fun – boring	0.853	–0.161
7	safe – dangerous	0.759	–0.052
12	full – empty	–0.155	0.781
15	easy – uneasy access	0.799	0.192
17	clear – unclear route	0.727	0.167

Table 5. PCA visually impaired participants (KMO Measure Sampling of Adequacy = 0.739 and Bartlett's Test of Sphericity Sig. = 0.000, N = 90).

		Factors			
		1	2	3	4
	Attributes	(25%)	(11%)	(10%)	(9%)
1	crowded – uncrowded	0.392	0.127	0.667	−0.046
2	comfortable – not comfortable	0.642	0.079	−0.205	0.400
3	noisy – quiet	−0.097	−0.200	0.832	−0.026
4	fun – boring	0.621	0.130	−0.075	0.405
5	rough – soft	−0.217	−0.587	0.302	−0.126
6	natural – artificial	0.317	0.101	0.111	0.425
7	safe – dangerous	0.676	−0.005	−0.042	0.094
8	unclear direction – clear direction	−0.777	0.097	−0.107	−0.063
9	far – near	−0.093	0.722	0.085	−0.250
10	slow – fast	−0.010	0.633	−0.064	0.123
11	know – don't know the location	0.753	−0.077	0.112	−0.040
12	full – empty	−0.190	−0.271	0.713	−0.008
13	scary – soothing	−0.714	−0.084	0.249	0.138
14	spacious – cramped	0.146	−0.222	−0.138	0.461
15	easy – uneasy access	0.733	−0.097	−0.122	0.143
16	slippery -coarse	0.462	0.218	0.066	0.327
17	clear – unclear route	0.765	0.084	0.065	−0.020
18	near – far traffic	0.005	−0.706	0.174	−0.057
19	flat – contoured	−0.180	0.132	−0.007	0.847

people appraise the sound environment in more detail, as was determined by Lessard et al. (1998), González-Mora et al. (1999), Dunai et al. (2015), and (Mediastika et al. (2019) and Mediastika et al. (2020)). Factor #1 is related to the dimension of pleasantness, direction, and safety at the same time. The semantic scale related to factor #1 is "comfortable", "fun", "safe", "clear direction", "know the location", "soothing", "easy" and "clear route". All attributes used to explain the factor of the pleasantness of sighted people are also used here, which is added by other attributes that describe direction and safety. Visually impaired people find pleasantness while walking on pavements when they believe in their direction and feel safe. The second soundscape dimension explains 11% of the variance, which relates to the perception of space. It is related to the semantic scale of "soft" (the antonym of rough), "far", "slow", and "far traffic" (the antonym of near traffic). The third soundscape dimension is related to the perception of eventfulness, which explains 10% of the variance. It is associated with the semantic scale of "crowded", "noisy", and "full". The fourth dimension is related to the perception of contour, which explains 9% of the variance. It is associated with the semantic scale of "flat".

Of the 19 visually impaired's attributes, only 16 were significant to determine four factors. The attributes "natural", "spacious" and "slippery" appear insignificant. The 3 insignificant attributes imply that the visually impaired expected to face certain conditions that did not occur during the survey. Their initial perception was not proven in the *in-situ* survey. Meanwhile, the initial perception of the sighted on the physical condition of pavements was all proven significant. The sighted seems to mix the use of senses of sight and hearing in the initial appraisal.

In the earlier study in parks, the perception of eventfulness emerged as the most dominant by visually impaired participants (Mediastika et al. 2020). It is unique because several soundscape studies by sighted people, including those by Axelsson, Nilsson, and Berglund (2010), Kang and Zhang (2010), and (Mediastika et al. 2020), showed that pleasantness is the most dominant dimension. Here, specific to the visually impaired participants, the soundscape dimension of pleasantness also links to the perception of direction and safety, which emerged in the earlier study but grouped in separate dimensions (Mediastika et al. 2020).

A connection between the data collected from the first and second sections of the questionnaire is built. The visually impaired participants' unfavourable perception found from the first section was more of their expectation of how the pavements might be improved. In other words, the visually impaired participants' negative response was caused by their expectations of the pavements. Even though the overall condition is decent, they still expect improvements to be made. In this study, they walked through the optimum and most improved pavements in Surabaya, which are in much better condition than the typical pavements. That is why, by the PCA, they perceived the surveyed pavements as providing elements of comfort (dimension of pleasantness). Even so, they noticed quite a few unfavourable aspects that they expect to be improved on the surveyed pavements.

The fourth dimension of contours arises because the participants were requested to walk and rate the pavements. It is uniquely reflected by the semantic "flat" and is confirmed as a significant element. This dimension might be related to the way visually impaired people characterise the environment. The rating of the dimension of contours is not linked to the pleasantness dimension and becomes one independent dimension, whereas the dimension of pleasantness is affected by the easiness of the access, the clear direction, and the safety.

3.3. Factors affecting walking on pavements

A further test to learn about the detailed attributes that affect participants' level of comfort while walking on pavements was conducted using the regression function in Excel. For sighted participants, the perception of pleasantness is affected by the access only (i.e., easy) (Table 6). The correlation of the affecting factors is 0.508. Meanwhile, the perception of pleasantness experienced by visually impaired participants can be modelled with the perception of the environmental sound (i.e., noisy), the environment (i.e., natural), and the access (i.e., easy). The correlation of the models is 0.633 (Table 7). It shows that for the visually impaired, a strong link is developed between pleasantness and the pavement's environment. The regression function indicates that for the visually impaired, pleasantness while walking on pavement is affected by sound, which is not the case with the sighted participants.

4. Conclusion

The study of pavements using a soundwalk method was conducted with both sighted and visually impaired people. Their responses and the pavement design implications are summarised as follows:

- At least 80% of the participants agreed that there are many shortcomings of the surveyed pavements. It is mainly about insufficient net width caused by both additional fixed and temporal elements on the pavements. Trees, plant containers, and benches are examples of fixed elements on pavements. Meanwhile, marketing signs,

Table 6. Factors affecting sighted participants walking on pavements.

Regression Statistics								
Multiple R	0.508324							
R Square	0.258393							
Adjusted R Sq.	0.244532							
Standard Error	0.694906							
Observations	110							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	2	18.00297	9.001486	18.64067	1.13E-07			
Residual	107	51.66975	0.482895					
Total	109	69.67273						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.71675	0.220128	3.256056	0.001513	0.280372	1.153129	0.280372	1.153129
easy access	0.441548	0.080981	5.452491	3.22E-07	0.281013	0.602084	0.281013	0.602084

Table 7. Factors affecting visually impaired participants walking on pavements.

Regression Statistics								
Multiple R	0.633155							
R Square	0.400885							
Adjusted R Sq.	0.380226							
Standard Error	0.648069							
Observations	91							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	3	24.44957	8.149858	19.40472	1.01E-09			
Residual	87	36.53944	0.419994					
Total	90	60.98901						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.982096	0.303181	3.239307	0.001698	0.379491	1.5847	0.379491	1.5847
noisy	−0.36513	0.11471	−3.18306	0.002022	−0.59313	−0.13713	−0.59313	−0.13713
natural	0.243045	0.101899	2.385161	0.019243	0.04051	0.445581	0.04051	0.445581
easy access	0.42408	0.082579	5.135478	1.7E-06	0.259946	0.588214	0.259946	0.588214

parking vehicles, and damaged spots are examples of temporal elements. According to Bloomberg and Burden (2006) and Rendy (2011), the current pavement width is sufficient, but it has to be freed from additional elements. Because shaded pavements are preferable, a fixed element that may provide shading such as trees can be maintained with a trunk size within a reasonable ratio to the overall pavement width.

- The dominant sonic perception of pleasantness and pleasantness-direction-safety elicited by both groups seems to disagree with the less-qualified pavements they perceived en route. It possibly means that apart from the low quality of the pavement, they still perceive the pleasantness of the surrounding conditions. Especially for the visually impaired, they assumed the pavement are quite passable when they have to pass the route on their own. However, the study also raises an issue that the visually impaired still expect an improvement of the pavement to reduce the unfavourable aspects. It implies that to accommodate the visually impaired group, the pavements should be clear of unnecessary obstruction, shaded and installed with standardised guiding blocks. These all will serve the visually impaired with clear direction and safety.
- A unique soundscape dimension of contours is raised in this study by the visually impaired. They built it since the FGD and verified to be a significant factor extracted from the semantic attributes. The finding implies that it is possible to design a contoured pavement for the visually impaired as long as it is safe, easy to access, has sufficient width, and has a clear direction.
- The sound environment was not perceived as the main issue during the survey. However, it played a role in helping visually impaired participants sense the pleasantness, direction, and safety of their surroundings. Traffic noise shares information to the visually impaired, whether they are near or far from the traffic. Proximity reflects an unsafe environment and vice versa (Mediastika et al. 2020).

The study's findings may be used as a reference by urban designers and the local authority to improve the condition of pavements so that they are more favourable and inclusive. Nonetheless, the conclusions drawn in this study are limited by the age span and the educational background of the participants. More importantly, the condition of pavements of Indonesian cities differs from that of other countries. The conclusions may not be instantly transferrable to other regions with different pavement characteristics or communities with different social backgrounds.

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