The Sound Environment Evaluation of Urban Commercial Space Users in Urban Commercial Area

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Abstract: With the globe getting highly internationalized, commercial activities have transformed from traditional buying and selling functions into more complicated functions. Thus, sounds coming from commercial activities are becoming much more multifarious, at the same time, more annoying. This is because of Taiwan's special residence custom. In Taiwan, most people live in the residence-commercial complex zoning, which means residents expose to the commercial activities noise in daily lives. In order to investigate residence-commercial complex zoning sound environment from user's point of view, there were 800 questionnaires handed round, and 273 questionnaires were replied. There are six evaluation factors in influencing molding commercial space sound environment. According to the users' observation and experience, three factors play important roles in influencing users' evaluation regarding sound environment design, including amenity(pleasant, comfortable or unpleasant, uncomfortable), vitality(active or inactive), and atmosphere of warmth (warm or cold). In the regression analysis, amenity and volume(Leq) have a negative relationship($r = -0.558$), which means volume is an important factor in commercial space sound environment molding. In the past, high volume amplifier system was applied extensively in commercial district to attract more crowds. However, amenity is declined under such noisy environment. It is a very important issue to study the trade-off relationship between these two situations and improve noise problem in residence- commercial complex zoning.

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1 Research Methodology and Summary of Survey

1.1 Research Content and Methodology

This research was carried out in two parts - physical and psychological surveys. The physical survey was conducted by grouping researchers into groups of two members each to survey the environment on foot and take background sound measurements at their allocated research areas and prescribed time periods. The results of the surveys were then entered into the Geographic Information System (GIS) together with the volume measurements of background sounds of corresponding geographic locations for information accuracy testing and measurement-time error adjustments. The result of the analysis corresponds to the environmental features of a city-the sound environment of city roads/ streets vary greater than that of smaller allies/ streets. Based on the results of the GIS analysis, three periods representing the main hours of commercial activities, morning (08:00 - 10:00), noon (14:00 - 16:00), and evening (20:00 - 22:00), were selected for sound environment research on commercial areas. In addition, indoor measurements of background sound volumes at seventeen categories of commercial spaces were also carried out. In the psychological survey, users of commercial spaces in five major commercial areas in Tainan City, Northern Central, East, West, South, and North Districts, were interviewed for their experiences and evaluations on the sound environments of respective commercial areas. Contents of the questionnaire include users' basic data (age, sex, office and school commuting time) and their evaluations on the sound environment of the chosen commercial spaces (including the importance of the

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sound environment, requirements of background music, users´ feelings towards sounds and noises, and the degree of disturbance of the sounds in these commercial spaces). The question of whether the train bell would stress train users were also surveyed in the questionnaire.

1.2 Subjects of Survey

Subjects interviewed in this research are major consumers of commercial areas in Tainan City. "Random Sampling" was utilized for on-site measurements and surveys. Research subjects are sampled from a wide range of daily and frequent users of commercial spaces. Geographic areas include five districts, the Central, East, West, South, and North Districts, located on the major commercial activity belt in Tainan City, and sampled interviewees are males and females age between 10 to 60. On-site questionnaire was adopted as the method of survey. Eight hundred subjects were surveyed and 273 questionnaires were returned. The rate of return is 34.13%.

1.3 Characteristics of Interviewees

Interviewees are composed of 58% of males and 42% of females. Among those, 7% are age 20 and below, 62% 21 to 30, 23% 31 to 40, 5% 41 to 50, 2% 51 and above. Occupations range from 22% of students, 33% office workers, 15% freelancers, 21% technical workers, and 9% housewives. For average commuting time, 28% of the interviewees take less than 15 minutes, 42% 16 to 30 minutes, 22% 30 to 60 minutes, 8% 60 to 90 minutes. In order to assemble a more reprehensive sampling for the purpose of deriving an accurate result that reflects users´ true evaluations of the sound environment of chosen locations, all subjects interviewed have been to their respective commercial spaces prior to the interview.

2 Indoor Sound Environment Imagery Survey of Various Commercial Spaces in Downtown Tainan City

From the above questionnaire, we derived that sound environments in commercial areas are very important regarding consumer behaviors. An adequate sound volume and good sound environment imagery are among the standards with which consumers choose their places for consumption. After comparing the above stated result to the measurements of on-site indoor background sound volume in commercial spaces, seventeen commercial spaces of different categories were selected for evaluation and surveys on users´ experiences. The main objective is to explore users´ opinions towards the sound environments provided by a variety of commercial spaces with different settings and purposes for use. In addition, the result of questionnaires and on-site background sound volume measurements were brought together for a factor analysis in expectation to derive users´ evaluation factors for various indoor sound environments in commercial areas. The result was then put under a three-directional cross- analysis to determine a level of sound volume that is deemed comfortable to users for the sound environment of commercial spaces. With the result, researchers further reviewed and summarized the commonalities among imagery factors of various sound environments of commercial spaces.

2.1 Measurement Methods

Seventeen commercial spaces with various settings in downtown Tainan City were measured for indoor background noises in this research. Precision noise measuring gauges (B&K 2260 and RION NA-27) were used to measure the Leq value for a minimum of 10 minutes at different commercial spaces. Microphones of the gauges were placed at a height and position near the measurers´ ears. Taking into consideration of different settings in different categories of commercial spaces, measurements were taken at various positions and actions such as sitting, standing, and walking. Measured sound sources are radio broadcasting, background music, and other sound sources. Information regarding the methods of measurement, measuring time, and results is listed in table 1.

2.2 Results of Measurements

The highest background sound volume measured in this research is the Jazz Restaurant where the sound of life-band music was measured at 88 dB(A). The lowest volume measured, on the other hand, was the comic book store at 53 dB(A). Commercial spaces with background sound measurements at 80 dB(A) or higher include video game arcade (84 dB(A)), KTV (86.5 dB(A)), and bowling alley (83.3 dB(A)). Measurements over 70 dB(A) were taken at Sichuan restaurant (74.1 dB(A)), seafood restaurant (75 dB(A)), fast-food restaurant (71 dB(A)), boutique for personalized items (70 dB(A)), billiard hall (79.3 dB(A)), restaurant complex (75.5 dB(A)), beverage bar (74.4 dB(A)), supermarket (70.5 dB(A)), and hypermarket (71.5 dB(A)). Places with measurements below 70 dB(A) include department store (65 dB(A)), fashion boutique (68.4 dB(A)), 24-h convenient store (66.

8 dB(A)) and comic book store (56 dB(A)).

2.3 Methods of Analysis

Seventeen commercial spaces of various types and settings were chosen for the survey of evaluation on users' experiences in this research. The main objective is to explore users' opinions towards the sound environments provided by a variety of commercial spaces with different settings and purposes for use. In addition, the result of questionnaires and on-site background sound volume measurements were brought together for a cross analysis in expectation to derive users' evaluation factors for various indoor sound environments in commercial areas. The result was then put under a factor analysis to determine a level of sound volume that is deemed comfortable to users for the sound environments of commercial spaces. With the results of this analysis, researchers further reviewed and summarized the commonalities among imagery factors of various sound environments of commercial spaces.

Table 1　Indoor Background Sound Volume of various commercial spaces

Commercial spaces	Locations of measurements	Length of time measured	Mode of survey	Category of sound sources	Sound volume Leq
1	Tainan Far Eastern Department Store, Shin Khong Mitsukoshi Department Store	60min	walk	Radio, BGM, talking, walking (movements)	65dB(A)
2	Chungcheng Road Sichuan Restaurant	15min	sit-in	BGM, cooking sound from kitchen,, walking (movements)	74.1dB(A)
3	Seafood restaurant	30min	sit-in	cooking sound from kitchen, finger-guessing game, laughter, talking, walking (movements)	75dB(A)
4	Video game hall	30min	sit-in	BGM, sound from video game machines, sound from children playing, talking, walking (movements)	84dB(A)
5	Fast food restaurant (MacDonald's)	30min	sit-in	BGM, talking, sound from children playing, talking, radio, walking (movements)	71dB(A)
6	Boutique for personalized items	15min	walk	BGM, talking, walking (movements)	70dB(A)
7	Fashion Boutique (Giordano)	15min	walk	BGM, talking, walking (movements)	68.4dB(A)
8	Billiard/Pool Hall	30min	standing	BGM, clicking sound from billiard balls, talking, laughter, walking (movements)	79.3dB(A)
9	Restaurant complex	30min	sit-in	BGM, talking, sounds from playing chess, sounds from playing cards, laughter, walking (movements)	75.5dB(A)
10	Beverage Bar	30min	sit-in	BGM, sounds from playing chess, sounds from playing cards, talking, walking (movements)	74.4dB(A)
11	Jazz Restaurant	60min	sit-in	BGM, sounds from life performance, dancing, laughter, greeting, talking, walking (movements)	88dB(A)
12	KTV	60min	sit-in	BGM, singing, radio, talking, greeting, walking (movements)	86.5dB(A)
13	24-h convenient store	15min	standing	BGM, talking, walking (movements), greeting	66.8dB(A)
14	Supermarket	30min	walk	BGM, radio, sounds from working machines, greeting, talking, walking (movements)	70.5dB(A)
15	Bowling Alley	30min	standing	BGM, laughter, talking, walking (movements), greeting	83.3dB(A)
16	Comic book store	30min	sit-in	BGM, talking, walking (movements)	56dB(A)
17	Hypermarket (Carrefour)	30min	walk	BGM, radio, sounds from working machines, talking, walking (movements), greeting	71.5dB(A)

The Main Composition Method of Factor Analysis within the sphere of Varied Volume Method was adopted in this research as the method of analysis. After analyzing the collected data, factors that have 70% or higher accumulated factor deviancy were organized and named individually. The relevant coefficient and load capacity of imagery factors of each element were then derived from the collected data. High factor loading capacities indicate that the sound environments of these high factor loading commercial spaces have some commonalities. From the data derived in the analysis, relationships between different settings of commercial spaces and users' sound environment imagery factors were then arrived.

2.4 Sound Environment Imagery Factors of Commercial

Spaces and the Result of Experience Evaluations

For the purpose of analyzing sound environment imagery factors of various commercial spaces, customers in seventeen different settings of commercial spaces were interviewed for their perceptions on their respective sound environments in the form of questionnaires. The contents of the questionnaire addressed seven main categories of whether the user perceives his/her chosen setting as quiet or noisy, plain or flashy, close or open setting, pleasant or unpleasant, comfortable or uncomfortable, lively or less lively and likeable or dislikeable. Perception indicators were set at a scale of 5. Subjects interviewed were to rate a certain attribute of the chosen place with a scale of 1 to 5. The results of these questionnaires were then brought together with the Leq value measured at the chosen commercial spaces for a factor analysis of commercial space sound environment imagery in expectation to explore and understand the imagery factors of users towards various commercial spaces.

Results of the questionnaires indicated that over 60% of users of traditional commercial spaces such as Sichuan restaurant, seafood restaurant, bowling alley, beverage bar, and pool/billiard hall find that the environments are noisier comparing to commercial spaces like 24-h convenient store and comic book store, which are perceived as quieter.

Table 2 Factor Loading with Varimax

Factors	Factor 1	Factor 2	Factor 3
Imagery Factors	Amenity	Liveliness	Warmth
sound volume	- 0.541254915	- 0.46106069	0.3101754
quiet- noisy	- 0.712063773	- 0.558432702	0.0098189
plain- flashy	0.241095626	- 0.777550954	0.1668105
closed- opened	- 0.142101405	- 0.685581468	- 0.0155952
unpleasant - pleasant	0.903627841	- 0.132647458	- 0.0352473
uncomfortable - comfortable	0.956193466	- 0.056769156	- 0.0817121
lively- less lively	0.176690307	- 0.901359144	- 0.1641897
cold- warm	0.136214448	0.188485948	0.9412911
dislike- like	0.728955941	- 0.342154932	0.1964709
explaining variable	3.19031143	2.58489482	1.0838816
accumulated contribution	0.354479048	0.287210536	0.1204312

The loading capacity (i.e. a factor's capacity to explain variances) of each factor was derived after a factor analysis is carried out with the aid of Statistica statistic software. Its induced accumulated variance explaining capacity (rate of contribution) reached 76.21% (Table 2). Loading factors with factor loading over ±0.7 were chosen to be the reprehensive as the major factor of the element. Three commercial space sound environment imagery factors were derived from the analysis. They are: factor 1, sound volume, quietness, pleasantness, comfort, and likeableness; factor 2, luxurious setting, openness, and liveliness; factor 3, warmth. The three factors are individually named as the following: factor 1- sense of pleasantness and comfort, factor 2 - liveliness, and factor 3 - warmth. Each factor was than put under a Factor Score Analysis to compare it with each of the chosen commercial spaces and derive the common factors among these settings (table 3).

Table 3 Factor Score of each category of commercial spaces

Factors	Factor 1	Factor 2	Factor 3
imagery factors	Amenity	Space Lively	Warmth
comic bookstore	1.33421	- 2.67479	- 0.04806
department store	2.27888	0.85669	- 1.40997
24-h convenient store	0.42646	- 1.34547	1.31873
fashion boutique	0.29493	0.56492	0.32619
personalized boutique	- 0.12469	0.74171	0.62903
supermarket	- 0.48219	0.19300	- 0.69460
fast-food restaurant	0.82020	1.08992	- 0.74928
wholesale store	- 0.07467	0.07529	- 1.26033
Sichuan restaurant	- 1.13615	- 1.05575	0.02094
beverage bar	- 0.35073	- 0.28379	0.04305
seafood restaurant	- 0.36433	- 0.97235	- 1.38709
restaurant complex	0.63722	0.81958	1.74128
pool/billiard hall	- 1.28495	- 0.24683	0.07658
bowling alley	- 0.68470	0.34649	0.40590
video game arcade	- 1.05599	0.73093	- 1.20054
KTV	- 1.26052	0.59216	0.80094
jazz restaurant	1.02703	0.56830	1.38725

After sorting out the common factors of each of the commercial spaces, commercial spaces that have the factor of "a sense of pleasantness and comfort" include department store, comic book store, jazz restaurant, fast - food restaurant, restaurant complex, 24-h convenient store, and fashion boutique. Sound environments that are classified as "unpleasant or uncomfortable" are pool/billiard hall, KTV, Sichuan restaurant, video game arcade, bowling alley, supermarket, seafood restaurant, beverage bar, boutique

for personalized items, and hypermarket (fig. 1(a)). Spaces that are considered as "lively" are fast-food restaurant, department store, restaurant complex, and boutique for personalized items. Places that are considered as "not lively" are comic book store, 24-h convenient store, Sichuan restaurant, and seafood restaurant (fig. 1(b)). Commercial spaces that are classified as giving a sense of "warmth" are restaurant complex, jazz restaurant, 24-h convenient store, KTV, and boutique for personalized items, and those that are considered as having "less warmth" are department store, seafood restaurant, and video game arcade (Fig. 1(c)).

From the above stated result, factor 1, "a sense of pleasantness and comfort" and factor 2, "liveliness" were put under a bi-directional cross analysis, and the result is shown in graph 5. Spaces with both "sense of pleasantness and comfort" and "liveliness" are department store, jazz restaurant, fast-food restaurant, restaurant complex, and fashion boutique. Places that have neither "a sense of pleasantness and comfort" nor "liveliness" are Sichuan restaurant, pool/billiard hall, beverage bar, and seafood restaurant. Spaces with "a sense of pleasantness and comfort" but not "liveliness" are comic bookstore and 24-h convenient store. Places that are considered as "lively" but not "pleasant and comfortable" are KTV, video game arcade, and bowling alley.

A relationship analysis of the "sound volume", "pleasantness and comfort", and "liveliness" indicates that the factors of "pleasantness and comfort" and "sound volume" have a negative relationship with relation coefficient at $r = -0.5582$, p value < 0.001, and standard error $= 0.2142$. "Liveliness" and "sound volume" have a positive relationship with relation coefficient at $r = 0.4857$, p value < 0.001, and standard error $= 0.2257$. From graph 6, we can see that as the sound volume increases, the level of "pleasantness and comfort" decreases, and the indicates that the level of "liveliness" increases as the "sound volume" increases, which suggest that the comfort of a commercial space is not determined by high volume. Lower volume, on the other hand, increases users´ comfort level. In contrary, the sound environment evaluation on "liveliness" indicates that higher volume indeed achieves liveliness for a commercial space. However, the topic again involves the issue that higher volume has a negative effect on "pleasantness and comfort". A comparison of this specific sound environment evaluation and the result derived in previous chapter indicates that the requirements for the sound volume in a commercial space vary according to different age groups of consumers. Nevertheless, for a pleasant and comfortable commercial sound environment, moderate sound volume is still most acceptable by all users. According to the results of a regression analysis carried out in this research, after the three factors derived from the factor analysis were corresponded to each of the commercial spaces, the "24-h convenient store" was chosen as the critical value (Fig. 1(a) – (c)). Substituting it into relevant graph of the regression analysis of background sound volume and experience evaluation data collected in the initial surveys, a sound volume of 60 dB(A) or below is arrived as the perceived level of comfortable and pleasant sound volume.

The result of previous analysis was further compared to the stipulated day-time and night-time noise allowances for various controlled zones according to relevant noise control regulations. A "residential-commercial mixed zone" is classified into the Second Category of Control Zones (which focuses mainly on the characteristics of an area for residential purposes that requires quietness; its principle of zoning is based mainly on the second and third classes of residential zoning laid out in the city planning). Its noise control standard is 65 dB(A) for day-time and 50 dB(A) or below for night-time. The average level for a pleasant and comfortable commercial sound environment derived in this research is 60 dB(A) and below. After modifying the indoor sound volume with a modifier of 10 to calculate the sound volume after it is transmitted outdoor, the ideal sound volume transmitted outdoor is arrived at 50 dB(A) and under. This result indicates that the derived sound volume for pleasantness and comfort corresponds to the standards of current noise control regulations.

From the results of this analysis, a controlled indoor sound volume at 60 dB(A) and below in commercial spaces satisfies not only the criteria for pleasantness and comfort but also the standard for noise control stipulated in the environmental protection laws. Deduced from the result, the ideal sound volume not only can induce a positive reaction for commercial behaviors, it is also more environmentally friendly. In addition, the results of this research further indicate that "sound volumes" have a direct effect on users´ experiences and evaluations of commercial spaces (ex: comfort, pleasantness, and liveliness). Therefore, the sound volume measurements (Leq value)

can serve as good "sound environment indicators" for commercial space operators, and, from which, users' "experience evaluation indicators" can also be deduced.

3 The Rhythm of Summer Soundscape in Tainan City Area – The Vibration of Sounds from the Nature

Tainan is a historic city. In 1661, Zheng Cheng Gong expelled the Dutch and established a municipality in Tainan. During that period, immigrants and commercial vessels from China flocked into the city, and stores sprout up one after another. The scale of Tainan City has since been established. In 1684, the Qing Government established the Taiwan Province and set up its capital in Tainan. Due to this historic background, Tainan City has much more historic landmarks than any other counties/cities on this island, and many of these landmarks are blessed with hundred-year-old trees, for examples, the Fig Park in Cheng Kung University, Tainan Park, Minsheng Green Park, and the old Plum tree in the Guan Yu Temple. In such a green environment, there are various kinds of natural Soundscape. This also indicates that Tainan City's natural sound environment is full of rhythms configured by the nature from morning to night, sun to moon, and summer to winter. Although we can not hear the vibration of the sound environment of the nature, from our records of a 24-h research on Tainan City, we can see that there is indeed a certain level of rhythm occurring repeatedly in the sound environment of the nature.

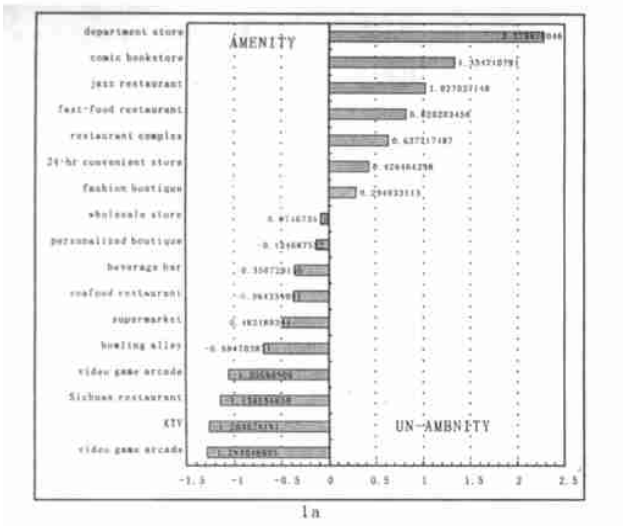

Fig. 1(a) Category of Amenity spaces

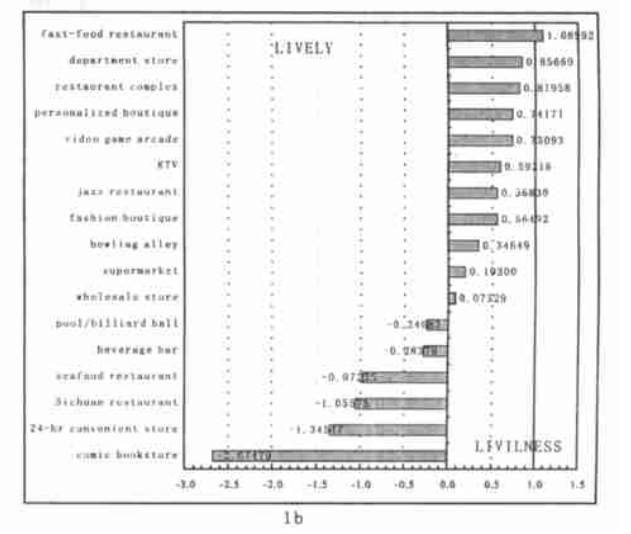

Fig. 1(b) Category of lively spaces

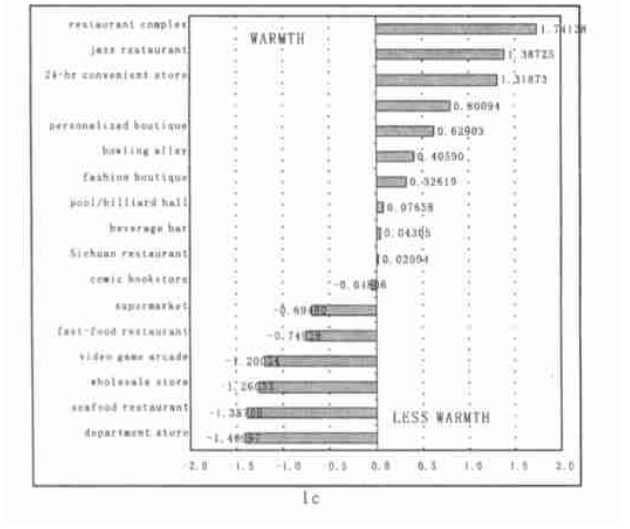

Fig. 1(c) Category of warmly spaces

In this research, the changes in the Soundscape of Tainan City were recoded 24-h a day for a period of time from observations of different segments in the living environment. Through observation, measurements, recording, and calculation, the researchers drew the changes in the Soundscape of Tainan City into a graph. Each city is possible to have a natural Soundscape rhythm that is endowed by the nature. It is like a symphony; in which, every instrument is played at the most appropriate time to assemble a piece of harmonic music.

In this research, tape recorders and high precision sound pressure gauges were employed to record the changes of natural Soundscape within 24-h in a residential area in downtown Tainan City. From graph 11, we can clearly see

the rhythms and cycles of sounds made by birds, cicadas, frogs, and crickets in the course of a day. This research utilized a B&K four-channel data collection analysis system to record and analyze the levels of sound pressure made by birds and cicadas during the day by hour and extracted the Leq value of the most stable minute in each hour as an hourly reprehensive sound volume for the specific kind of natural Soundscape.

After screening the sound sources, we discovered that other than noises, natural soundscape can be classified into four categories, birds, cicadas, frogs, and crickets. During the research period, we found that the most beautiful and soothing sound of all is the first bird chirp during dawn (around 4:30 in summer). When the first chirp starts, all sounds made by frogs and other insects suddenly "quiet" down. These rhythms of natural Soundscape are like the main melodies of movements in a piece of music (Fig. 2).

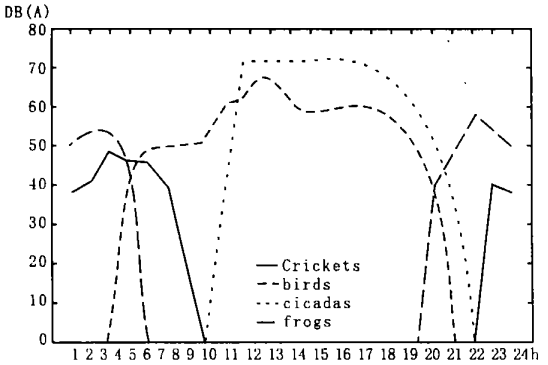

Fig. 2　The Rhythms of Natural soundscape in Downtown Tainan City

4　Conclusion

The objective of this research is to explore users' imagery factors, identify users' perceptions of commercial spaces, and gain the knowledge of users' "experience evaluation" on the sound environments of commercial spaces. In the on-site survey of the sound environments in Tainan City area, a Geographic Information System (GIS) was employed to construct the distribution graph of the sound environments. After merging with the updated drawing of the city layout, the two sides of major roads in the city are proved to be the noise belts. For the part of natural soundscape research, a distinct rhythm curve was derived from the actual survey on the rhythms of natural sound environment in Tainan City. Under the situation that the rate of complains of excessive noises has become increasingly higher, after successfully raised the awareness of dwellers in residential areas, awareness of environment users should also be promoted so that users will consciously reduce the artificial noises in the city and live harmoniously with the sound environment of the nature. The rhythm of the nature does exist in a city. The conclusions of this research are summarized in the following section: Most users of commercial spaces in the business district of Tainan City prefer to use commercial facilities in a pleasant and comfortable sound environment. However, the results of actual surveys on commercial sound environments indicated some certain variables to the above mentioned statement.

1. The average indoor background noise value of various commercial spaces measured in this research is 74 dB(A), which is considered high. Most business operators think that a higher volume of background music has positive effects in attracting customers. However, the results of this research shows that 63% of users think that a "moderate level" of sound volume is preferred, which evidently is in contrary to the opinions of the business operators. Nevertheless, 22% of users think that background music in commercial spaces is "the louder the better". This opinion is mainly shared by users age between 15 to 25. In contrary, 15% of users interviewed answered the same question as "the lower the better", which is an opinion share mainly by users at their 40s. Therefore, we can reach a conclusion that commercial space users of different age groups prefer different levels of sound volumes.

2. Three evaluation factors were derived from the constructed model of users' experience evaluation on the sound environments of commercial spaces. They are "pleasantness and comfort", "liveliness", and "warmth". The factors of "pleasantness and comfort" and "liveliness" were further put under a relationship analysis. From the results, the factor of "pleasantness and comfort" appears to have a negative relationship with the "sound volume". The relation coefficient is $r = -0.5582$, p value < 0.001, and standard error = 0.2142, which suggests that commercial settings do not need high sound volumes to achieve pleasantness and comfort. Derived from the result of a regression analysis, the sound volume perceived as pleasant and comfortable is 60 dB(A) and below. This figure also satisfies the volume standards stipulated in relevant noise control regulations.

3. The environments of spaces on commercial activity belts are greatly affected by load speakers and music, which transform the areas into high noise belts. Adding the noise

from the traffic, the whole business circle is infused with all kinds of noises. The place with the highest noise volume was measured at the Chungcheng Business Circle with a noise level reading at 86 dB(A), and the measurement of the lowest noise level was taken at the surrounding areas of the Cheng Yi Park at 46 dB(A). The maximum sound volume difference between the surrounding areas of a city green belt and spaces in a commercial area is as high as 40 dB(A).

4. By controlling the indoor sound volume to a level below 60 dB(A), a sense of pleasantness and comfort can be achieved as well as the standards of sound volume regulation stipulated in relevant noise control laws. This result suggested that an appropriate level of sound volume can not only induce a positive effect on commercial behaviors but also transform the commercial space into a more environmental friendly setting. According to the results of this research, "sound volume" corresponds directly to users' experience evaluation (ex: a sense of comfort or liveliness towards the commercial space). Therefore, the sound volume measurements (Leq value) adopted in this research can be used as "sound environment indicators" for evaluating a commercial space, and users' "experience evaluation indicators" can also be deduced from the data.

5. In the business district, loud speakers set up on the walkways by business operators often cause the background sound volume of the area to reach a volume level as high as 75 to 80 dB(A) during business hours. If the use of loud speakers can be limited, the situation can be greatly improved. The maximum sound volume in commercial areas in Tainan City can reach as high as 82 dB(A) and minimum sound volume 46 dB(A), which was taken in a residential area inside of a commercial district. The difference is 36 dB(A).

6. Comparing the density to noise level, commercial areas in the metropolitan that are further away from the two major commercial districts, the Chungcheng and Ximen districts, have relatively lower noise level. The sound volume distribution can be seen from the distribution of major roads in the city. In which, areas around or inside the greenery reserves in the city are all low noise areas (45 to 50 dB(A)), which suggests that open fields and greeneries are effective in reducing noises. Low noise areas in the city include Chungshan Park, Sports Park, Chen-Yi Park, and the surroundings of Cheng Kung University.

This research uses the "comfort" level evaluation indicator derived from the regression analysis on users' experience evaluation and utilized the calculation method and statistical results of physical measurements to effectively derive the most suitable sound volumes for users in commercial spaces. Utilizing the Geographic Information System (GIS) to pinpoint the sound environments in Tainan city has also been an effective method of model construction. This research serves as a substantial reference for implementing city sound environments and constructing the sound environments for commercial spaces.

REFERENCES

[1] Southworth M. The sonic environment of cities[J]. Environment and Behavior, 1969, 1: 49- 70.

[2] R P LAI. The study on urban green-sound environment index and strategy[R]. NSCT NSC- 89- 2621- Z006- 008, 1999.

[3] K T Tasi, R P Lai, The research of interactions between environmental sound and sight[A]. 17th International Congress Acoustics[C]. Rome, Noise, Soundscape, 2001, 9: 24- 25.

[4] K T Tasi. The study on urban green sound environment in Tainan area[D]. Tainan: Chengkeng University, 2002.

[5] K T Tasi. The study on the elements of soundscape in Tainan residents[D]. Tainan: Chengkeng University, 2002.

[6] K T Tasi, R P Lai, The sound environmental evaluation of urban commercial space users in Taiwan[A]. 8th Pacific Regional Acoustics Conference[C]. Melbourne, 2003.

[7] R P Lai, K T Tasi. M M Wu, et al. The Research & Development on Perforated Absorbing Structures[A]. 8th Pacific Regional Acoustics Conference[C]. Melbourne, 2003.

[8] K T Tasi, R P Lai. The research of interactions between environmental sound and sight[A]. 17th International Congress Acoustics[C]. VolumeⅢ, Noise, Soundscape, Rome, 2001.

[9] K T Tsai, R P Lai. The study on green sound environment of residential district in urban area[A]. The Seventh Western Pacific Regional Acoustics Conference[C]. Japan, 2000.