Building and Environment 237 (2023) 110267

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Indoor soundscape model: Assessing contextual factors in open-plan offices on university campuses in Surabaya, Indonesia

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A R T I C L E I N F O

Keywords:
Indoor environment
Soundscape perception
Open-plan office
Social-cultural characteristics
Employee behaviour
University building

A B S T R A C T

Evaluation research in Western countries shows that soundscape perception and work behaviour in an open-plan office are negative due to uncontrolled sound levels and diminished visual and acoustic privacy. This condition resulted in a noteworthy diminution in employee performance and comfort. Most offices in large cities, including those in Indonesia, also follow the trend of adopting an open-plan system. For this reason, it is necessary to conduct further studies in the local environment. Contextual experience is a key aspect in indoor soundscape studies, of which subjective evaluation is an important part. This study further investigates the causal relationship between contextual factors related to space usage and personal and demographic aspects on psychological, expectation, soundscape perception, and work behaviour aspects. The questionnaire survey was conducted on full-time employees at six administrative offices on two university campuses in Surabaya. Partial least squares structural equation modelling (PLS-SEM) was used to analyse statistically the collected data and to test the formulated hypotheses. The results reveal a significant path from personal and demographical to psychological, which has the highest estimated t value of 9.438 and is supported by a significance level of $p < .01$ ($t_{0.01}>2.58$). Social-cultural characteristic indicators, namely, societal values and lifestyle, have the highest loading and consequently have a large influence on soundscape perception and work behaviour in the local environment. This results in certain work behaviour reflected in the reactions, responses, soundscape preferences, and activities of employees working in the local environment, which differs from that of those residing in Western countries.

1. Introduction

In recent years, research related to soundscapes has been widely applied to indoor spaces. Researchers have started to describe how people experience, understand, and interact with indoor soundscapes in the context of their residences, workplaces, and other indoor spaces [1]. Several researchers have discussed the soundscape perception of certain types of buildings, such as residential buildings [2–5], offices [6–8], libraries [9,10], maintenance facilities [11–13], study rooms [14], historic buildings [15,16], restaurants [17], shopping centres [18,19], public transport spaces [20] and educational facilities [21].

In the development of office buildings, the open-plan concept has become the dominant interior design strategy. The open-plan system, without walls and partitions, is one of the most popular workspace layouts and is preferred by business owners over conventional layout types.

Open offices are becoming popular because of lower building costs due to reduced partitions required, lower rental costs due to increased employee density, ease of customization and better access to natural lighting. Cubicles can be easily reconfigured at minimal cost to meet changing needs. In open office studies, the work environment has been studied in terms of the number of partitions, partition height, space density, and openness. An open-plan office is believed to enhance cooperation, and social relations, facilitating communication between individuals, groups and even entire departments, feedback, solidarity and knowledge sharing among employees. In addition, open offices provide accommodation for a large number of employees by reducing individual workspaces [22]. However, the open-plan system, which is

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https://doi.org/10.1016/j.buildenv.2023.110267
Received 15 November 2022; Received in revised form 3 February 2023; Accepted 31 March 2023
Available online 8 April 2023

popularly adopted in Western countries, often shows acoustic conflicts due to unsatisfactory acoustic performance results [23,24]. Generally, there is a negative impact related to indoor soundscape assessments due to reduced visual and acoustical privacy, as well as uncontrolled sound levels, which then lead to a significant decrease in employee satisfaction and performance outcomes [25].

One of the primary causes of worsened soundscape conditions is low speech privacy, in which employees find it difficult to concentrate due to unwanted voices and the prospect of being overheard [26]. Conversational sounds are the noise source that particularly interferes with cognitive performance, especially during reading and memorizing activities [27–30]. Memorizing activities are more sensitive to conversational disturbances than calculation-related tasks [31–33]. Similarly, the sound of individuals circulating within the corridor between cubicles and telephone rings often become irritating distractions [30,34,35]. The decline in cognitive performance reaches its peak when other conversations are audible and not because of the volume of the conversation. Dissatisfaction with the negative impact of a workspace soundscape can harm individuals in terms of health (physical and psychological), comfort, well-being and job satisfaction [36,37]. Soundscape conditions with uncontrolled sound levels are the most frequent source of dissatisfaction among all other negative parameters [38]. To address these problems, several researchers have tried to provide a solution to the acoustic design by performing adequate speech control. Various solutions were carried out, such as extending the distance between the cubicles, utilizing acoustical damping materials on the ceiling and walls, installing partitions between cubicles, and applying a noise-masking system [39–42].

Offices in major cities around the world, including those in Indonesia, have begun to adopt an open-plan layout. The results of measuring the objective acoustic parameters based on ISO/DIS 3382-3:2012 [43] on six cases of administrative offices on two university campuses in Surabaya show that the majority of acoustic conditions tend to be noisy. The results of field measurements show that the noise criterion is > 40, the reverberation time is > 0.6 s, and the speech transmission index is > 0.50 above the standard, so employee performance may be disturbed due to the clarity of colleagues' voices. The calculation results of the A-weighted sound pressure level (SPL) of speech at 4 m from the sound source are above the standard 48 dB-A. The distraction distance exceeds the standard 5 m. The spatial decay rate of the A-weighted SPL of speech is below the standard 7 dB-A. This shows that the usage of sound-absorbing materials in the interior elements and cubicle partitions within the six offices is not functioning optimally because most of the absorption coefficients of the interior elements used are below 0.15. This condition is similar to the results of studies in Western countries [27–30,44], indicating that the majority of office typologies on an open system tend to be noisy. The negative impacts of soundscape conditions may lead to dissatisfaction and health issues (physical and psychological) and interfere with employees' cognitive performance, as is the case in Western countries [44]. Therefore, the soundscape perception and work behaviour in the open-plan offices in Surabaya must be verified. Individual experiences and social-cultural effects can have different influences on soundscape perceptions and work behaviour in the local environment.

Indoor soundscape analysis is still in the embryonic stage; thus, some gaps exist within the models and factors associated with standardization [45]. By reviewing many literature studies [9,46–51] and ISO 12913 series guidelines [52–54], it is possible to investigate and develop, and perhaps also revise or integrate, the indoor soundscape factors and methods based on the case and local culture. The ISO 12913 series contains standards for evaluating soundscapes from numerous aspects, such as definitions and frameworks, data collection methods, and data analysis [52–54]. Since the three standards are published for urban soundscape principles, indoor soundscape standards still need to be studied promptly and developed further in an exceedingly specific scope [45]. The study of contextual factors related to causal relationships between variables has not been examined or tested in detail. Therefore, this study is very important to reidentify the contextual factors associated with the six administrative office cases in Surabaya, considering the interactions among contextual factors and assessing the effect of each category on soundscape perception and work behaviour within the local environment.

To assess the interactive effects among contextual factors, it is very important to develop a conceptual framework to reflect the soundscape perception and work behaviour in an open workspace in the local environment. The analytical technique using structural equation modelling (SEM) is considered the most appropriate to assess the interactive effects between variables and has been validated in a similar study [16]. Through partial least squares structural equation modelling (PLS-SEM), the categories in the conceptual model, which are latent constructs, are observed and measured. This multivariate statistical method can be used to infer the categories of the conceptual framework [16].

1.1. *Contextual experience factors: A literature review*

The first variable of the indoor soundscape system is the assessment of space usage, which consists of three defining and distinctive dimensions, namely, preference, usage frequency, and time spent factors [9,50]. Therefore, it is necessary to consider space usage assessment in this study and develop it according to the literature findings and case study testing. Preference is a key aspect in terms of space usage because it indicates whether a user likes or dislikes a certain space. If the space is not likeable, then it will not be utilized by the people [50]. For this reason, the analysis of a person's tendency to like/dislike a workspace should be evaluated first. The term spatial preference is considered in this study because it is related to the workspace and the perception of a healthy work environment in the contextual experience of the user. Second, usage frequency is important to consider in this study because it is not solely associated with time [45,46] but is also related to frequent or infrequent user activities in cubicle and is associated with noise disturbances; therefore, it may carry a significant correlation, according to the study [9,50]. Third, a study [56] clearly shows that noise disturbance and longer time spent indoors have an effect on users' perception and contextual experience. For that reason, this study also considers the time spent within the workspace, because the length of time a person is in the workspace (and exposed to noise) will have an effect on the user's perception and experience.

The next most important basic characteristic to consider in this study is to classify the sample population through demographical factors. Therefore, different user profiles might mirror different soundscape perceptions and behaviours [9,50]. The study of Dokmeci and Kang focused on individual physiological characteristics associated with age, gender, and social-cultural characteristics that reflect the background and behavioural patterns of the sample cluster respondents. The study shows that the most common questions are related to education, cultural background, and cultural characteristics [50]. A different study [45] develops it into personal and demographical factors, which include aspects of individual characteristics and social-cultural characteristics. The study [45] focuses on a conceptual model from Ref. [51], which includes personal and demographical information such as age, gender, personal characteristics, sociocultural differences, health conditions, and lifestyle, which are believed to have an effect on soundscape expectation and preference. Questions related to personal and demographic factors show a very large variety. Given the different contexts, the individual characteristic aspect in this study is presented more comprehensively and divided into two parts. The first part is used to look at the respondent's profile through personal attribute data grouping, which includes age, gender, educational background, work type, job position, seniority in the company, seniority at work, and years of service. The second part is used to examine the personal characteristics through introversion, extraversion, noise sensitivity, and user's health condition data taken from the study [57]. Similarly, it has been argued [45,46,50] that it is necessary to emphasize investigations related to cultural background. Cultural differences and social and lifestyle backgrounds must be considered to understand the factors that influence soundscape perception [4,7]. Therefore, the social and cultural context will verify the human activity system [58]. The social aspect is extremely useful in expressing culture through societal values and lifestyles to visualize the mindset, actions, and behaviour of people or groups of people in certain environments [59]. This shows that detailed aspects related to social-cultural characteristics, including societal values and lifestyle, related to this study require further investigation and consideration. These two aspects can be used to understand a certain group of users, situations, and the local environment [59], which may influence soundscape perception and human behaviour.

Contextual factors related to psychological categories are developed in more detail within some studies [45,46], including sensation, attention, mood during listening, past experiences, and expectations that can affect soundscape perception and behaviour (user reaction and response to the acoustic environment and soundscape preference in an area). It is necessary to consider the evaluation results on audial sensation, audial attention, mood, and past experience of users in this study and carry out the research according to the literature findings and case study testing. The four dimensions become the basis of expectations for a place and the effect (positive/negative, pleasant/disturbing) on people's evaluation of the soundscape. Ultimately, the results can be reflected through one's behaviour (reaction, response, soundscape preference, activity) in the local environment [45,46]. This is important to consider in indoor soundscape studies, as suggested by Ref. [60], because the results of soundscape preferences can be different in different places.

The categorization considered for this study is based on the literature findings [9,45,46,50] and case study testing. It has been adapted and rearranged to integrate the cultural context within the local environment. This can be useful to improve understanding and facilitate an appropriate and efficient evaluation tool for future researchers to obtain more accurate results. The categorization (latent constructs) includes space usage, personal and demographical, psychological, expectation, perception and work behaviour factors (refer to Table 1).

1.2. Theoretical model of contextual factors on open-plan offices

The study's main objective is to develop a model and validate the results of an indoor soundscape questionnaire specifically for open-plan offices, which was adapted and developed from a previous study [9,45,46,50]. For this reason, it is necessary to examine the dependence of the psychological, expectation, soundscape perception, and work behaviour factors on space usage and personal and demographical conditions based on the user's experience in a local environment where cultural values and social effects also play a part. The main research question is how space usage and personal and demographical factors, especially social-cultural characteristics related to societal values and lifestyle, affect soundscape perceptions and work behaviour in the local environment.

A theoretical model is designed to assess the causal relationship between space usage and personal and demographical experiences and the user's psychological condition before assessing its impact on employee expectations, soundscape perceptions, and reactions (which are reflected in work behaviour). Based on the literature review [9,45,46,49–51,56,60], the subsequent theoretical model is proposed (refer to Fig. 1).

The hypotheses on the contextual experience factors within the local environment are proposed as follows:

Hypothesis 1. 'Space usage' significantly influences 'personal and demographical'. The tendency of an individual to like/dislike space should be analysed first [9,50] because it will affect the health and well-being of the people. Operationally, one's satisfaction with space

Table 1
Observable variables based on a summary of the literature.

Latent Constructs	Code	Observable Variables on Contextual Factors	References
Space Usage Factors:			
- Spatial preference	SU1	You prefer to use the workspace provided by the institution to do individual or collaborative work with colleagues	[9,45,46,50]
	SU2	You prefer to use the workspace provided by the institution because of the healthy work environment.	
	SU3	You prefer to use the workspace provided by the institution because the physical environment is comfortable (light, air circulation, sound, thermal, humidity).	
	SU4	You prefer to use the workspace provided by the institution because you can control the physical environmental conditions (light, air circulation, sound, thermal, humidity) to make you feel comfortable.	
- Usage frequency	SU5	You frequently use the provided cubicle to do individual work as well as collaborative work (working in groups, talking on the phone, interacting with colleagues).	[9,45,46,50,55,56]
	SU6	You frequently use the provided cubicle because the position of your cubicle is comfortable.	
	SU7	You frequently use the provided cubicle because the equipment in your cubicle is complete.	
- Time spent	SU8	The proportion of working time in the office is spent mostly (90%) in your workspace.	[9,45,46,50,56]
	SU9	The proportion of working time in the office is spent mostly (90%) in your cubicle.	
Personal and Demographical Factors:			
A. Individual Characteristics:			
- Introversion	IC1	Generally, is it accurate that you are shy.	[9,45,46,50,57]
	IC2	Generally, is it accurate that you are quiet.	
- Extraversion	IC3	Generally, is it accurate that you are friendly.	
	IC4	Generally, is it accurate that you are talkative.	
- Noise sensitivity	IC5	You are sensitive to noise.	
- Health condition	IC6	You are still energetic after a long day at the office.	
	IC7	You can still concentrate after a long day at the office.	
	IC8	Overall, your physical health condition is still good, even though there is noise disturbance in the office.	
	IC9	Overall, your psychological health condition is still good, even though there is noise disturbance in the office.	
B. Social-Cultural Characteristics:			
- Societal values	SC1	Generally, you can tolerate the noise conditions in the workspace or cubicle.	[9,45,46,50,58,59]
	SC2	Generally, you can tolerate the noisy behaviour of colleagues in the workspace or cubicle.	
- Lifestyle	SC3	Generally, you are familiar with the noisy condition in the work environment.	

(*continued on next page*)

Table 1 (*continued*)

Latent Constructs	Code	Observable Variables on Contextual Factors	References
	SC4	Generally, you are familiar with the noisy behaviour of colleagues in the work environment.	
Psychological Factors:			
- Auditory sensation	PS1	You feel comfortable when colleagues speak clearly near your cubicle.	[46,61]
	PS2	You find it easy to work in a noisy workspace all the time.	
- Auditory attention	PS3	You can still focus (concentration) despite noise interference from equipment in the work environment.	[46,62]
	PS4	You can still focus (concentration) even though there are distractions caused by your colleagues' activities in the work environment	
- Mood	PS5	You often feel enthusiastic in your acoustic environment.	[17,45,63]
	PS6	You often feel energetic in your acoustic environment.	
- Past experience	PS7	You feel comfortable about the noise conditions in the workspace.	[45,47,64–66]
	PS8	You feel comfortable about the working conditions in the workspace.	
	PS9	You feel comfortable about the noise control in the workspace.	
	PS10	You feel comfortable with the behaviour of your colleagues in the workspace.	
	PS11	You feel comfortable with the activities of your colleagues in the workspace.	
	PS12	You feel comfortable about the voice information obtained in the workspace (phone calls, colleague conversations, announcements).	
Expectation Factors:			
- Expected sound	PS13	The expected sound in the workspace meets your expectations.	[9,17,45,46,49,50,63,67]
- Expected place	PS14	The expected workspace condition meets your expectations.	
- Expected control	PS15	The expected noise control in the workspace meets your expectations.	
- Expected behaviour	PS16	The expected colleague behaviour in the workspace meets your expectations.	
- Expected activity	PS17	The expected colleague activity in the workspace meets your expectations.	
- Expected information	PS18	The expected voice information in the workspace (phone calls, colleague conversations, or announcements) meets your expectations.	
Perception Factor:			
- Soundscape perception	PS19	Overall, in your opinion, you feel comfortable with the acoustic environment in your workspace or cubicle.	[9,45,50,61]
Work Behaviour Factors:			
- Reaction	WB1	You feel undisturbed by the noise in the work environment.	[9,46,50,61]
	WB2	You don't have to anticipate distractions in the work environment.	
- Response	WB3	You aren't tired (physically) due to noise disturbance at the end of the working day.	[46,68,69]
	WB4	You aren't stressed (psychologically) due to noise disturbance at the end of the working day.	
- Soundscape preference	WB5	You prefer a 'peaceful' or 'tranquil' working environment.	[17,46,60,63]
	WB6	You prefer a 'lively' or 'exciting' working environment.	
- Activity	WB7	Overall, in your opinion, the noise problem does not interfere with your daily work activities.	[17,63]

usage is indicated by his or her satisfaction with the arrangement of the physical environment and is closely related to occupational health and safety [70,71].

Hypothesis 2. 'Space usage' significantly influences 'psychological'. Preferences regarding likes/dislikes of space, usage frequency, and time spent by users within the workspace are important factors in the assessment of indoor soundscapes because they can affect the psychological condition and user experience in the local environment [9,50,56].

Hypothesis 3. 'Space usage' significantly influences 'expectation'. Expectations are related not only to sound sources, but also to place, control, behaviour, activity, and sound information that the user expects to be in the room [49].

Hypothesis 4. 'Personal and demographical' significantly influences 'psychological'. Personal and demographical information is important for the soundscape because it characterizes the users of a place [45]. Thus, personal and demographical characteristics, especially aspects of societal values and lifestyle that are typical in the local environment [59], can have an impact on the psychological condition of users.

Hypothesis 5. 'Personal and demographical' significantly influences 'expectation'. Personal and demographical information (such as gender, age, individual characteristics, health conditions, lifestyle, and social-cultural characteristics) have an impact on soundscape expectations and preferences [45,51].

Hypothesis 6. 'Psychological' significantly influences 'expectation'. People base their decisions on their informational backgrounds in previously visited locations that are comparable to the current location. Expectations for a place are mostly established from the user's psychological experiences [45].

Hypothesis 7. 'Expectation' significantly influences 'soundscape perception'. Expectations are related not only to sound sources but also to place, control, behaviour, activities, and information that users expect. When the six dimensions meet expectations (positive), then the user's perception becomes positive even though there are disturbing noises [49]. Expectations have an impact on how people perceive and assess soundscapes and whether they conclude that the soundscape is pleasant or unpleasant [45].

Hypothesis 8. 'Soundscape perception' significantly influences 'work behaviour'. The whole process begins with expectations, followed by perceptions, and ends with reactions such as behaviour-oriented actions [45,50]. If a person is in a different location or performing a different activity, the outcomes of their preference for sound may be different [60].

1.3. *Research methodology: Triangulation method for soundscape evaluation*

Postpositivist philosophy and deductive reasoning are used to frame the study's epistemological viewpoint and to assess the hypotheses that were derived from the literature. Similar methods have been applied to investigations of indoor soundscapes [9,46,50,61,72], especially in the

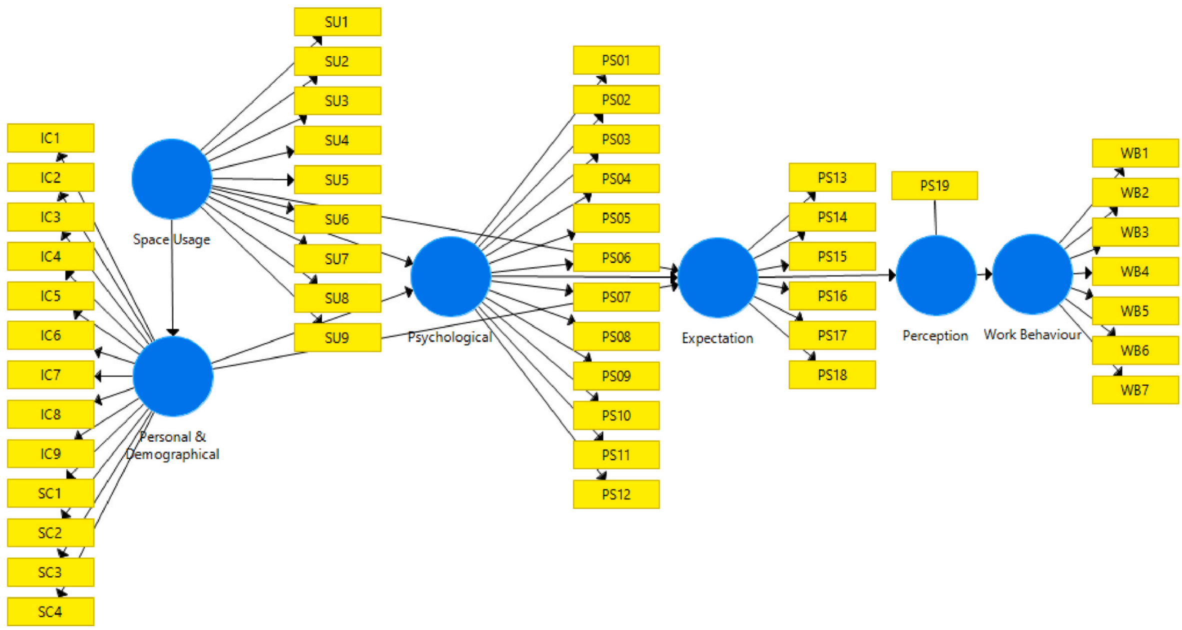


Fig. 1. A theoretical model for the interaction of contextual factors.

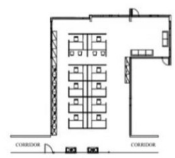
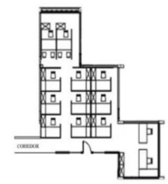
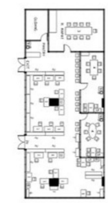
case of open-plan offices [24,25,29]. This study adapts the post-occupancy evaluation (POE) methodology to carry out an integrated evaluation by looking at the relationship between spatial experience, soundscape perception, and work behaviour in which the user is a key element. POE can be used for a structured data collection process to assess the relationship between physical elements and social differences [46]. POE was adapted and carried out in three stages which build upon one another by conveying information to the next stage from the collected data of the previous stage. First, the indicative stage includes observation (spatial and behavioural) and sonic measurements as the basis for further research. Measurement of sonic characteristics and physical environment is useful for identifying environmental conditions. Second, the investigation stage is including giving GABO questionnaires [73], essays, interviews (related to space usage, psychology, and social context) and architectural surveys (spatial and architectural design) where users participate through interactive communication in the interviews. The second stage information was evaluated and the results were used to develop the content of the Likert scale questionnaire and interviews. These two phases (indicative and investigative stages) are useful for the initial identification of spatial experience, soundscape perception and work behaviour factors. Finally, the diagnostic stage is to conduct a soundsit (assessment in the cubicle) where users fill out a Likert scale questionnaire and semi-structured interviews to understand the specific relationship between spatial experience, soundscape perception and work behaviour. The last phase is an overall evaluation of the previous phase (indicative and investigative) and everything is integrated to provide final confirmation which will lead to a more structured final evaluation.

1.3.1. *Case studies and architectural characteristics*

The study by Kim and de Dear stated that open offices include cubicles with high partitions, cubicles with low partitions and cubicles with no partitions often have problems with visual privacy, sound privacy, and noise disturbance so that they can reduce workspace satisfaction [29]. This study intends to select the six administrative offices from two different campuses which also have the same setting system as the previous study in Ref. [29]; the General Administration and Personnel Bureau (abbreviated as GAPB) with 11 employees, Student Affairs Academic Administration Bureau (abbreviated as SAAB) with 12 employees, Financial Administration Bureau (abbreviated as FAB) with 12 employees located on Petra Christian University (abbreviated as PCU) campus. Directorate of Education (abbreviated as DE) with 15 employees, Financial Bureau (abbreviated as FB) with 34 employees, and Directorate of Research and Community Service (abbreviated as DRCS) with 20 employees located on Institut Teknologi Sepuluh Nopember (abbreviated as ITS) campus, Surabaya, Indonesia (refer to Table 2).

The GAPB, SAAB, and FAB workspaces are on the 1st floor. Each workspace is separated by a wall but can be connected through a corridor. All three workspaces have a cubicle with low partitions type for employees and division heads. The photocopy room with the door always open is shared. The GAPB workspace is located near the main entrance access, photocopy space, and toilets so that it is possible to visually and audial distract employees. Finishing materials are dominated by walls-glass, ceramic tiled floors, and gypsum ceilings. The materials can be classified as a low-medium absorbents for the indoor frequency range. The DE workspace is on the 1st floor, using a cubicle with low partitions types for employees and three cubicles with high partitions types for division heads. The photocopy area is in the middle of the room and is shared so that employees may be distracted by the traffic of colleagues. Finishing materials are dominated by walls-glass, ceramic tiled floors and gypsum ceilings, and are classified as low-medium absorbent. The FB workspace is on the 2nd floor, using a cubicle with a low partition type for employees and division heads. The stairs are near the main entrance and exit. The FB workspace has a shared photocopy area in the middle of the room. The television is placed on the wall near the exit door and is always on, but no sound. The workspace is equipped with a pantry and prayer room. Finishing materials are dominated by walls-glass, ceramic tiled floors, and gypsum ceilings, which have the absorption qualities of the finishing materials that are low-medium. The DRCS workspace is a relatively new building in comparison to the other five workspaces. The workspace is on the 1st floor, using a cubicle with no partition type for employees and division heads so that it is possible for employees to be visually and audial distracted by the passing of colleagues. The elevator line is near the main entrance. The photocopy area for the DRCS workspace is in the centre of the room and is shared. Television was placed near the main entrance as a means of public information. The workspace is equipped with a pantry and storeroom. Finishing materials are dominated by glass walls, ceramic tiled floors, and acoustic panels on the ceiling so that the

Table 2
Spatial and architectural analysis of General Administration and Personnel Bureau (GAPB), Student Academic Administration Bureau (SAAB), Financial Administration Bureau (FAB), Directorate of Education (DE), Financial Bureau (FB), and Directorate of Research and Community Service (DRCS).

Factors	Aspects	PCU Campus			ITS Campus		
		GAPB	SAAB	FAB	DE	FB	DRCS
							
Services	Public office	Personnel administration	Student administration	Financial administration	Student administration	Financial administration	Personnel administration
Dimensions	Area	249.50 m^2	105.26 m^2	114,46 m^2	201.65 m^2	418.57 m^2	257.50 m^2
	Volume	785,91 m^3	331.57 m^3	360.54 m^3	629.16 m^3	1276.63 m^3	1030 m^3
Spatial Elements	Office location	1st floor	1st floor	1st floor	1st floor	2nd floor	1st floor
	Corridor	Interconnected corridor between GAPB, SAAB, FAB			Single corridor	Single corridor	Single corridor
	Openings	The entrance is on the side of the corridor area and the exit is on the opposite side. The clear glass windows are 0.75 m above the plastered brick wall on one side of the wall.	The entrance is on the side of the corridor area and the exit is on the opposite side. The clear glass windows are 0.75 m above the plastered brick wall on one side of the wall.	The entrance is on the side of the corridor area and the exit is on the opposite side. The clear glass windows are 0.75 m above the plastered brick wall on one side of the wall.	The entrance, as well as the exit, are on one side of the wall. The clear glass windows are 0.75 m above the plastered brick wall on the two opposite walls.	The entrance is on one side and the exit is on the other side near the toilets, pantry and stairs down. The windows are 0.75 m above the plastered brick wall on the two opposite walls.	The entrance and exit doors are made of tempered glass on the same side. There are no windows that can be opened.
Materials	Wall material	2 plastered brick walls (h: 0.75 m) with a glass partition above it (h: 2.40 m), 1 plastered brick wall (h: 2.15 m) with a glass partition above it (h: 1.00) and a row of metal filing cabinets in front of the wall (h: 1.85 m), 1 partition wall with opening/door (h: 2.15 m) with a jalousie partition above it (h: 1.00 m). All plastered brick walls finished with painted white.	1 plastered brick wall (h: 0.75 m) with a glass partition above (h: 2.40 m), 2 plastered brick walls (h: 2.15 m) with a glass partition above it (h: 1.00 m) and a row of metal filing cabinets in front of the wall (h: 1.85 m), 1 partition wall with opening/door (h: 2.15 m) with a jalousie above it (h: 1.00 m). All plastered brick walls finished with painted white.	1 plastered brick wall (h: 0.75 m) with a glass partition above (h: 2.40 m), 2 plastered brick walls (h: 2.15 m) with a glass partition above it (h: 1.00 m), 1 partition wall with opening/door (h: 2.15 m) with a jalousie partition above it (h: 1.00 m). All plastered brick walls finished with painted white.	2 plastered brick walls (h: 0.75 m) with a clear glass window above it (h: 2.25 m) face to face, 1 plastered brick wall (h: 2.00 m) with a glass partition above it (h: 1.00 m), 1 glass wall with opening/door (h; 3.00 m). All plastered brick walls finished with painted cream and orange.	1 glass wall with opening/door (h: 3.00 m), 2 plastered brick walls (h: 0.75 m) with a clear glass window above it (h: 2.25 m) face to face, 1 plastered brick wall (h: 3.00 m). All plastered brick walls finished with painted white.	3 tempered glass walls surrounded (h: 4.00 m), which 1 side used as an opening/ door consisting of 1 entrance and 1 exit; 1 plastered brick wall was on the other side and finished with painted white.
	Ceiling material	Gypsum panel finished with white paint.	Gypsum panel finished with white paint.	Gypsum panel finished with white paint.	Gypsum panel finished with white paint.	Gypsum panel finished with white paint.	Acoustic panel finished with grey colour 75% and black colour 25% (only public corridor).
	Floor material	Ceramic tile (90 × 90 cm), cream colour with a matte texture.	Ceramic tile (90 × 90 cm), cream colour with a matte texture.	Ceramic tile (90 × 90 cm), cream colour with a matte texture.	Terrazzo (30 × 30 cm), cream and maroon red colour combination and matte texture.	Ceramic tile (40 × 40 cm), cream colour with a glossy texture.	Ceramic tile (90 × 90 cm), cream colour with a glossy texture.
Furniture	Cubicle type	Cubicle with low partition (h: 1.10 m) for employees and division heads; materials using plywood with finishing HPL.	Cubicle with low partition (h: 1.10 m) for employees and division heads; materials using plywood with finishing HPL.	Cubicle with low partition (h: 1.10 m) for employees and division heads; materials using plywood with finishing HPL.	Cubicle with low partition (h: 1.10 m) for employees and cubicle with high partition (h: 1.70 m) for 3 division heads; materials using plywood with finishing HPL.	Cubicle with low partition (h: 1.10 m) for employees and division heads; material using plywood with finishing HPL.	Cubicle with no partition for employees and division heads; material using plywood with finishing HPL.

absorption quality is classified as lower than the other five workspaces.

1.3.2. Population and sample size

The sample for this research included 104 permanent employees from six administrative offices with an open system consisting of two personnel administration offices, two student administration offices, and two financial administration offices from two university campuses. The employees work full-time; 75–90% of them work in cubicle space with low partition and high partition (for some division heads). The employees have clear job descriptions and at least two years of working experience (indicating they have enough experience being exposed to noise). The respondent data were holistically obtained through observation, interviews, and documentation.

1.3.3. Pilot study and questionnaire design

As a first step in introducing the respondents' condition in the work environment of each office case, Gene acoustique dans les bureaux ouverts (GABO Questionnaire) 2013 was adapted and given to the respondents. The purpose of this survey is to learn respondents' opinions on their physical workplace and how it affects them [73]. This instrument is useful for complementing a sound environmental assessment in an open system workspace, considering the feelings and well-being of employees. The GABO Questionnaire is an open-ended questionnaire that allows employees to answer questions about their general views according to the four dimensions related to the general information and work station, noise environment of work area, relationship with noise in general, and self-assessment of health [73]. The respondents' self-assessment of each other's health and general noise served as a guide for the researchers to assess variants of soundscape perceptions in the work environment and to see whether each respondent was eligible to fill out the next questionnaire.

Respondent data collection (pilot study and main study) was carried out under special conditions during the COVID-19 pandemic in 2021–2022 when some employees worked at home while others worked in the office in shifts according to the institution's schedule so that the number of attendees in the office is not optimal. For this reason, an essay was prepared to help the respondents verbally recall an experience in the past (memory recall) by answering several questions in writing. This technique allowed the respondents to organize their answers according to their thoughts and memories regarding noise in the work environment when they were still working as a full team before the pandemic. Using the essay technique followed by interviews, they can re-explain the spatial experience, soundscape perception and work behaviour during normal conditions so that this does not affect the generalization of the research.

Furthermore, an indoor soundscape closed questionnaire was specially designed for the needs of an open-plan office. Closed questionnaires were considered suitable to accelerate the demand for quantitative data in assessing interactive effects among contextual factors. This questionnaire was prepared to collect more complete and detailed data related to the contextual experience of users in open system workspaces. This closed questionnaire consists of six parts and uses a five-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree). The scale was chosen because it made it easier for the respondents to express their opinions (refer to Table 1). A literature review and preliminary interviews were conducted to validate and refine the list of closed questionnaires identified.

The views of the pilot participants in each office case were used to assess the questionnaire list and look for information on whether the proposed Likert scale questionnaire was appropriate for further use in research, whether the questions covered all possibilities related to contextual factors, whether there were factors that can be added or removed from the questionnaire. Several aspects were deleted or combined, until finally 48 questionnaires were formed which were adapted and rearranged regarding the factors to be tested for a complete and detailed *in situ* questionnaire survey. Before distributing the questionnaire sheets, several trials were conducted to determine the time required to complete the questionnaire and ensure that the instructions and questions were clearly understood by the respondents.

1.3.4. Data collection

After briefly being introduced to the research objectives, the respondents were asked to complete the GABO Questionnaire to identify the initial physical and mental conditions in their work environment. Next, they were required to respond to questions in an essay to verify their decisions and ensure that their responses were consistent with an *in situ* narrative interview. In the next meeting, the respondents were given an indoor soundscape questionnaire that was specially designed for the needs of an open-plan office (refer to Table 1). The results of face-to-face contact from 104 surveys showed that 96 valid questionnaires were completely completed (response rate: 92.31%). Each answer was checked and matched by conducting an *in situ* narrative interview. This process started with general narrative questions that provoked the respondents to relate their experiences of working as a full team before the pandemic. Data in the form of stories of the respondents' experiences were obtained and examined to obtain detailed research results.

1.3.5. Data analysis using the PLS-SEM technique

The partial least squares structural equation modelling (PLS-SEM) technique was chosen as the data analysis method for this study. The PLS-SEM is one of several techniques designed to develop theories and analyse causal models involving multiple constructs with multiple measures [74–76]. Therefore, PLS-SEM is suitable for assessing interactive effects and constructing predictive models among contextual factors.

The PLS-SEM is suitable for testing hypotheses with a limited sample size of nonnormally distributed data [77,78]. The PLS-SEM is a more suitable tool for evaluating more intricate models that contain several observable latent variables as well as reflective and formative constructs [78]. The fundamental prerequisites for statistical analysis must be satisfied by a sufficient sample. The data must have a minimum sample size of 30 and satisfy the conditions of the limit theorem. The sample size for this study is valid since it meets the limit theorem and is appropriate for PLS-SEM statistical analysis, as evidenced by the fact that 96 of 104 respondents successfully completed the questionnaire.

In using PLS-SEM, the first thing to do is to build a relationship model between constructs (i.e. categories of space usage, personal and demographical, psychological, expectation, perception, and work behaviour) and their indicators. All constructs are measured reflectively against their indicators and are followed by model testing through reliability and validity tests. The model reliability test used Cronbach's alpha, composite reliability, and rho-alpha, while the model validity test used convergent validity (through factor loading and average variance extracted) and discriminant validity (through Fornell & Lacker criteria, cross-loading and heterotrait-monotrait correlation ratio). Model testing is continued with structural testing that establishes potential relationships among contextual factors. Structural testing is examined for multicollinearity using the variance inflation factor. Furthermore, the significance test of the relationship (i.e. hypotheses 1–8) was performed using bootstrapping analysis. Bootstrapping analysis was used to test the significance of all the path coefficients [78]. All hypotheses of the data that were not normally distributed could be measured using the bootstrapping analysis (refer to Fig. 3). The t values are the coefficients of bootstrapping analysis used to assess the path significance. Paths with t values of 1.65 (level of significance = 10%), 1.96 (level of significance = 5%), and 2.58 (level of significance = 1%) were considered significant for the two-tailed test [78]. In addition to conducting a test of significance, structural testing was further evaluated by estimating the effect sizes of contextual factors. The effect sizes of several categories of contextual factors were further estimated. The effect size (f^2) assessment is used to evaluate the substantive impact size of the exogenous construct on the endogenous construct [78]. The effect sizes were calculated by assessing changes in R^2 to determine the likelihood of interactive effects among contextual factors. The result of the change in R^2 was used to calculate f^2 using Equation (1) as used in Ref. [78].

$$f^2 = (R^2\text{included} - R^2\text{excluded}) / (1 - R^2\text{included}) \quad (1)$$

where R^2included and R^2excluded are the R values of the endogenous constructs when the selected exogenous construct is included or excluded from the model, respectively [78]. The last step is using IPMA to measure the importance and performance of constructs on the target construct (i.e. work behaviour) as used in Ref. [79].

2. Results

2.1. Respondents' profile

The Statistical Package for Social Science (SPSS) was used to perform the descriptive analysis of the respondent profiles. According to the findings, 29.2% of the respondents worked in personnel administration, 26.0% in student administration, and 44.8% in financial administration. In terms of job titles, most of the employees worked in administration (75%), and the rest served as heads of divisions and deputy heads of administration (25%). The dominant age range was 36–65 years (84.4%), and the rest were 18–35 years (15.6%). According to gender, the majority consisted of female employees (56%), and the rest were male (44%). In terms of education level, the majority of employees were undergraduate graduates (65.6%) and master graduates (12.5%). The rest were Diploma 3 and high school graduates (21.9%). According to seniority in the department (the length of time an employee has worked in the department), most had been working for >5 years (84.4%), and the rest had worked for 1–5 years (15.6%). Meanwhile, in terms of seniority at work (the length of time an employee has worked in a division within a department), most had been working for >5 years (75%), and the rest had worked for 1–5 years (25%). Regarding work experience (the length of time an employee has worked at the institution), they had been working for 16–25 years (34.4%), 26–35 years (25%), >36 years (6.3%), <5 years (12.5%), and 6–15 years (21.9%). The work experience profiles of the respondents provide the needed data to assess the interactive effects between contextual factors and evaluate their impact on daily comfort and performance.

2.2. Descriptive statistics and validity analysis

First, the data validity was evaluated using Cronbach's alpha (CA) from the closed questionnaire and SPSS data analysis. A CA threshold >0.700 is recommended for data validity [78]. The overall CA assessment results indicated sufficient data validity (refer to Table 3). The standard deviation and mean were calculated for each indicator. The mean scores of the indicators underlying the constructs are used to rank them. If two indicators had the same average value, their standard deviation determined their ranking. The indicator with the lower standard deviation was ranked higher in this case. The mean scores and standard deviations of the indicators are shown in Table 3. 'The proportion of working time in the office is spent mostly (90%) in your workspace' is the top-ranking criterion of the space usage construct. 'Generally, it is accurate that you are friendly' is the top-ranking criterion for the personal and demographical construct (individual characteristic). 'Generally, you can tolerate the noise conditions in the workspace or cubicle' is the top-ranking criterion for the personal and demographical construct (social-cultural characteristic). 'You can still focus (concentration) even though there are distractions caused by your colleagues' activities in the work environment' is the top-ranking criterion of the psychological construct. 'The expected workspace condition meets your expectations.' is the top-ranking criterion of the expectation construct. 'Overall, in your opinion, you feel comfortable with the acoustic environment in your workspace or cubicle' is the top-ranking criterion of the soundscape

Table 3
Descriptive statistics.

Code & Construct/categories		Mean Score	Standard Deviation	Rank	Overall Cronbach'sAlpha
Space Usage (SU):					0.779
SU1	You prefer to use the workspace provided by the institution to do individual or collaborative work with colleagues.	4.11	.844	4	
SU2	You prefer to use the workspace provided by the institution because of the healthy work environment.	4.23	.827	2	
SU3	You prefer to use the workspace provided by the institution because the physical environment is comfortable (light, air circulation, sound, thermal, humidity).	4.18	.821	3	
SU4	You prefer to use the workspace provided by the institution because you can control the physical environmental conditions (light, air circulation, sound, thermal, humidity) to make you feel comfortable.	4.11	.928	5	
SU5	You frequently use the provided cubicle to do individual work as well as collaborative work (working in groups, talking on the phone, interacting with colleagues).	3.91	.941	8	
SU6	You frequently use the provided cubicle because the position of your cubicle is comfortable.	3.82	.894	9	
SU7	You frequently use the provided cubicle because the equipment in your cubicle is complete.	4.07	.729	6	
SU8	The proportion of working time in the office is spent mostly (90%) in your workspace.	4.26	.785	1	
SU9	The proportion of working time in the office is spent mostly (90%) in your cubicle.	3.99	.775	7	
Personal and Demographical:					0.920
Individual Characteristics (IC)					
IC1	Generally, is it accurate that you are shy.	2.57	1.140	8	
IC2	Generally, is it accurate that you are quiet.	2.52	1.114	9	

(continued on next page)

Table 3 (*continued*)

Code & Construct/categories		Mean Score	Standard Deviation	Rank	Overall Cronbach'sAlpha
IC3	Generally, is it accurate that you are friendly.	4.24	.407	1	
IC4	Generally, is it accurate that you are talkative.	3.11	.916	7	
IC5	You are sensitive to noise.	3.13	1.181	6	
IC6	You are still energetic after a long day at the office.	4.09	.712	5	
IC7	You can still concentrate after a long day at the office.	4.12	.677	4	
IC8	Overall, your physical health condition is still good, even though there is noise disturbance in the office.	4.20	.482	2	
IC9	Overall, your psychological health condition is still good, even though there is noise disturbance in the office.	4.17	.523	3	
Social-Cultural Characteristics (SC)					
SC1	Generally, you can tolerate the noise conditions in the workspace or cubicle.	4.41	.537	1	
SC2	Generally, you can tolerate the noisy behaviour of colleagues in the workspace or cubicle.	4.12	.579	4	
SC3	Generally, you are familiar with the noisy condition in the working environment.	4.38	.549	2	
SC4	Generally, you are familiar with the noisy behaviour of colleagues in the working environment.	4.27	.588	3	
Psychological (PS):					0.885
PS1	You feel comfortable when colleagues talk clearly near your cubicle.	2.61	1.137	12	
PS2	You find it easy to work in a noisy workspace all the time.	3.25	1.173	9	
PS3	You can still focus (concentration) despite noise interference from equipment in the work environment.	4.27	.823	5	
PS4	You can still focus (concentration) even though there are distraction caused by your colleagues activities in the work environment.	4.36	.571	1	
PS5	You often feel enthusiastic in your acoustic environment.	2.64	1.249	11	
PS6	You often feel energetic in your acoustic environment.	2.71	1.313	10	
PS7	You feel comfortable about the noise conditions in the workspace.	3.31	.777	8	
PS8	You feel comfortable about the working conditions in the workspace.	4.26	.668	6	
PS9	You feel comfortable about the noise control in the workspace.	4.09	.656	7	
PS10	You feel comfortable with the behaviour of your colleagues in the workspace.	4.34	.583	2	
PS11	You feel comfortable with the activities of your colleagues in the workspace.	4.33	.511	3	
PS12	You feel comfortable about the voice information obtained in the workspace (phone calls, colleague conversations, or announcements).	4.29	.724	4	
Expectation:					0.895
PS13	The expected sound in the workspace meets your expectations.	3.74	.976	6	
PS14	The expected workspace condition meets your expectations.	4.02	.858	1	
PS15	The expected noise control in the workspace meets your expectations.	3.91	.816	4	
PS16	The expected colleague behaviour in the workspace meets your expectations.	4.00	.846	3	
PS17	The expected colleague activity in the workspace meets your expectations.	4.00	.834	2	
PS18	The expected voice information in the workspace (phone calls, colleague conversations, or announcements) meets your expectations.	3.89	.825	5	
Perception:					1.000
PS19	Overall, in your opinion, you feel comfortable with the acoustic environment in your	4.06	.625	1	

(*continued on next page*)

Table 3 (*continued*)

Code & Construct/categories		Mean Score	Standard Deviation	Rank	Overall Cronbach'sAlpha
	workspace or cubicle.				
Work Behaviour (WB):					0.879
WB1	You feel undisturbed by the noise in the working environment.	4.20	.706	3	
WB2	You don't have to anticipate distraction in the work environment.	3.46	.965	6	
WB3	You aren't tired (physically) due to noise disturbance at the end of the working day.	4.14	.807	5	
WB4	You aren't stressed (psychologically) due to noise disturbance at the end of the working day.	4.16	.881	4	
WB5	You prefer a 'peaceful' or 'tranquil' working environment.	3.04	.930	7	
WB6	You prefer a 'lively' or 'exciting' working environment.	4.54	.714	1	
WB7	Overall, in your opinion, the noise problem does not interfere with your daily work activities.	4.38	.749	2	

perception construct. 'You prefer a 'lively' or 'exciting' working environment' is the top-ranking criterion of the work behaviour construct and the aspect with the highest mean score in categories.

2.3. PLS-SEM results: Estimation of the measurement model

PLS-SEM analysis was carried out using SmartPLS version 3.2.8 to evaluate the interactive effects of the contextual factors and their effect on work behaviour. Good convergent validity properties are indicated by the high value of the loading factor. Hair et al. [80] suggested that the loading factor value should be 0.5. According to Chin [81], a loading value of 0.50–0.60 is considered sufficient for research in the early stages of developing a measurement scale. This study uses a loading value scale >0.60 to ensure that the size of the reflection is high. To determine the measurement model, factor loadings of indicators that are less than 0.60 are removed from the analysis. The factor loadings ranged from 0.60 to 0.95, meaning that all items were good measures of their respective factors [81]. The results of a valid and reliable measurement model are shown in Table 4.

Hair et al. [80] state that an average variance extracted (AVE) value of 0.5 indicates adequate convergence. The latent variables capture at least half of the measurement variance. All the factor loadings and AVE are >0.50, which indicates valid data (refer to Table 3). The composite reliability (CR) measure is a determinant indicator that indicates whether the convergent validity is good or not. Hair et al. [80] state that CR 0.70 includes good reliability. The CR and Rho_A values are higher than the required 0.70 (refer to Table 3). This result implies that the measurement model is reliable [79,80]. The interpretation of the CR and CA scores is similar, with [79,81] suggesting above 0.700 as a benchmark.

Table 4
Results of the measurement model.

Construct/category	Code	Loading[a]	AVE[b]	CR[c]	Rho_A[c]	CA[d]
Space Usage	SU5	0.789	0.697	0.873	0.800	0.779
	SU6	0.726				
	SU7	0.781				
Personal & Demographical	IC8	0.785	0.716	0.938	0.924	0.920
	IC9	0.809				
	SC1	0.918				
	SC2	0.857				
	SC3	0.871				
	SC4	0.830				
Psychological	PS3	0.647	0.556	0.909	0.886	0.885
	PS4	0.677				
	PS7	0.779				
	PS8	0.795				
	PS9	0.834				
	PS10	0.752				
	PS11	0.752				
	PS12	0.712				
Expectation	PS13	0.846	0.706	0.923	0.905	0.895
	PS14	0.865				
	PS16	0.750				
	PS17	0.901				
	PS18	0.831				
Soundscape Perception	PS19	1.000	1.000	1.000	1.000	1.000
Work Behaviour	WB3	0.933	0.891	0.943	0.904	0.879
	WB4	0.955				

Items removed: indicators' factor loadings <0.6: SU1; SU2; SU3; SU4; SU8; SU9; IC1; IC2; IC3; IC4; IC5; IC6; IC7; PS1; PS2; PS5; PS6; PS15; WB1; WB2; WB5; WB6; WB7.

[a] All item loadings ≥0.6 show indicator reliability.

[b] All average variance extracted (AVE) > 0.5 suggest convergent reliability.

[c] All composite reliability (CR) and Rho alpha (Rho_A) ≥ 0.7 imply internal consistency.

[d] All Cronbach's alpha (CA) > 0.7 indicate reliability.

2.4. Assessment of discriminant validity

The measurement model was evaluated using variable cross-loading, the Fornell–Larcker criterion [82], and the heterotrait-monotrait correlation ratio (HTMT) [78]. In terms of cross-loading, all contextual factor indicators had the highest loadings in the constructs they were hypothesized to measure [83] (refer to Table 5, values in bold). According to the Fornell–Larcker criterion, each construct should have the highest correlation with itself [82,84] (refer to Table 6, values in bold). The new HTMT criterion [85,86] to achieve discriminant validity requires the HTMT score to be between the confidence interval values −1 and 1. All HTMT correlations (refer to Table 7) confirm the results of the measurement model's adequacy in terms of discriminant validity.

2.5. PLS-SEM results: Estimation of the structural model

The results of the reliability and validity test of the measurement model have met the requirements so that the data can be used for the development of a structural model. Path analysis is used to calculate the structural models, which assess the impact of the constructs among themselves. A structural model was developed to assess the interactive effects between categories and their impact on work behaviour. Fig. 2 depicts the structural model's results of the contextual factors.

2.6. Assessment of the structural model

The significance of the hypothesis was determined using a structural model assessment. First, the variance inflation factor (VIF) was used to test multicollinearity in the structural model. The small values of VIF corresponding to the variables suggest no collinearity problem [87]. The multicollinearity test results indicate that minimum results are obtained because all VIF estimation values are <5.00, which means there is no

Table 5
Variable cross loadings.

Variable	Space Usage	Personal and Demographical	Psychological	Expectation	Soundscape Perception	Work Behaviour
SU5	**0.789**	0.271	0.398	0.216	0.094	0.078
SU6	**0.826**	0.372	0.482	0.355	0.251	0.251
SU7	**0.781**	0.276	0.365	0.449	0.327	0.210
IC8	0.223	**0.785**	0.532	0.233	0.428	0.453
IC9	0.343	**0.809**	0.700	0.185	0.454	0.479
SC1	0.340	**0.918**	0.608	0.117	0.266	0.396
SC2	0.383	**0.857**	0.632	0.089	0.199	0.322
SC3	0.308	**0.871**	0.630	0.092	0.270	0.460
SC4	0.262	**0.830**	0.571	0.170	0.180	0.343
PS03	0.377	0.547	**0.647**	0.079	0.339	0.290
PS04	0.330	0.577	**0.677**	0.172	0.405	0.287
PS07	0.349	0.579	**0.779**	0.080	0.257	0.268
PS08	0.494	0.512	**0.795**	0.260	0.345	0.289
PS09	0.418	0.611	**0.834**	0.163	0.358	0.359
PS10	0.393	0.508	**0.752**	0.342	0.265	0.178
PS11	0.302	0.544	**0.752**	0.340	0.310	0.196
PS12	0.307	0.472	**0.712**	0.407	0.588	0.413
PS13	0.235	0.086	0.239	**0.846**	0.392	0.195
PS14	0.424	0.160	0.239	**0.865**	0.468	0.261
PS16	0.448	0.274	0.387	**0.750**	0.161	0.096
PS17	0.357	0.118	0.227	**0.901**	0.314	0.121
PS18	0.278	0.096	0.242	**0.831**	0.472	0.151
PS19	0.278	0.356	0.480	0.444	**1.000**	0.473
WB3	0.272	0.433	0.398	0.157	0.399	**0.933**
WB4	0.164	0.479	0.330	0.220	0.486	**0.955**

*Each indicator with a bold value had the highest loading on its respective construct.

Table 6
Fornell–Larcker criterion test.

Constructs/categories	Expectation	Soundscape Perception	Personal & Demographical	Psychological	Space Usage	Work Behaviour
Expectation	**0.840**					
Soundscape Perception	0.444	**1.000**				
Personal & Demographical	0.172	0.356	**0.846**			
Psychological	0.313	0.480	0.729	**0.744**		
Space Usage	0.415	0.278	0.371	0.499	**0.801**	
Work Behaviour	0.202	0.473	0.484	0.382	0.225	**0.944**

Table 7
Heterotrait-monotrait correlation ratio (HTMT).

Constructs/categories	Expectation	Soundscape Perception	Personal & Demographical	Psychological	Space Usage	Work Behaviour
Expectation						
Soundscape Perception	0.455					
Personal & Demographical	0.209	0.369				
Psychological	0.362	0.512	0.805			
Space Usage	0.492	0.305	0.429	0.600		
Work Behaviour	0.218	0.499	0.535	0.439	0.286	

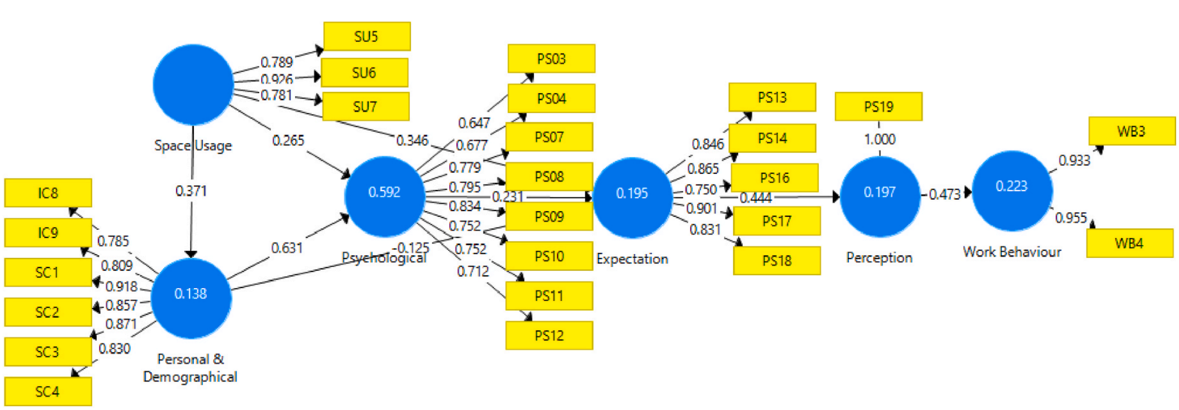


Fig. 2. Structural model of the contextual factor with path coefficient values.

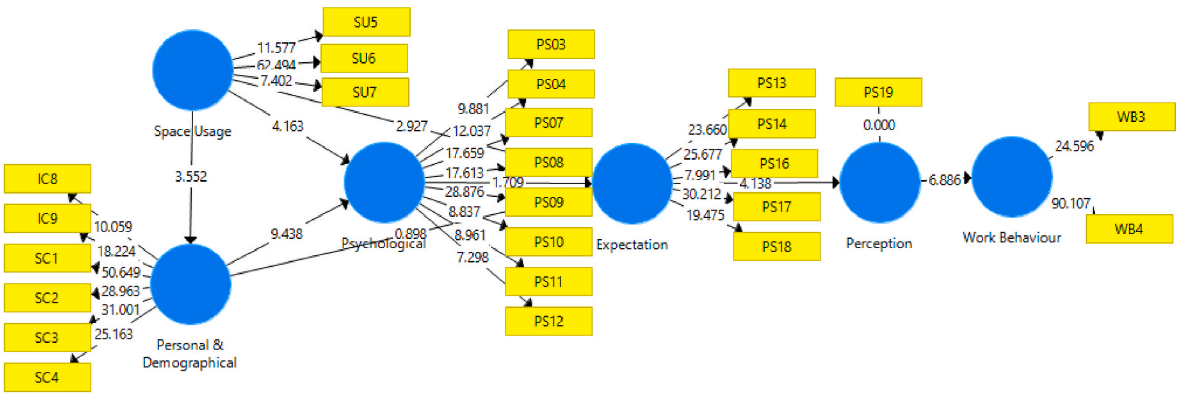


Fig. 3. A bootstrapping analysis result of the structural model for contextual factors.

multicollinearity problem [88,89]. Furthermore, the coefficient of determination (R^2) was used to assess the structural model, which aimed to evaluate the total effect size and variance described in the work behaviour construct through the five categories. The R^2 of the work behaviour construct is 0.523, as recommended by Ref. [90]. This ensures the statistical and practical significance of the variance explained by the endogenous variable.

2.7. Validation of the hypotheses

The interactive effect t values of 3.552 for the path of 'space usage' to 'personal and demographical', 4.163 for the path of 'space usage' to 'psychological', 2.927 for the path of 'space usage' to 'expectation', 9.438 for the path of 'personal and demographical' to 'psychological', 4.138 for the path of 'expectation' to 'soundscape perception', and 6.886 for the path of 'soundscape perception' to 'work behaviour' was supported at the level of significance $p < .01$ ($t_{0.01} > 2.58$). In addition, the interactive effect t value of 1.709 for the 'psychological' to 'expectation' path was supported at the level of significance $p < .10$ ($t_{0.1} > 1.65$). However, no level of significance supports the t value of 0.898 for the 'personal and demographic to expectation' path (refer to Fig. 3).

2.8. Effect sizes estimation of the structural model

Changes in the value of R^2 were estimated by performing the PLS path analysis twice: first, with an independent construct included that resulted in R^2included; and second, with an independent construct excluded that resulted in R^2excluded. A construct's effect size is categorized as small effect if $0.02 \leq f^2 < 0.15$, medium effect if $0.15 \leq f^2 < 0.35$, and large effect if $f^2 \geq 0.35$ [78,91]. Table 8 shows the estimated values of f^2 for several paths. The effect sizes of the 'space usage' path on the 'psychological' ($f^2 = 0.149$) and the 'space usage' path on the 'expectation' ($f^2 = 0.112$) were considered small effects. Meanwhile, the 'space usage' path on 'personal and demographical' ($f^2 = 0.160$), the 'psychological' path on 'expectation' ($f^2 = 0.227$), the 'expectation' path' on 'soundscape perception' ($f^2 = 0.245$), and the 'soundscape perception' path on 'work behaviour' ($f^2 = 0.287$) indicated medium effect sizes. The effect size of the 'personal and demographical' path on the 'psychological' ($f^2 = 0.842$) was considered large. However, the 'personal and demographical' path on 'expectation' can be ignored, as the value of $f^2 = 0.009$ is below the range of small effect ratings.

2.9. Importance–performance map analysis (IPMA)

The importance and performance of the five categories to the target construct (work behaviour) can be measured using importance–performance map analysis (IPMA). Fig. 4 shows the total effects describing the standardized path coefficients (importance or strength) of the five constructs presented on the x-axis, while the average values of the performance of the five constructs on the work behaviour construct are presented on the y-axis. The performance values are between 0 and 100 [92]. The construct that has the highest total effect is the target for decision-making using the IPMA results. The results show that soundscape perception has the highest total effect (0.473), with a performance of 71.615%. This means that soundscape perception has a substantive impact on work behaviour in the local environment and therefore deserves more attention from policy-makers and practitioners. The IPMA results show another important category where expectation has an effect size of 0.210, with a performance of 70.925%. Soundscape perception is identified as the effect that comes from expectation (refer to Fig. 3), which means that the result of IPMA implies an expectation-perception-reaction relationship. The majority of employees' responses to noise sources in the work environment do not interfere with their routine performance because the sounds are considered typical in office activities (positive expectations lead to positive perception and result in nonreaction).

Table 8
Path coefficient and hypothesis testing.

Hypothesized Path		Standardized Beta	t values	f^2 values	p values	Decision
H1	Space Usage - > Personal and Demographical	0.371	3.552***	0.160	0.000	Supported
H2	Space Usage - > Psychological	0.265	4.163***	0.149	0.000	Supported
H3	Space Usage - > Expectation	0.346	2.927***	0.112	0.004	Supported
H4	Personal & Demographical - > Psychological	0.631	9.438***	0.842	0.000	Supported
H5	Personal & Demographical - > Expectation	−0.125	0.898	0.009	0.370	Not Supported
H6	Psychological - > Expectation	0.431	1.709*	0.227	0.000	Supported
H7	Expectation - > Soundscape Perception	0.444	4.138***	0.245	0.000	Supported
H8	Soundscape Perception - > Work behaviour	0.473	6.886***	0.287	0.000	Supported

According to R^2 of work behaviour = 0.523.
According to t values ***$p < .01$, **$p < .05$, *$p < .10$.
According to f^2values, effect sizes are 0.35 (large), 0.15 (medium), and 0.02 (small).

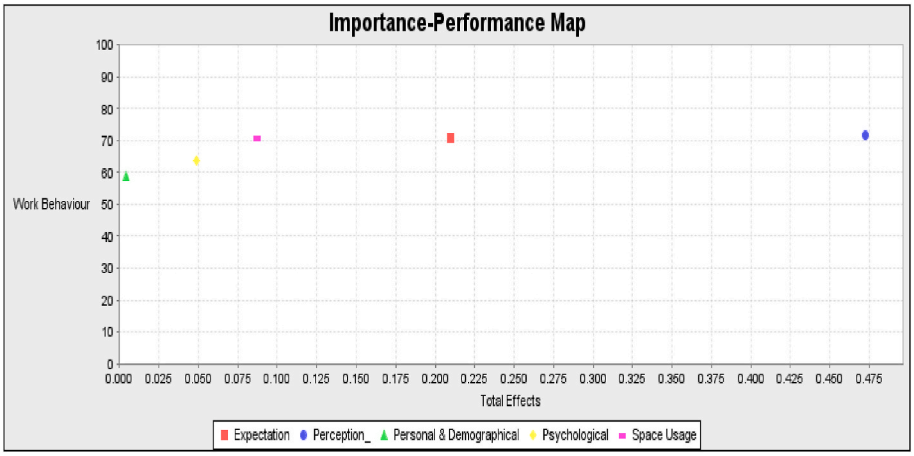


Fig. 4. An importance–performance analysis for contextual factors.

3. Discussion

3.1. Path of 'space usage' to 'personal and demographical'

All previous research has demonstrated the significance of usage frequency in investigations of indoor soundscapes [50]. In the context of this study, the usage frequency aspect related to case conditions was developed further than in previous studies [50,55,56,93]. Usage frequency is assessed not only in terms of time but also in terms of often or not often employees use the cubicle provided by the institution (SU5-7). The majority of the employees of the six office cases often use cubicles (75–90%). The activity frequency of using a cubicle type with a high/-low partition provided by the institution has proven to have a significant effect on the physical (IC8) and psychological (IC9) health conditions of employees. For example, employees with higher positions such as head of the division, whose jobs are more complex and require high concentration, often complain that noise disturbances and noisy activities and behaviour of friendly colleagues (IC3) around them affect their physical and psychological condition. This is especially true if they are given a cubicle type with a low partition (1100 mm in height) and are placed in the same room as other employees. Consequently, they become unhappy and demand a more private cubicle.

This finding indicates that one's satisfaction with space usage, in an operational sense, is closely linked with the subject's satisfaction level with the physical environment arrangement, as well as occupational health and safety [70,71]. For this reason, designers and practitioners need to consider the size of the work demands, health, and employee well-being. This is especially true for employees with higher positions, whose work is more complex and requires high concentration, by providing visual and acoustic protection as recommended by Refs. [94,95].

3.2. Path of 'space usage' to 'psychological'

Physiologically (visual and audial), employees who often conduct their activities in the cubicle and perform daily routine administrative work are not disturbed by the noisy conditions around the cubicle. As seen in Table 1, employees can still concentrate even though there is noise disturbance (PS3) and distraction coming from their colleagues' activities around the workspace (PS4) (highest score). Psychologically, employees feel comfortable with routine noise conditions in the work environment and are not disturbed by the noisy activities and behaviour of colleagues in the work area (PS7-12). Both 'you feel comfortable with the behaviour of colleagues in the workspace' (PS10) and 'you feel comfortable with the activities of colleagues in the workspace' (PS11) indicate high scores (refer to Table 1). The noise coming from office equipment and the 'hustle and bustle' of colleagues is, in fact, considered mandatory by employees in creating a 'lively' and 'exciting' office atmosphere. Preferences about space likes/dislikes, usage frequency, and time spent by users in the workspace are important factors in the assessment of indoor soundscapes because they can affect the psychological condition and user experience, such as studies [9,50,56].

Generally, the effect of an open workspace is inversely related to employee satisfaction. The relationship is strongly influenced by acoustic disturbance and perceived privacy, as stated in the study [96]. However, this finding shows that although the need for privacy to some extent is very strong, in general, most employees prefer to work with colleagues around them rather than being completely alone, as in Ref. [97]. Employees do not want a 'peaceful' and 'tranquil' atmosphere like in a meeting room because it can cause drowsiness. Some employees can even follow a colleague's conversation and jump in while still working in a cubicle, as discovered through this study. This shows that people's soundscape preferences can be different in different places (context-based) and for different activities, such as studies [60]. Employees of both campuses tend to pay more attention to the needs and comfort of architectural aspects (66%), such as cubicle quality, cubicle position, completeness of equipment inside the cubicle, and physical environmental conditions, compared to acoustic quality (34%). For this reason, both institutions are advised to always involve employees in layout and furniture design (participatory design), as recommended [95], when planning a renovation in the future.

3.3. Path of 'space usage' to 'expectation'

Expectations are related not only to sound sources but also to place, control, behaviour, activity, and sound information that the user expects to be in the room [49]. Both employees who often conduct their activities in their cubicles and are faced with deadlines and employees with higher positions such as division heads who usually have more complex jobs and require higher concentration expect better acoustic quality (PS13) (e.g., no noise interference from certain people, low volume, voice audibility when receiving a call, noise protection from other rooms or divisions, noise control, and no interference from the activities and behaviour of colleagues around the cubicle) and workspace or cubicle conditions (PS14). If this condition is not met, they tend to look for a quieter space to complete their work, such as in a meeting room, or work late to get a quieter workspace atmosphere. This is especially true for the head of division who is given the cubicle type with a low partition like general employees. Furthermore, the head of the financial administration division demands an isolated space to distance him/herself from the behaviour and activities of colleagues (PS16-17) and better speech privacy (PS18) than other divisions. As a result, they expect the institutions to provide cubicles with high partitions.

This finding shows that minimal noise interference from various sources becomes more important when the usage frequency of cubicle is more frequent and the time spent in the workspace is longer [56], especially for employees with higher positions. The level of privacy required of employees may vary across job types and levels, as Ref. [98] suggested. Employees with higher positions, whose jobs are more complex and require high concentration, expect a physical environment with good acoustic quality and better conversation privacy. Therefore, conversation privacy is strongly related to job satisfaction, as described in the study [96]. For this reason, open workspaces that use the cubicle type with high partitions are suitable for employees at the level of head of the division, especially in the financial administration division, because they require a higher level of visual and audial privacy (speech privacy) than administrative employees from other divisions, as in this study.

3.4. Path of 'personal and demographical' to 'psychological'

The results of this study show that employees with daily routine work are not disturbed by the noisy conditions around the cubicle. They are used to office noise and are able to tolerate the noisy activities and behaviour of friendly colleagues (IC3 has the highest score). They still have good physical (IC8) and psychological (IC9) health after a long day at the office despite being exposed to noise in the workspace. This finding shows that the social-cultural characteristics, especially aspects of societal value (SC1-2) and lifestyle (SC3-4) of the Indonesian people (represented by the city of Surabaya, Indonesia), which are believed to be mainly communal, play a large part in the process. Employees always see themselves as part of a group to express harmony, sympathy, and empathy for others [7]. These characteristics mean that the mindset, actions, and work behaviour of Western society can be vastly different from those of their Eastern counterparts, which are loaded with social interaction, complex relationships, high solidarity, togetherness, connectedness, cooperation, tolerance, close relations, and comfort around others. As a result, employees with daily routine work can still pay attention despite the office equipment noise or the audial and visual disturbances caused by colleagues around the cubicle (PS3-4). Assessment of past experience related to noise disturbance due to adjacent cubicle conditions, lack of noise control, and noisy activities and behaviour of colleagues (PS7-12) suggest that the factors do not hinder employees from carrying out their daily routines.

This conclusion is different from that in Western countries [23–25]. Several researchers [99–101] have investigated and tried to provide solutions to reduce noise due to disturbing acoustic conflicts in open workspaces by exercising adequate speech control [7]. Several solutions were carried out, such as extending the distance between the cubicles as part of the workspace layout design, using acoustic-dampening materials on ceilings and walls, installing partitions between cubicles, and implementing a noise masking system [22,96,99–101]. Findings based on a detailed examination of case studies strengthen Ref. [4,7,9,45,50], that the social-cultural characteristics and habits of individuals or groups need to be considered before studying soundscape perception in the local environment because they can affect the user's psychological condition. The assessment of societal values and lifestyle aspects as proposed in this study can be used to understand a specific group of users, situations, and the local environment as recommended [58,59].

3.5. Path of 'psychological' to 'expectation'

The results of this study show that employees do not experience difficulty concentrating on work, even though there is noise from office equipment (PS3) and activities and noisy behaviour of colleagues (PS4). This condition is shown through the results of the past experience assessment (PS7-12), where employees with daily routines feel comfortable doing activities in the cubicle, and their performance is unaffected. The expectation of a place consists mostly of the user's experience because people make decisions using background information taken from similar places [45]. Consequently, expectations of the sound sources in the office (PS13), workspace and cubicle conditions (PS14), behaviour (PS16) and activities of colleagues (PS17), and voice information (PS18) are mainly positive. Since the six dimensions meet the user's expectations, it is possible that the user's perception is not negative even though there are disturbing sounds [102] and that such a thing is considered a common occurrence in an open-plan office. Furthermore, expectations of workspace or cubicle conditions indicate the highest score. This implies that employees expect architectural conditions related to workspaces and cubicles to receive better attention from institutions. Acoustic matters such as sound sources in the workspace, ease of noise control, noisy behaviour and activities of colleagues, and sound information are expected to receive less attention from employees. This result appears to be different from previous studies [23–26], where open-plan offices, which are popularly adopted in Western countries, often show acoustic conflicts causing a significant decrease in employee satisfaction and performance outcomes.

This finding shows that social-cultural characteristics related to societal values and lifestyle also influence the psychological condition and expectations of users. The study [103] states that Indonesian people are used to being in a noisy urban soundscape. This condition causes the urban lifestyle to be carried over to indoor soundscapes. It can affect the psychological condition and expectations of employees in the local environment because expectations are largely formed from users' past experiences [45].

3.6. Path of 'expectation' to 'soundscape perception'

Expectations are related not only to sound sources, but also to place, control, behaviour, activities, and the information that users expect. When the six dimensions meet expectations (positive), the user's perception becomes positive, even when disturbing noises are present [49]. The results of this study suggest that the sounds around the office cases, which include people's working activities (e.g., keyboard tapping, opening/closing drawers), machine operations (e.g., ventilation, PCs, printers, calculating machines), and the sound of people passing by near the cubicle, do not interfere with the employees' work activities in the administrative offices. Employees claim that the sounds are common in any workspace and therefore are not considered a problem (positive expectation - > positive perception). Employees of both campuses with certain jobs that require higher concentration feel more disturbed by noise from the activities and behaviour of colleagues (84.16%) than noise from sounds present in the work environment (15.84%). Employees' expectations of sounds that commonly appear in an office based on contextual experience cause the soundscape perception to be positive. As a result, they are neither disturbed nor annoyed by it. This situation appears to be different from previous studies [30,34,35]. On the other hand, sources of noise in the form of telephone rings (unanswered calls), slammed doors, construction noise from the vicinity (intermittent noise), certain people's voices, and overheard conversations can be seen as annoying. This is especially true with counting jobs (cashier and financial administration) and data input (front desk and cashier) because it can interfere with cognitive work concentration (non-expectations - > negative perception). If an unexpected noise suddenly appears (nonexpectations), the soundscape perception becomes negative, resulting in negative reactions such as feelings of momentary annoyance or disturbance.

This finding shows that the evaluation of the expectations related to the sounds expected by users of workspaces and cubicles in an open-plan office is a fairly important initial assessment because it can affect employees' perception of the soundscape in the work environment [45]. Differences in position, type of work, need for concentration, and speech privacy also contribute to differences in the expectations and perceptions of employees' soundscapes in open workspaces.

3.7. Path of 'soundscape perception' to 'work behaviour'

The whole process begins with expectations, then perceptions, and ends with reactions such as behaviour-oriented actions [45,50]. The results of a person's preference for sound can be different if they are in different places or for different activities [60]. Employees' perception of noise does not interfere with their performance (PS19). As a result, the majority of employees (90.63%) with daily routines did not complain of physical fatigue (WB3) or psychological stress (WB4) due to noise caused by the activities and behaviour of colleagues in the workspace (positive expectations - > positive perception - > positive response) (refer to Fig. 4). In terms of soundscape preference, employees prefer a "lively" and "exiting" local environment (highest score, refer to Table 1) to a 'peaceful' and 'tranquil' environment, as discussed [60]. In their opinion, a quiet workspace can cause boredom and drowsiness. Additionally, employees cannot solve work problems alone; they need help, attention, and recognition from their colleagues. Even if they deem some distractions harmful, they can still tolerate the condition because it comes from their coworkers, whom they consider brothers and sisters. This means that to understand a person's reaction or response to noise, it is necessary to investigate their past experience and expectations, in addition to acoustic indicators and noise values.

This finding shows that noise in the work environment of the office case is believed not to influence the daily routines of employees. A noisy environment is even preferred by employees in general. Thus, it can be understood that the findings of previous studies [104] state that the cognitive performance of respondents decreases in a high-noise environment compared to a low-noise environment; respondents experience a greater increase in (psychic) stress from before to after-work sessions at high noise levels compared to low noise levels; and respondents' self-assessment of fatigue (physical) effect and decreased motivation when working in a high noise environment compared to a low noise environment are not proven in their daily routines in the open-plan office cases in Surabaya.

4. Conclusions and recommendations

This study evaluated the predictive model among contextual factors and assessed the interacting effects. A special open-plan office questionnaire for indoor soundscapes evaluation was administered to comprehensively investigate and reveal causal relationships among contextual factors in the local environment. The significance of the structural model of the contextual factor built and was proven through the PLS-SEM statistical approach. The study findings highlight that soundscape perception and work behaviour depend not only on the acoustic characteristics of a workplace, but also on the auditory perception, which is influenced by physiological, psychological and social-cultural characteristics (especially societal value and lifestyle aspects) in the local environment. The results of the assessment of soundscape perceptions and work behaviour in the office case were found to be significantly different from those in Western countries. This proves that cultural differences between the East (represented by the city of Surabaya) and the West play an important role in indoor soundscape evaluation. Therefore, it can be concluded that social-cultural characteristics, especially those related to societal values and lifestyle in the local environment, must be considered in future indoor soundscape assessments. Societal values and lifestyles should be the focus of policy-makers and practitioners. These two aspects are important factors and need to be included in the process of evaluating user experience, particularly in discussing the possibility of establishing standards, developing policies and guidelines regarding noise, and studying indoor soundscapes in the local environment in the future.

Currently, topics related to multi-cultural and cross-cultural studies are needed, given the lack of these topics research, especially in other cities with diverse cultures. The initiative can have a large impact on how policies are developed, especially in enhancing people's quality of life and well-being. Considering the outcomes of this study, to determine more about cultural differences as a factor that influences soundscape perception and obtain a strong conclusion, similar future research can consider the context of the workspace by integrating other cultural groups. Finally, to understand the extent of the influence of social-cultural characteristics on soundscape perception, further empirical studies and similar cross-cultural studies can be carried out in Asian cities within culturally diverse countries for comparison purposes.

CRediT authorship contribution statement

Hedy C. Indrani: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft. **Sri Nastiti N. Ekasiwi:** Writing – review & editing, Supervision, Funding acquisition. **Dhany Arifianto:** Software, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

The authors would like to acknowledge the support from the Directorate of Research, Technology, and Community Service, the Ministry of Education, Culture, Research and Technology Republic of Indonesia (Grant No. 3/E1/KP.PTNBH/2021 and Grant No. 008/E5/PG.02.00.PT/2022). The authors thank Drs. Jani Rahardjo, MBA, PhD, for his guidance in statistical analysis. The authors also gratefully acknowledge the Vibration and Acoustics Laboratory, Department of Engineering Physics, Institut Teknologi Sepuluh Nopember in Surabaya, for its collaboration in indoor acoustics analysis.

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