Optimization of Ambient Acoustics in Los Angeles Restaurant by Material Selection

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Abstract. This paper explores the acoustic characteristics of Hai Di Lao Hotpot restaurant in the Los Angeles area and utilizes noise reduction technology to improve the acoustics of the restaurant in the modeling of ODEON software. First, 5 questions are designed to collect satisfaction level from eaters in the restaurant, and 12 different audio recordings are collected in the different locations of the restaurant. According to the analysis of results of questionnaire by Excel and decibel detection by Apple Watch, the improvement of acoustic environment is proven to be necessary to conduct in this restaurant. The collected audios tracks are then processed in the Audacity software to ensure that the sounds are close to sounds people heard in the restaurant as much as possible and the sound collection equipment (iPhone) won't negatively affect the quality of audio too much. Then, an extant model in the library of ODEON software is chosen, and audios collected in the restaurant are inserted as audios for the chosen model. Some places in the model are also determined to place receivers. After that, by replacing original building materials in the model by materials that has better sound insulation or better sound concentration effect, the acoustic environment in the model is adjusted. By analysis provided by ODEON software, the audios after material adjustment are proven to be better with the change of building environment.

Keywords: Acoustic characteristics, Chinese restaurant, Excel, Apple Watch, Audacity, ODEON, Model simulation, Material selection, Noise reduction techniques.

1. Introduction

The acoustic environment of a common space plays an important role in determining the comfort level for people staying in it. However, few academic studies have been conducted on the influence of acoustic environment on restaurants. People seem to be used to noisy restaurants with loud BGM. In fact, the levels of noise within restaurants can significantly affect communication between customers and staff, resulting in dissatisfaction and reduced productivity. Besides, in 2017, six restaurants in Yinchuan, China, were forced to close due to excessive noise from oil fumes. This incident highlights the importance of managing the acoustic environment in restaurants, not only for the comfort of customers but also for the safety of workers. The impact of noise pollution on health and well-being has been well-documented, and it is crucial for restaurants to take steps to mitigate noise levels.

Therefore, in this paper, I examine the indoor acoustic environment of Hai Di Lao Hotpot, a renowned Chinese restaurant situated in Los Angeles. By utilizing a questionnaire to collect satisfaction level from customers in the restaurant and recording audio files at various locations within the restaurant, this paper explores the implementation of a noise reduction technique, building material selection. Furthermore, this paper assesses the impact of material selection on enhancing communication, elevating customer satisfaction, bolstering the restaurant's reputation, and ultimately increasing productivity using the statistical analysis provided by the ODEON software.

2. Literature Reviews

2.1. Acoustic Environment of Chinese Restaurants

In many Chinese restaurants, the cooking methods focus on stir-frying, scalding and barbecuing, resulting in a serious noise problem. Therefore, there have been some relevant studies on the indoor

environment of Chinese restaurants. Among them, Zhang et al. (2015) 's study on signal to noise ratio (SNR) in restaurant environment is noteworthy. They conducted a detailed study on the how the distance between the listener and the speaker in the restaurant would influence the speech clarity, while also analyzed and modeled the problem through questionnaires and ODEON software. Besides researches on a specific perspective of dining acoustics environment, there are also general researches on the psychological side of verbal communication relating to the cocktail-party effect and Lombard effect in the restaurants (Rindel, 2017) that suggests to build greater volume of the environment based on model simulations.

2.2. Optimization of Acoustic Environment Design

People often pay more attention to acoustic Spaces outside of restaurants, such as car interiors, hospital consulting rooms, etc. In these cases, the acoustic environment presents more serious health and safety-related impacts and is therefore richer in relevant research. For example, in Song et al. (2019) 's study on multifunctional conference hall, they also used ODEON software to study the best materials used in conference room space. It is also proposed to change the ceiling material of the conference room to an alumina blanket sound-absorbing material. In my research, I took their opinions for reference in the modeling of the restaurant. When optimizing the acoustic environment of the restaurant, the material of the ceiling was changed into one with a density close to that of alumina blanket.

3. Research Methodology

Step 1: I collected the satisfation level of customers at Hai Di Lao hot pot restaurant in the form of questionnaire, and collected sound from 12 sources in the restaurant. I also measured acoustic values such as decibel levels by Apple Watch, and adjust the sound using Audacity software.

Step 2: I selected materials from the sound-absorbing material library according to mimic the original materails of floor, ceiling, partitions in the restaurant, and then used ODEON software to obtain the reverberation time.

Step 3: Additionally, I decorated a private dining space with carefully selected materials to create the best possible acoustic environment, and then compared the measured values with the ideal ranges for both reverberation time and noise sound pressure level for the receiver at public dining place and the receiver in the VIP room. The ideal noise sound pressure level should be around 60-65 decibels, and a range of 0.5-1.5 seconds is considered appropriate for most restaurants.

Step 4: I adjust the material selection of the VIP room according to the performance of sound received, until the reverberation time for each frequency was within the ideal range, and the visual effects were satisfactory.

4. Data Collection and Preprocessing

4.1. Statistical support from customers

Before collecting acoustic data, I administered a five-question survey scaling from 0 to 5 to the diners at Hai Di Lao Hotpot to gauge their comfort level with the restaurant's sound environment. The survey is designed to assess customers' perceptions of noise levels, speech intelligibility, and overall comfort in the dining space. I also asked for the diners’ suggestions on how the restaurant could improve its acoustic environment. The survey was distributed to 100 random customers during various times of day and days of the week to ensure a representative sample. By collecting this information, I aim to gain a better understanding of the customers' experience in the acoustic environment. This result proves that the whole investigation is meaningful.

I designed the following five questions:

1. How comfortable do you feel while dining in this restaurant?
2. How would you rate the overall noise level in this restaurant during your dining experience?

3. How would you rate the clarity of conversations at your table during your dining experience?
4. How important is a comfortable and quiet dining environment to you when choosing a restaurant?
5. Would you be more likely to dine at this restaurant again if the acoustic environment was improved?

The result is shown below:

Table 1. Questionnaire results

#Question / Score	1(worst)	2	3	4	5(best)
1	3	12	32	34	19
2	9	7	36	40	8
3	2	4	25	46	23
4	11	16	62	9	2
5	1	7	6	20	66

From the above statistical diagrams we can see that most of the customers are not that satisfiactory with the current acoustic environment the restaurant provided with the highst score 5 seldomly appeared in the rating of the environment, so the improvement of the acoustic environment of this restaurant is necessary. People also give their own suggestions on how the environment could be better, like changing the background music to be softer or adding the isolation space for each table to promise the provacy of conversation. These are all potential aspects that can be investigate further. Besides, the result of last question shows that the improvement of sound environment has great space to make the restaurant more attractive, meaning the improvement is potentially lucrative.

4.2. Field Measurements

4.2.1. Noise Level Detection

Besides the psychological feelings of the customers, the quantitative measure of the ambient acoustic level can also be easily done. I measured the sound intensity of the acoustic environment using Apple Watch Noise Meter App for 10 times in different locations of the restaurant with the noise range set to be above 80 decibels (default range), and the decibel quickly went to the “loud” region for 8 times out of 10, meaning that the improvement should be done. The random error of Apple Watch noise app is around 2-3 decibels according to *The Noise Chap*, which is an acceptable range for the purpose of this research.

Figure 1. Noise level detection by Apple Watch in the restaurant

4.2.2. Sound Collection

I also collected 12 different sound in the restaurant as the source sound for the model simulation in the next step, including six tracks of sound at the 6 different places located symmetrically in the restaurant, the clanking of silverware and dishes, the grinding of tables and chairs against the floor, the loud background music, the whirring of machines, the sound of a waiter talking to a customer

when the receiver is the customer, and the voices of the guests at the next table. Due to the consideration of privacy, the restaurant didn't allow me to collect the sound in their kitchen, but what I had is already enough to mimic a sound environment in the restaurant.

4.3. Preprocessing of Sound

Since I only had an iPhone 11 as my recording device, and the height and ease of my recordings varied from location to location, I used Audacity to adjust the volume of my recordings so that they all sounded closer to the real volume I would hear in a restaurant. The supporting material online for how the volume of sound sounds realistic is few, so I can only adjust the loudiness by the feeling of my raw ears, resulting in some inaccuracy.

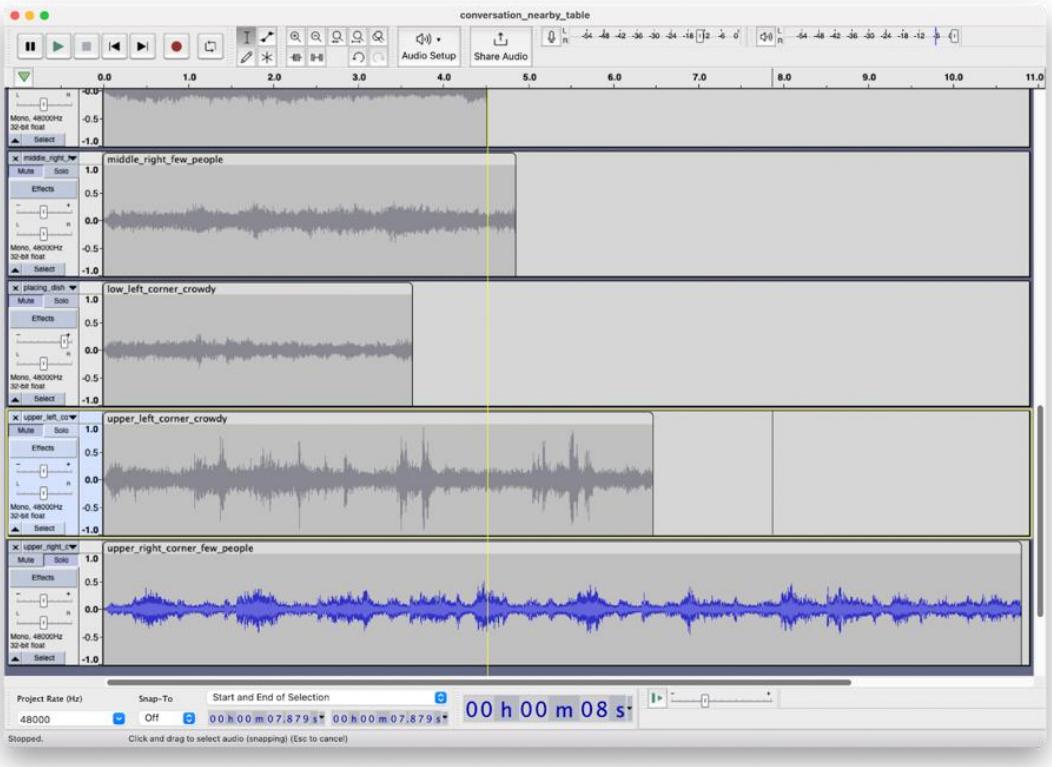

Figure 2. Preprocessing of sounds in the Audacity software

5. Noise Optimization

5.1. Model Simulation

I applied to the restaurant for their architectural drawings, but I didn't get them due to the problem of personal permission. Meanwhile, although ODEON software is convenient for sound processing, most of the models cannot be used within my limited budget, nor can I have the authority to transform the models. Therefore, I can only select the model closest to the structure of Haidilao Hotpot restaurant from some free models, and insert the sounds collected in the restaurant into the model. Fully resource available ODEON software costs close to hundreds of thousands of dollars, so I'm sure most acoustic experts and builders will find themselves in the same situation when using this software as I. Therefore, to select the model closest to the required space among the free models is already the optimal solution.

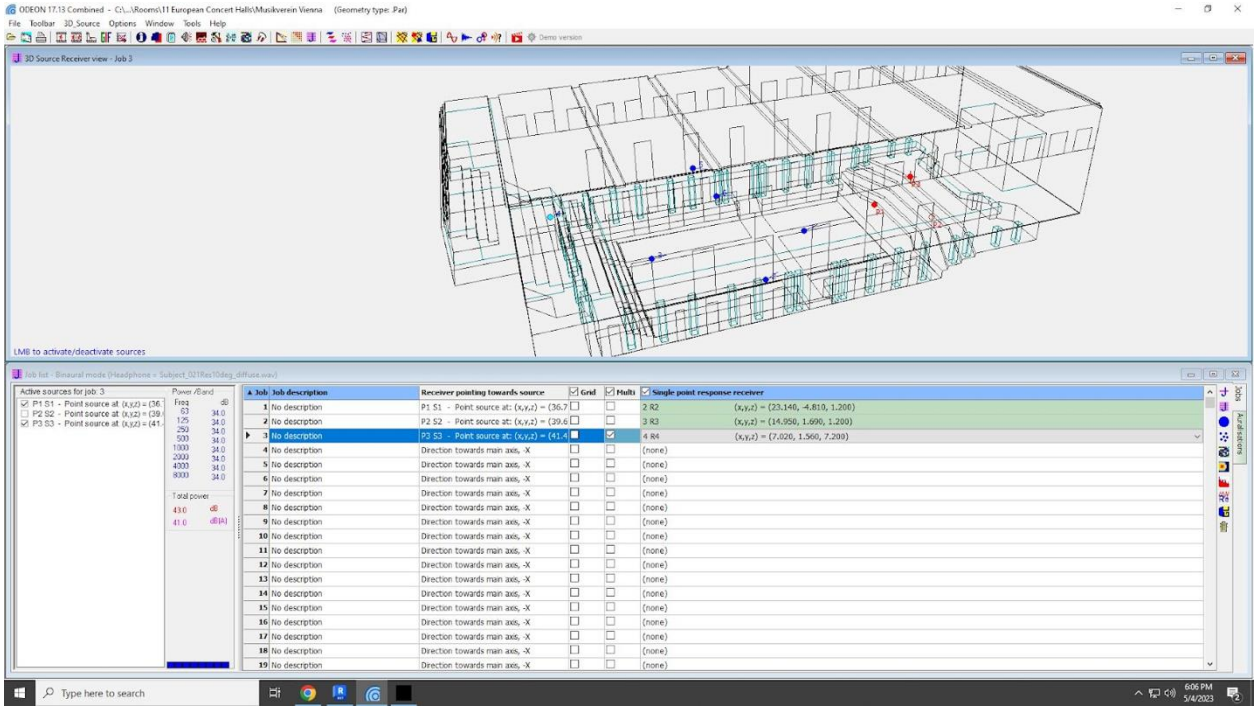

Figure 3. Model selected in the demo version of ODEON

5.2. Material Selection

5.2.1. Public area and private room

To make comparision between the original place and the one applied noise reduction techniques, I selected a small portion of model, the right side of the place, as the “VIP” room in the restaurant. I recover the original design of the restaurant as much as possible in the public dining area, while conducting material selection in the VIP room. This is in accordance with the deisgn of many restaurants nowadays.

5.2.2. Ceiling material selection

In an open Chinese restaurant, the ceiling is a large important sound-absorbing surface, and a necessary stop for long-distance sound reflection. To achieve a reverberation time between 0.5-1 second for each frequency in the restaurant, I changed the ceiling material in the VIP room to be alumina with high absorbing rate.

5.2.3. Wall material selection

Interior wall finishes serve the purpose of protecting the walls, ensuring normal use of the space, and beautifying the space. Thus, considering the other functions of the wall, the lower part of the wall can incorporate a hard-resonance sound-absorbing structure, which not only protects the wall but also reduces the low-frequency reverberation time. The upper part of the wall can use porous sound-absorbing materials and resonance sound-absorbing structures.

6. ODEON Analysis

Rooms with more early reflections, better sound diffusion and absorption, and fewer delayed and reverberant reflections are generally considered to have better acoustic properties. These data can all be obtained through the analysis diagrams provided by ODEON software.

For instance, the diagrams of Dietsch echo curves below show the time intervals between direct sound and the first reflection from different surfaces within the room. They appear as distinct peaks in the decay curves. The height indicates the sound level of the first reflection, and the width represents the time delay between the direct sound and the reflection. The Dietsch echo curves in the

revised room has steep decay slope and stops earlier, meaning this space has more early reflections and less reverberations and the speech intelligibility is preserved in this space.

Figure 4. Dietsch echo curves in the original space

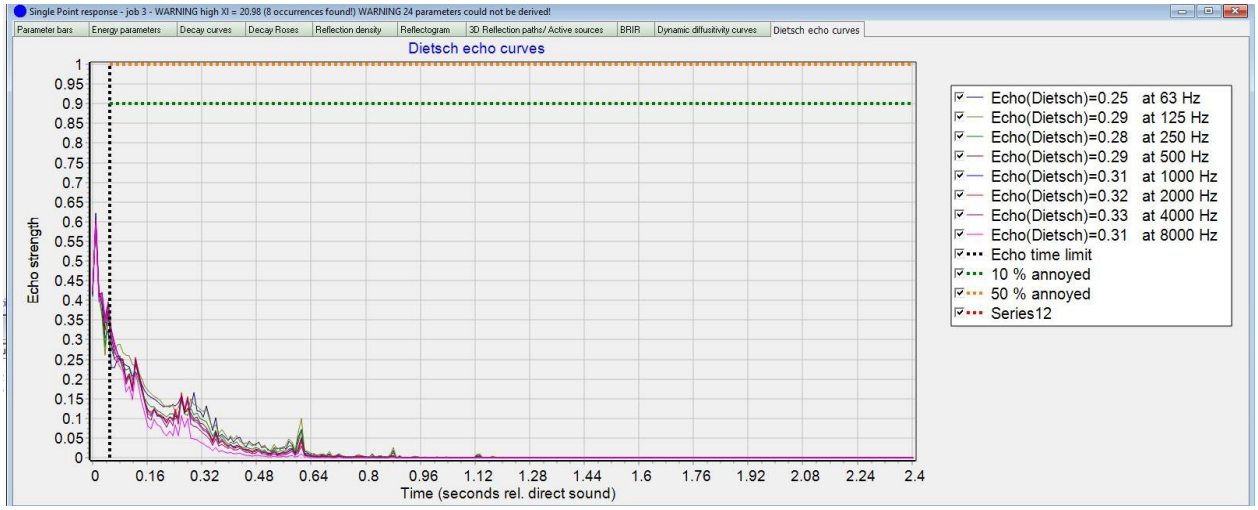

Figure 5. Dietsch echo curves in the revised space

Similarly, the BRIR (Binaural Room Impulse Response) curves can be used to show the acoustic transfer path of the audio signal from the loudspeaker to the listener in each room. The diagrams below are the time-domain response of the sound wave for each position. The x-axis represents time in milliseconds, and the y-axis represents the amplitude or intensity of the sound wave. While both rooms balance the acoustics received in the left and right ear well, the sound is more centralized in the revised space, with quality of less sound reflection and better sound absorption.

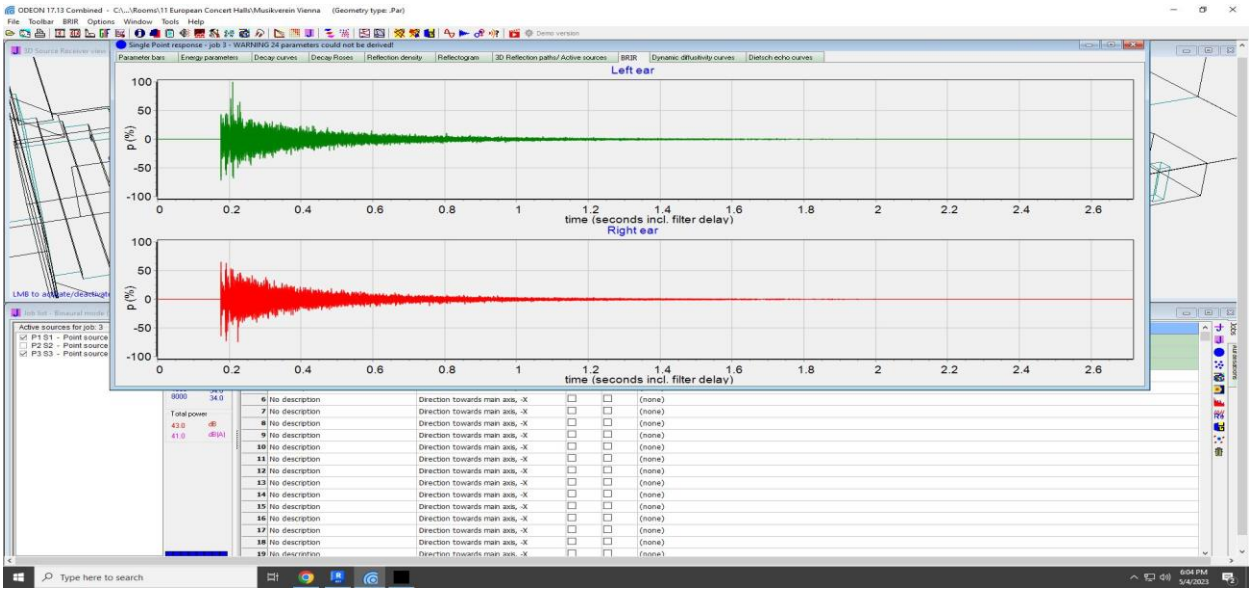

Figure 6. BRIR curves in the original space

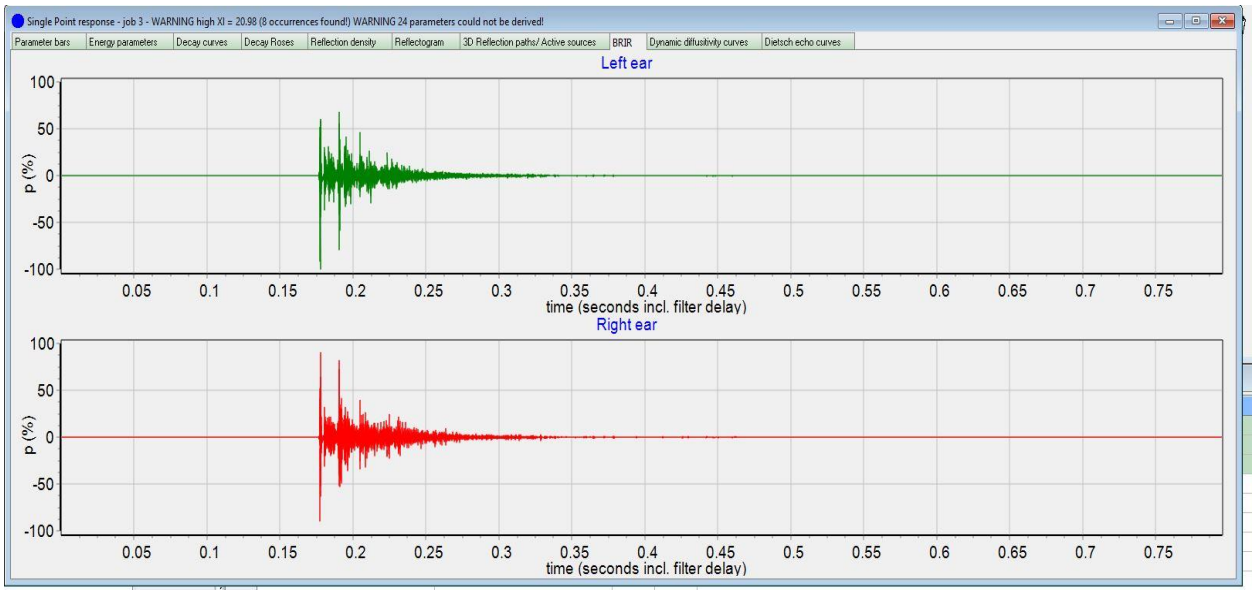

Figure 7. BRIR curves in the revised space

7. Summary

7.1. Conclusion

Overall, this study suggests that the acoustic environment of the Hai Di Lao hot pot restaurant needs improvement. Through a combination of field surveys, analysis, simulation, and material selection, this paper optimizes the acoustic environment and achieve the ideal reverberation time and noise sound pressure level for the selected restaurant. It highlights the use of advanced software, such as ODEON software, to optimize the acoustic environment of a restaurant. While it is common to measure acoustic values, such as decibel levels and reverberation time, the use of simulation software to create a virtual model of the restaurant and test different scenarios is not widely employed.

7.2. Limitations and Challenges Encountered

The limitations and challenges encountered during this study include the following issues:

First, the use of a demo version of the ODEON software, which doesn't provide a fully realistic simulation of the ambient acoustics of the restaurant. This limitation affected the accuracy of the results obtained and thus the recommendations made for optimizing the acoustic environment.

Additionally, the study was limited by the lack of access to the CAD model of the restaurant and the kitchen, which are important sources of noise in the restaurant. Without access to these models, it was difficult to accurately model the acoustic environment of the restaurant and make precise recommendations for optimizing the acoustic performance.

What's more, due to the limitation of the device, I can't fully reproduce the environment there so we download some background music to simulate the environment.

Besides, Hai Di Lao Hotpot didn't allow me to enter the kitchen region, which has the most severe noise issue. This limitation makes it impossible to collect one important acoustic source, resulting in less accuracy of the model I simulated.

Finally, the research was conducted in only one restaurant, which may limit the generalizability of the findings to other restaurants or different types of spaces.

7.3. Recommendations for Future Research

Based on the difficulties I encountered, I suggest the following ways for future research:

First, future acoustic specialties can conduct a similar study in different types of restaurants to examine the variability of the acoustic environment optimization process across different restaurant types since my research only focused on one single restaurant due to the time and budget limitation.

Besides, on the psychological aspect, it's worthy to investigate the impact of acoustic environment optimization on customer satisfaction, retention, and spending behavior in restaurants more detailed.

Also, I changed the materials of the building in ODEON to improve the acoustic environment while didn't conduct careful investigation on the common building materials, so in the future the effectiveness of different types of sound-absorbing materials and their optimal placement for achieving better acoustic environments in restaurants can be further studied.

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