Primary Study on the Feasibility of Tranquil Space Design Based on the TRAPT Model, Considering the Visual and Auditory Factors—Take Zhao-lin Park as an Example

Huan QIN[1, 2, a*], Yuan-ting LIU[3,b] and Li-yu ZHANG[4,d]

[*]qinhuan0401@foxmail.com[a], liuyuanting@bdu.edu.cn[b], 2219673387@qq.com[c]

[1]School of Architecture, Harbin Institute of Technology, Harbin, China
[2]Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, Harbin, China
[3] School of Marxism, Baoding University, Baoding, China
[4]Xianyang Normal University, Xi'an, China

Abstract: Recently, more and more Chinese citizens are suffering from the unhealthy noisy hazards, especially because of the increasing of the cars in cities. It is necessary to provide some tranquil space for people in order to improve the quality of their urban lives. This study applied one approach named TRAPT which combine the visual and auditory factors together to conduct the tranquil space design. The results revealed that the TRAPT is coincident with subjects' tranquil feeling which evaluated by questionnaire survey. Also, some interesting and potential useful conclusions are shown in this study. (1) When TR is in the range of 4-5, upgrading the TR value could not significantly improve the tranquil feeling. (2) The plants' layouts have different impacts of tranquillity. Widening the planting area to decrease the noise level would be more useful than that prolonging the planting area to upgrade the value of NCF. (3) Although, artificial elements would decrease the NCF value, some particular elements, such as buildings could also decrease the noise level. Therefore, not all the artificial structures must be banned, even the tranquil space need some man-made structures as noise barriers to improve the tranquillity in some cases. This research provides the rules that could be used as potential references to conduct the tranquil space design in future.

Keywords: tranquillity, plants, noise, park, building

1 INTRODUCTION

Urban noisy pollution is one of the four major environment hazards in the world. The chance of suffering myocardial infarction would increase by 30% if people expose to noisy environment over a long period of time [1]. Neuroimaging studies revealed that tranquil space could improve the human brain's processing of sensory input by facilitating audio-visual interaction [5]. Kaplan found that green space could make people happy, the sound of nature could help people to recover from mental fatigue [9]. Researches by Berg, Lechtzin, Grahn and Ulrich shown that tranquil space could play a crucial role in stress reduction, happiness, longevity, pain relief, and the brain's processing of auditory signals [6, 7, 10, 12]. Herzog defined tranquillity as one composition of two parts: pleasant and quiet [11]. The tranquil space consists of background noise

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dominated by natural sounds or low artificial sounds for auditory experience, and comfortable green environment for visual experience. In this kind of environment, the comprehensive feeling of human body's hearing and vision is called the sense of tranquillity.

As one popular kind of noise reduction barrier, plants not only have a significant attenuation effect on noise but also make people happy through beautiful colours and pretty forms. So, planting could be considered as a package approach to create a tranquil space. Hu investigated the role of planting in creating a quiet environment by measuring the value of noise attenuation when the noise passing through the green belt [3]. In terms of vision, Tang reviewed the theory, methods and techniques of visual landscape assessment [14]. Also, some evaluate indicators were used in previous studies such as Green View Index (GVI), Google Street View (GSV) and Scenic Beauty Estimation (SBE) [4, 13].

This study adopted Tranquillity Rating Prediction Model (TRAPM) as a tool. The approach merged both visual and auditory factors together in consideration, and its work principle is just shown in Figure 1. This research aims to explore the feasibility of tranquil space design by green planting which owns the ability of two functions such as noise reduction and landscape creation.

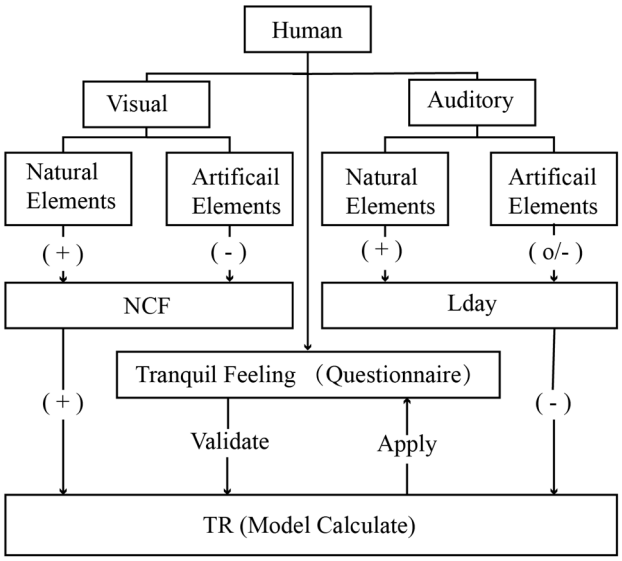

Figure 1: TRAPT's work principle

2 METHODOLOGY

2.1 Evaluation Indicator

The "Tranquillity Rating Prediction Model" that applied in this paper provides a more accurate approach for tranquillity assessment by incorporating visual and auditory factors together into the model. It is proposed by Watts who have made some outstanding contributions to rules' as well as standards' compiling about noisy control in UK [8]. And this model was also be validated

and calibrated in urban green space. The further researches' results shown that there would be a high correlation between tranquil environment and mental relaxation level ($r = 0.98$, $p < 0.001$) [2]. Formula of this model is shown as below (1):

$$TR = 10.55 + 0.041NCF - 0.146Lday + MF \quad (1)$$

In Formula (1), TR is short for Tranquillitzy Rating. NCF is short for Natural and Contextual Features and this parameter is a proportion value of the natural component in the entire visual scene (not include the sky area). Lday is short for Daytime Equivalent Constant A - weighted Level, and this parameter is used to assess the noise level. MF is short for Moderating Factors which is used to keep the TR value is in the range of 0 to 10.

Although, TRAPT is set up based on data from residents in UK, the subsequent studies found that the tranquil degree perceived by people who experienced different region and culture backgrounds, varies in a scale range according to verification of people's cognition on the tranquil degree of the same environment in different regions. For example, the value of TR=5.0 predicts that one space may have the potential to help almost 50% people obtain the benefit from its tranquillity. And the criteria for judging the TR is shown as below (Table 1):

Table 1: Criteria for judging the TR.

Range of TR	Criteria
[0.0 to 5.0）	Unacceptable
[5.0 to 6.0）	Acceptable
[6.0 to 7.0）	Good
[7.0 to 8.0）	Tranquil
[8.0 to 10.0）	Very tranquil

In order to obtain the value of NCF, we take pictures at every test point and then calculate how many the area of natural component occupying in entire photograph. Human horizon in the vertical plane without head rotation is about ±20°, which is similar as the visual angle of camera. Therefore, the pictures recorded in the vertical direction of the camera are basically in line with the human's perspective. So, we fixed the camera at the height of 1.5 meters (as same as adults' average visual height) above ground and used the devices' panoramic mode to record panoramagram of the test point.

To collect the data of noise, sound level meters (BSWA801) were used and it is necessary that sound calibrators were adjusted to 94dB in order to correct it before tests. Each test, these devices were set to record 18 numerical values simultaneously and these data values were collected 10 seconds interval.

In some practical cases of TRAPT, some special elements may have additional effects according to previous studies. For example, the sound of water could improve the tranquil sense, while rubbish could reduce the TR value by 1 unit. So, it is essential to apply MF to keep the TR value in the range of 0 to 10.

2.2 Experiment Details

2.2.1 Test Site

In this study Zhao-lin Park was selected as the test place. This park situated next to streets on 3 sides, and every street have busy traffic flow with severe noisy pollution.

Figure 2: Zhao-lin Park and the test points

Figure 2 shown 4 test points in this park, and these points were selected because of their differences in terms of NCF, plants density, planting layout and environment components et.al.

2.2.2 Questionnaire Design

Likert summated rating scale was used in questionnaires in order to measure the scale of subjects' psychological feelings such as **visual sense**, auditory sense and the overall tranquil sense. These indicators were used to assess the naturalness level (1=very low, 2=low, 3=normal, 4=high, 5=very high), noise level (very noisy, noisy, neutral, quiet, very quiet), and tranquil level (very bad, bad, normal, good, very good) respectively.

2.3 Data Manipulation

2.3.1 Sound Pressure Level

Each test point, we measure the sound pressure level data twice in order to make sure that the result is objective and accurate. The mean value of 2 group of data in point A test is 54.42dB and 54.58dB respectively. And the overall mean value is 54.50dB. Applying the same method, we get the data at point B, the value is 59.61dB, 58.37dB respectively. And the overall mean value is 59.00dB. Data we collect in point C is 61.38dB, 60.97dB respectively. And the overall mean value is 61.17dB. In pint D test, they are 66.57dB, 67.37dB respectively and the overall mean value is 66.97dB. Figure 3 shown the record data in the experiments as below:

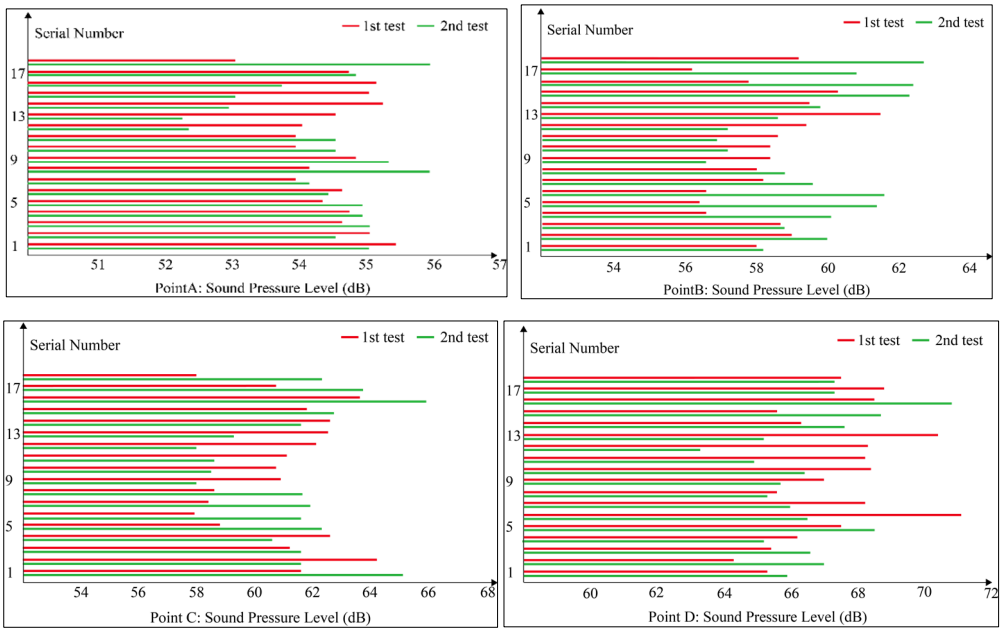

Figure 3: Value of Sound Pressure Level at 4 test points

2.3.2 NCF Calculation

We used grid-counting method to calculate the NCF with the help of AUTO CAD and the figure 4 shown the details.

Figure 4: NCF calculate by grid-counting method

The results shown that the value of NCF at point A, B, C, D is 46.3%, 65.5%, 53.2%, 57.1% respectively.

2.3.3 TR Calculation

There is no water around these 4 test points, so the MF value should be 0. However, at the point A, there is a rubbish bin exposing to people's sight, so the MF value of point A should be -1.

The TR formulas as below:

$$TR_A = 10.55 + 0.041 \cdot 46.3 - 0.146 \cdot 54.5 - 1 \approx 4 \quad (2)$$

$$TR_B = 10.55 + 0.041 \cdot 65.5 - 0.146 \cdot 59.0 + 0 \approx 5 \quad (3)$$

$$TR_C = 10.55 + 0.041 \cdot 53.2 - 0.146 \cdot 61.1 + 0 \approx 4 \quad (4)$$

$$TR_D = 10.55 + 0.041 \cdot 57.1 - 0.146 \cdot 67.0 + 0 \approx 3 \quad (5)$$

Formulas (2) to (5) shown the TR calculation processes of the point A, B, C, D respectively.

3 RESULT AND DESCUSSION

3.1 Plant Density

We compared the data of point B with point C, and the details are shown in table 2. Plant species around Point B and C are almost same. The plants consist of grass, shrub and arbor. However, the density of plants at point B is slightly higher than C. Therefore, the noise attenuation effect at B is more significant than C. The data shown that noise attenuation value at point B is 2dB higher than point C. Furthermore, there are memorial square and monument around point C, so the NCF here is only 53.2% while point B is 65.5%. Overall, the TR value is 5 for point B and 4 for point C, according to TRAPT model calculation.

Results of the questionnaire survey shown that the naturalness vote at point B is "slightly high" while at point C is "slightly low". And the noise vote at point B is "slightly neutral", while at point C is "slightly noisy". Although, on both aspects of visual and auditory sense, B is better than C, the tranquil feelings at these 2 points are both "normal", even the TR value of B (TR=5) is 1 unit higher than C (TR=4).

This means that the range of residents' tranquillity assessment is wider in the degree of "normal" than previous study. So, at these 2 test points, the tranquil level is acceptable for Harbin local people.

3.2 Green Blet Width

Green belt width between the road and the park inner side test points are different, such as C and D particularly. Therefore, this study compared the test point C with D, and the details are shown in table 3. It is apparently to find that the green belt width at point C is wider than D. And the value of Lday at point C (61.17dB) is lower than D (66.97dB), as a result of plants' noise attenuation effect. However, the NCF at point D is 57.1% while at point C is just only

53.2%. Furthermore, the TR value is 4 for C and 3 for D.

Meanwhile, the result of the questionnaire is almost coincident with objective data. According to the results of the survey, at point D the naturalness vote is “normal” and noise vote is “noisy”. For the results of point C, the naturalness vote is “slightly low” and the noise vote is “slightly noisy”. Although, in the terms of visual sense, point D is better than C, and in terms of auditory sense, point D is worse than C. However, feeling of tranquillity at point C is normal while at the point D is bad. For residents, the tranquil level at point C is “acceptable” (TR=4) and at point D (TR=3) is “unacceptable”.

Overall, there would be more significant effect of auditory factor than visual factor in tranquillity. The result shown that widening the green belt would be more worthy than that only prolonging it, to be an effective approach of tranquil space design.

3.3 Natural and Artificial Elements

We compared the results of point A and point D, and the details are shown in table 4. There is a building and rubbish bin around the point A, therefore the NCF there is only 46.3%, and the value is much lower than the value of NCF (57.1%) at point D. However, the Lday value at point A (54.50dB) is much lower than D (66.97dB), as a result of building’s noise attenuation effect. Also, the MF in point A’s TR formula is -1 because of the existing of the garbage bin, while MF is 0 in A’s formula. However, TR at point A is 4 and at D is 3 according to the TRAPT model. The TR value of point A is still 1 unit higher than D.

Furthermore, the results of questionnaire survey are coincident with TR, NCF as well as Lday in this experiment. The vote of naturalness at point A is “low”, while at point D is “normal” And the noise vote at A is “neutral”, while at D is “noisy”. In terms of visual sense D is better than A, however in terms of auditory sense A is better than D. People’s tranquil feeling at point A is normal, while at point D is bad. For residents, the tranquil level at point A is acceptable and at point D is unacceptable. This means that the auditory impact is more significant than visual, and this conclusion is as same as above “3.2”.

Overall, the existing of building at point A decrease the NCF but the tranquil is better than D because of the lower noise level value. So, some artificial elements such as buildings in park would also be needed to improve the tranquillity of park by their perfect significant noise attenuation effect than plants in some cases.

Table 2: Detail information of B & C

	Point B	Point C
NCF (%)	65.5	53.2
Lday (dB)	59.00	61.17
Planting Detail	Grass-shrub-arbor	Grass-shrub-arbor
Artificial Elements	YES	YES
TR	5	4
Naturalness Vote	Slightly High	Slightly Low
Noise Vote	Slightly Neutral	Slightly Noisy
Tranquillity Vote	Normal	Normal
Noise Attenuation(dB)	13.00	10.80

Table 3: Detail information of C & D

	Point C	Point D
NCF (%)	53.2	57.1
Lday (dB)	61.17	66.97
Planting Detail	Wide	Narrow
Artificial Elements	NO	NO
TR	4	3
Naturalness Vote	Slightly Low	Normal
Noise Vote	Slightly Noisy	Noisy
Tranquillity Vote	Normal	Bad
Noise Attenuation(dB)	10.80	5.03

Table 4: Detail information of A & D

	Point A	Point D
NCF (%)	46.3	53.2
Lday (dB)	54.50	61.17
Planting Detail	Not lush	Lush
Artificial Elements	YES	NO
TR	4	3
Naturalness Vote	Low	Normal
Noise Vote	Neutral	Noisy
Tranquillity Vote	Normal	Bad
Noise Attenuation(dB)	17.50	5.03

4 CONCLUSION

According to the above comparative experiments' results, 4 important conclusions were obtained and they could be potential as some references to conduce the tranquil space design.

Firstly, TRAPT is feasible as a tool to evaluate the space tranquillity, according to their coincident results of TR, NCF as well as Lday with questionnaire survey.

Secondly, when the value of TR is in the range of 4 to 5, the tranquil feeling could be same and acceptable for residents. However, it is possible to improve the tranquillity by planting more plants to upgrade the NCF as well as decrease the noise value according to the TRAPT.

Thirdly, it could be more effective to widen the green belt width to decrease the noise level than prolong the length of green belt to upgrade the NCF for tranquil space design.

Lastly, artificial elements such as buildings, squares could decrease the NCF, but they have different impacts on the space tranquillity. Buildings could also be regarded as an effective noise barrier to decrease the sound pressure level significantly, so it could still be useful to improve the tranquillity. However, the area of square is larger the tranquil assessment would be worse, so some special artificial elements could be minimized for tranquil space design.

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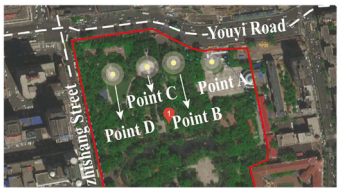
APPENDIX

Details of questionnaire is shown as below:

Q1. You are now standing at the test point of :



Q2. What do you think about the natural elements?
(The vote of naturalness)

1	2	3	4	5
Very Low	Low	Normal	High	Very High

Q3. What do you think about the noisy level?
(The vote of noise)

1	2	3	4	5
Very Noisy	Noisy	Neutral	Quiet	Very Quiet

Q4. What do you think about the tranquil level?
(The vote of tranquillity)

1	2	3	4	5
Very Bad	Bad	Normal	Good	Very Good