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The complexity of sound environment contributing to acoustic comfort in urban intermodal transit spaces

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ABSTRACT

The urban intermodal transit spaces have mixed spatial forms, linking different transport modes and surrounding urban spaces in this area such as castles, public squares, commercial area, residential area, historic area, lanes and roads. The inside mixed functions are representative and commonly found in urban transit spaces, such as platforms, waiting area, café, bars, restaurants, shops, money changing center, information board, chemist, toilet/shower, etc. Meanwhile, it has attracted a wide range of passengers and citizens, this indicates that the building is likely to have a complex acoustic environment. Previous studies have focused on reduce people's exposure to excessive sound levels from transportation, more research is needed on people's appeasement and psychophysical well-being. This study is able to explore the complexity of sound environment contributing to health and better quality of sounds perception in urban intermodal transit spaces. On-site measurements were performed at a case study site in Vienna, and an acoustic comfort survey was simultaneously conducted. It was observed that in the interior spaces increases the complexity of the sound sources type, the subjective loudness are increased, meanwhile the sound comfort level decreases. Regarding the effect of different zones on the sound environment and acoustic perception, people's influence on the acoustic environment and acoustic perception in different areas is subjectively, depends on the types of the sound sources.

Keywords: urban intermodal transit, acoustic comfort, sound environment, sound sources
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1.INTRODUCTION

Types of sounds have effects on acoustic comfort and sound enviornment in different sizes and types of spaces. Railway Stations have been traditionally associated with waiting and transit spaces. In the past, this was due to the fact that they used to host a relatively limited number of functions (e.g. comunicating, broadcast annoncement and walking) that did not include any particular sound source. Nowadays traveling function has shifted towards new means of transport. New religion become shopping and usage of all commercial services, offered in ever-expanding terminals. It seems that architecture of transportation is now balancing between commercial and cultural function which is called urban intermodal transit spcaces[1]. In urban intermodal transit spaces, the complex acoustic environment leads to various influence among users' comfort[2]. At the same time, the preference and loudness of differnet sound sources are also extremely important to users. Therefore, a thorough analysis of the function of sound sources on acoustic perception and evaluation of acoustic comfort is very important to architectural researches.

Current acoustic design tend to use acoustic meterails to absorb, diffuse and resonate sounds in spaces, by reaching a certain sound pressure level and reverberation time[3]. Bandyopadhyay et al. measured the SPLs in the platforms and found the SPLs endanger the healthful living of the users[4]. Liu et al. used acoustics testing and simulation to study the reverberation time and speech transmission index of public broadcasting system[5]. But reduction of 'sound level', does not always deliver the required improvements in quality of life [6]. In contrast, soundscape research involves human and social sciences and physical measurements for the diversity of sound environment. Moreover, it treats environmental sounds as a resource rather than a waste [7]. In recent years, soundscape was a wellestablished approach to increase the sound quality[8-9] and also a recognised key method to managing sound environments in urban spaces [10-11]. However, there are relatively few studies investigating the quality of acoustic environments of indoor public spaces through the soundscape approach which could make important contributions to design. The absence of considerations of human perceptions and human activities from the acoustic design strategy for the transit spaces makes it a good example through which to explore the difference between traditional approaches to acoustic design and a soundscape approach to design for acoustic comfort in urban intermodel transit spaces.

This study, therefore, explores the quality of the acoustic environment in a typical urban intermodal transit station in Vienna from a soundscape perspective and discusses design strategies for achieving acoustic comfort in multi-function, open-plan intermodel transit spaces. The overall comfort level and sound environment in different functional zones were studied using a questionnaire survey. First, overall sound environment and appropriateness were analyzed. Then, the effect of different types of sound sources on acoustic comfort were analyzed. This is followed by an examination of sonic compostion effect on sound enironment and aoucstic perception in different zones.

2.METHODS

2.1 Survey site

Taking a case study method [12], this study is able to explore the complexity of real life situations contributing to soundscapes and people's perceptions in a railway station. Vienna Main Station (Wien Hauptbahnhof) was selected as a typical case of urban intermodal transit spaces with mixed spatial forms, linking different transport modes and surrounding urban spaces in this area such as castles, public square, commercial area, residential area, historic area, lanes and roads. The mixed functions inside Prague Train Station are representative and commonly found in urban transit spaces, such as café, bars, restaurants, shops, money changing center, information board, chemist, toilet/shower, etc. Meanwhile, it has become a major urban development in its own right to include various office, retail and educational facilities. Vienna Main Station attract a wide range of passengers and citizens, this indicates that the building is likely to have a complex acoustic environment.

The Vienna Main Station has three floors, the grounded floor is the platform floor, which has 16 tracks and 15 platforms, including five roofed platforms and ten platform edges. A 20,000 m^2 shopping centre accommodated around 100 shops and restaurants is positioned below track level, and the underground car park has spaces up to 600 cars and 1,110 bicycles. To facilitate a high rate of pedestrian movement across the station, a total of 29 escalators and 14 elevators are present to provide full step-free access to all areas13. In total, 800 seats spread throughout the station. A special "Kids Corner" facility is for families with young passengers. As shown in Fig.1.

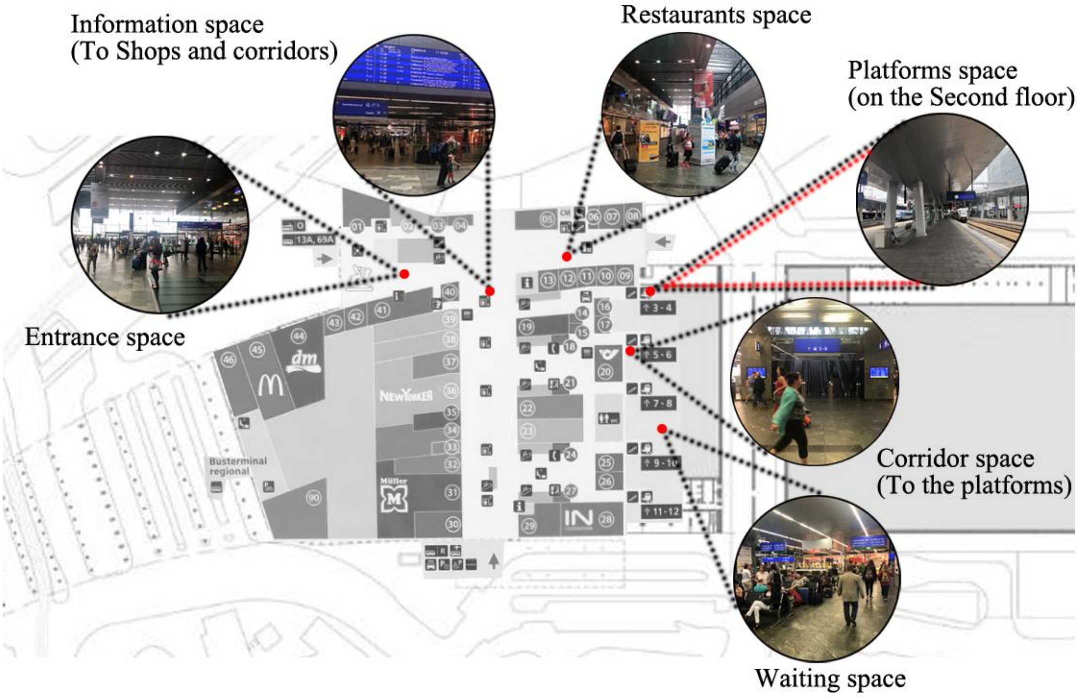

Fig. 1 Examples of the architectural characteristics of the Vienna Main Station.

2.2 Acoustic comfort survey

To study the influence of the complexity sound environment on acoustic comfort, some questionnaire survey was conducted at this case site. Every questionnaire survey was generally done by the interviewer in 3–5 min [14]. In terms of subjective investigation, 180 valid questionnaires were obtained at the survey site. To ensure the representativeness of the spaces, six typical spaces in the railway transport hub including the platform (PL), waiting space (WA), passageway (PW), entrance space (ET), restaurants space (RS) and information space (IF) were selected.The contents of the investigation concerned sound sources type, comfort evaluation and interviewees' social backgrounds[15] such as sex, age, education level, income, visit time and visit duation. The results obtained from the six spaces were typical and obviously diverse.

In terms of evaluation of acoustic comfort, a five-point scale[16] was used in the questionnaire design. The evaluation of acoustic comfort was divided into five levels: 1, very uncomfortable; 2, uncomfortable; 3, neither comfortable nor uncomfortable; 4, comfortable; and 5, very comfortable. After the survey, the results of the subjective evaluation were analyzed with the software SPSS 15.0.

3. Results

On the basis of the survey results, this section discusses the influence of sound sources on sound environment and acoustic comfort. The reliability coefficient of the questionnaire was estimated as 0.83 (Cronbach's alpha). The KMO values of the subscales were greater than 0.5, and for the Bartlett spherical test, $p < 0.01$, with a reliability coefficient $0.9>\alpha\geq0.8$, the questionnaire meet the reliability[17].

3.1 Overall comfort level and sound environment

Fig. 2 shows the subjective evaluations of the overall sound environment and acoustic comfort in six spaces. The sound environment and acoustic comfort of the in the transportation hub was acceptable with the mean values of 3.81 and 3.91). It can be seen that the evaluations of sound environment and acoustic comfort in PL and ET were relatively higher (mean values of 4.23/4.42 and 4.08/4.1, respectively), and the evaluation of comfort in WA and RS were slightly lower (mean value of 3.58/3.69 and 3.36/3.48, respectively). Pearson correlation analysis between the sound environment and acoustic comfort was conducted, and the correlation coefficient was 0.683 ($P < 0.01$). This reflected that there is significant positive correlation between sound environment and acoustic comfort. In other words, the evaluation on sound environment affected the evaluation on acoustic comfort.

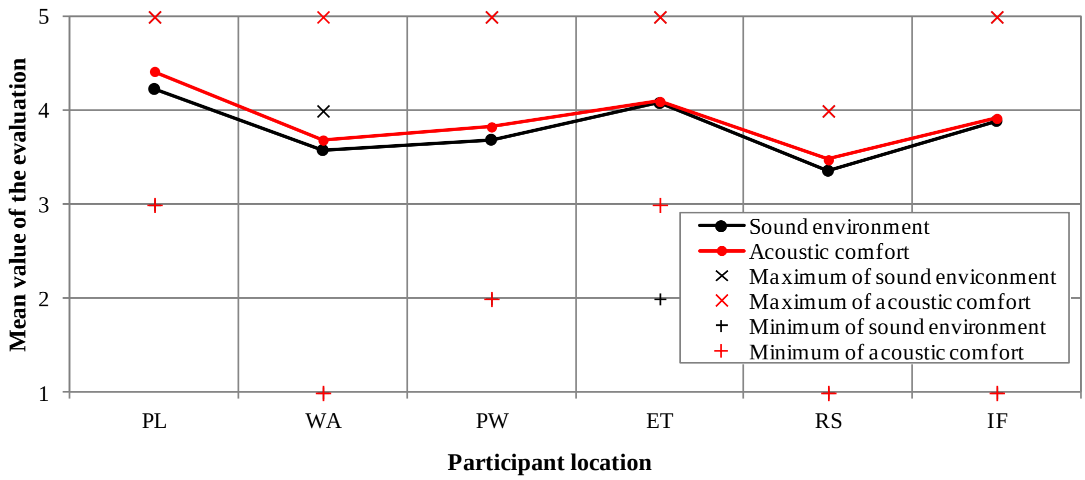

Fig. 2. Evaluations of the overall sound environment and acoustic comfort

There is no significant difference ($p < 0.1$) between males and females. But the age difference was significant ($p < 0.01$ or $p < 0.05$). Acoustic comfort was higher for older passengers. Education level and income difference were also significant factors ($p < 0.01$ or $p < 0.05$) for the passengers' acoustic comfort. Participants with high education level and income tend to gave positive evaluation. Differences in the frequency of visits caused a significant difference in the comfort evaluation of the sound environment in six spaces ($p < 0.05$); passengers who visited the station frequently (the mean value was 3.28) gave a more critical evaluation than passengers who did not (the mean value was 3.66). It was also found that the visit duration in a space had a significant negative correlation ($p < 0.01$) with acoustic comfort.

It is interesting to note that the evaluations on long staying spaces such as WA and RS were lower than other traffic spaces. Participants mainly reported “neither noisy nor quiet ”(31.2%) and “quiet” (36.7%), however, 19.3%

participants thought that the acoustic comfort was “noisy” and “very noisy”. On the evaluation of acoustic comfort, they mainly reported “neither comfortable nor uncomfortable”(29.4%) and “comfortable” (38.9%), however, 16.8% participants thought that the acoustic comfort was “uncomfortable” and “very uncomfortable”. The results shows that the noisy the environment, the uncomfortable the acoustic comfort. This was consistent with the result of Chen and Kang on acoustic comfort on dining spaces[18], as a key factor, the background noise was affected the acoustic comfort. Existing research indicated that the background noise in transport hub was an important objective index affecting passengers' acoustic comfort evaluation in the presence of composite sound sources[2]. Therefore, the following part focuses on studying the influence of sound sources in background noise on acoustic comfort evaluation.

3.2 Sonic composition

In order to identify various independent sound sources in background noise and determine the type of sound sources, participants were required to list five sound that they heard at that moment. Finally, various individual sound sources in six survey spaces are shown in Table 1.

Table 1. Type of sound sources in different survey spaces.

Type of sound sources		Survey space					
		PL	WA	PW	ET	RS	IF
Broadcast		●			●		●
Speech sound	Speech sound of companions	●	●	●	●	●	●
	Chatting sound of other passengers	●	●	●	●	●	●
	Speech sound of staff		●			●	●
	Shouting		●			●	●
	Phone call	●	●	●	●	●	●
	Crying	●	●	●		●	
Activity sound	Footsteps		●	●	●	●	●
	Dragging luggage	●	●	●	●	●	●
	Food preparation by staff					●	
Traffic noise	Train noise	●					
Mechanical noise	Air-conditioning		●	●			
	Ventilators		●	●			
	Elevators		●	●			

Sound sources that were mentioned could be divided into five types: broadcast, speech sound, activity sound, traffic noise and mechanical noise. Speech sound and activity sound were fundamental in most spaces as key sounds. Broadcast is a common and essential sound source in the transit spaces, it only catches in PL, ET and IF spaces, it is easily to be covered by other sound sources in noisy spaces. Speech sound consisted of the sounds of chatting (companions, other passengers and staff) and special speech sound which were hardly merged by noises such as shouting, phone call and crying. Speech sound was mentioned as a key sound, speech sound of companions, chatting sound of other passengers and phone call could be heard in every spaces. Activity sound is the sound of users performing various activities, including footsteps, dragging luggage and food preparation by staff. Dragging luggage is a key sound that could be heard in every spaces, food preparation sound is a special sound source that only occurred in RS. Traffic noise is the noise made by trains as they enter and exit the station, since the platform space is on the second floor, the train noise was not easy to hear, it only appeared in PL. Mechanical noise is created during the equipment operating such as air-conditioning, ventilators and elevators.

It is interesting to note that the evaluation on sound environment and acoustic comfort in the spaces with large number of sound sources (WA, PW and RS) were lower than the spaces with relatively simple sonic composition (PL, ET and IF). The spaces that could heard various speech sound and mechanical noise made the participants felt uncomfortable and noisy. However, RS was neither had the most complex sound sources nor could heard the mechanical noise, the evaluation score on sound environment and acoustic comfort was the lowest. The reason caused the result may because the proportion of the activity sound, it can be seen from Table 2, three types of activity sound and all types of speech sound could be heard in RS which made the participants in the space felt more noisy and uncomfortable.

3.3 Acoustic comfort of different types of sound sources

As a key sound, the broadcast was fundamental in most spaces. The intelligibility of this sound did not get satisfied by participants both in noisy and quiet spaces, but the preference degree tended to be a comfortable score. Most participants considered the speech sound of companions as comfortable and very comfortable (38.2% and 19.8%), with the increasing of background noise, the loudness and sound level increased, the intelligibility and the preference degree decreased. The chatting sound of other passengers and the speech sound of staff were the same pattern. The comfort and preference degree of shouting, phone call and crying got relatively lower score. Most participants considered the shouting and crying as neither comfortable nor uncomfortable and not comfortable (33.6% and 26.7%), the reason is these two sound sources had high loudness and sound level, which may cause a decrease on the evaluation of the total acoustic environment. Although the sound level of footsteps was in a lower scale, but the loudness was high. This result in higher score on comfort and preference degree. The sound of dragging luggage is a special sound source that appears everywhere in the transit hub. The acoustic indexes of this sound source were similar in different functional spaces. Train noise was only being proposed in PL, although the loudness and sound level were high, but the comfort and preference degree were satisfied with 33.6%/28.8% felt comfortable/ like and 19.2% /20.1% very comfortable and like a lot. The sound of food preparation by staff only appeared in RS, the loudness, intelligibility and sound level were very high, which caused dissatisfied on comfort and dislike on preference degree, this sound source may the reason that cause bad evaluation on overall sound environment and acoustic comfort in RS. The evaluation of mechanical noise was relatively lower. In WA and PA, three types of mechanical noise could be heard very clear, but it is interesting to note that the comfort and preference degree of these sound sources were at a high level. In other words, mechanical noise was not the reason that cause bad evaluation on overall sound environment and acoustic comfort in these two spaces.

A statistical analysis using the Pearson correlation between the acoustic comfort evaluation of various individual sound sources and overall sound environment in each space ($p < 0.01$) were proposed. The results showed that there was a positive correlation among the acoustic comfort evaluation of shouting, phone call, crying, food preparation, train noise and overall acoustic comfort. The correlation coefficient was 0.25–0.5.

4. CONCLUSIONS

In this study, on the basis of a soundscape approach by questionnaire survey conducted at an urban intermodal transit hub, the influence of various sound sources on the evaluation of sound environment and acoustic comfort were studied.

With regard to the overall sound environment and comfort level, it is found that there was a significant positive correlation between subjective comfort evaluation and sound level measurement, the noisy the environment, the uncomfortable the acoustic comfort.The evaluations in PL and ET were relatively higher, and the evaluation of comfort in WA and RS were slightly lower. The sonic composition of sound sources in the railway station included broadcast, speech sound, activity sound, traffic noise and mechanical noise. The evaluation on sound environment and acoustic comfort in the spaces with large number of sound sources (WA, PW and RS) were lower than the spaces with relatively simple sonic composition (PL, ET and IF).

With regard to individual sound sources, results shows that the intelligibility of broadcast needed to be improved, speech sound of conversation was accepted, but shouting, phone call and crying had been paid great attention and needed to be weakened. Special sound sources that appear only in certain spaces also need attention such as train noise in PL and food preparation by staff in RS. Mechanical noise was not the reason that cause bad evaluation on overall sound environment and acoustic comfort. In order to improve acoustic environment, the sound sources of shouting, phone call, crying, food preparation, train noise was considered to have the greatest impact on the overall sound environment and acoustic comfort. Overall, this case study suggests that it is worth investigating the sound environment of urban intermodal transit spaces from a soundscape perspective might be implemented to enhance users' acoustic comfort in such spaces.

5. ACKNOWLEDGEMENTS

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