# Noise attenuation to Shenzhen international low-carbon eco-city

L. Yu[1], C. Wang[1], X. L. Zhang[1], Z. Yang[1]

[1] Shenzhen Graduate School of Harbin Institute Technology Science and Technology, R425 E-Building, HIT Campus, Shenzhen University Town, Shenzhen, Guangdong 519055, CHINA, Leilayu@hitsz.edu.cn

## ABSTRACT

The Shenzhen International Low Carbon Eco-city is located in the Ping Di area of Shenzhen Long Gang. It is a low-density place with a mixed land-use function where only one main road lying in. It is a quiet place and will be transformed into an eco-city according to the Shenzhen Master Plan. Aiming at to be a low carbon-emission area, noise attenuation has to be taken into account to help implement nature ventilation especially to the buildings along the roads. A noise mapping technique is then considered at the design stage for controlling noise ambition. Two standards are used to control noise problems in this study. One is to compare noise map of the current situation and the planned situation ensuring the planned one is no worse. The other is to use a standard derived from subjective evaluations based on on-site surveys to evaluate the noise ambition according to the noise map analyses of the master plan. Eventually, this study is going to provide feasible design approaches to control noise problems that might occur after the area development with using noise map analyses.

## INTRODUCTION

The Shenzhen International Low-Carbon Eco-city (SILCE) is located in the Ping Di, Shenzhen. Correspondent to serious environmental problems, a low-carbon developing concept is transformed into this project (Fan & Ma 2011). The whole area of the SILCE is about 53 square kilometres including manufacture, residential and commercial service sectors. The Area's is surrounded by hills on its north side and faces to a river on its south side. It is on the Economic Axis of the Shenzhen and Huizhou City and plays a key role in connecting the two economic and also a main logistics line from the Shenzhen to inner land. At present, the Area is a not well developed but with a rather good nature feature. An aim of the SILCE is to transform this un-well developed area into a low-carbon emission town as a deputy center outside the Shenzhen inner city. It will be a complement of the Shenzhen's redevelopment and also a low-carbon developing city model for the entire China. Through this low-carbon redevelopment project, the Area is going to attract high-class international low-carbon industrial's investment, which is why the project is named the SILCE. It is planned to be a mixed land-use area containing low-carbon manufactures, low-carbon financial services, residential, and public and commercial services, which a low-carbon living style is encouraged. According to the project master plan, a population of approx. 100 million will be obtained and plenty manufacture buildings as well as living apartments will be built (UPDIS 2013). In the meantime, the original town centre will be renewed to achieve a low-carbon development goal. Therefore, a low-carbon spatial urban form has to be transformed into the Area's re-forged, while an environment friendly supporting social well-beings is crucial in the project. It then has to take physical comfort into account, where acoustic comfort basically determining by noise impact cannot be ignored (Schulte-Fortkamp 2002; Yu & Kang 2008). In this paper, a study of environmental noise

attenuations to support acoustic comfort has been studied. The purpose of the study is to analyze the current noise environment and compared to the noise environment created by the master plan in order to make sure that the created noise environment is better at least not worse than the current situation.

## NOISE INVESTIGATION FOR CURRENT SITUATION

### Methodology

In order to analyse noise problems, it is essential to study noise-controlling standards in advance. According to Chinese national noise standards (NNS) in urban area, different land-use area has its different noise level limit as shown in Table 1. It can be seen that according to the NNS, the studied area currently falls to 2&3 functional zones, which the noise limit level is 60&65dB at daytime, and 50&55dB at nigh time respectively (CSAQSQ 2008).

**Table 1:** China national noise standards in urban areas.

| Functional zone | | Noise level limit | |
|---|---|---|---|
| | | Daytime (dB) | Nighttime (dB) |
| 0 – High-class residential recuperation area | | 50 | 40 |
| 1 – Residential & education & institute area | | 55 | 45 |
| 2 – residential, commercial and industrial mixed area | | 60 | 50 |
| 3 – Industrial area | | 65 | 55 |
| 4 | 4a – along a city's main road area | 70 | 55 |
| | 4b – along a city's railroad area | 70 | 60 |

As the NNS may not represent the local people's quietness requirement to a noise environment, on-site social surveys with simultaneously measurements have been done in order to obtain local people's exact noise requirement based on their evaluations. Four sites named Ge Keng, Gao Qiao, Fu Di, and some part of the Shen Hui road covering 2&3 functional zones have been investigated. In each site, fifty interviews have been randomly selected to get their quietness evaluations corresponding to the on-site noise environment. The result is illustrates that nearly 80% interviewees giving evaluations better than neither quietness nor noisy evaluations on the ge Keng and Gao Qiao. This means that 80% people would not be interfered by on-site noise, whereas this percentage drops to less than 50% on the Fu Di and the some part of the Shen Hui road. It is found that a noise level of the Ge Keng, Gao Qiao, Fu Di, and the some part of the Shen Hui road is 45dB, 55dB, 65dB, and 70dB respectively, implying 55dB could make apparently different for people's noise feeling. Comparing the on-site investigation result with the NNS, it is noticed that no different quietness feeling has been found according to the land-use difference. It is then using 55dB as a noise-impact standard for this study to evaluate a noise environment in this study. It is called without noise-impact standard (WNIS). It is interesting to note that the WNIS is a standard for 1 functional zone according to the NNS. In this study, these two evaluation standards are used to analyse a noise environment in order to completely present the noise environment of the area for aiding urban planners.

### Current noise map analyses

At present, the Area has only 250,000 people with a dis-advanced transportation network, which is the main source to contribute the area's noise environment. In order to give an entire noise distribution to the current situation, a noise map has

been produced using Cadna/A software for analysing the current noise environment of the area. As shown in Figure 1, it is found that a noise level along a road is usually higher than 65dB that is much noisier than inside a building block. A heavier transportation a road carries a higher noise level it has. The map shows that the Bei Tong, Shen Hui Road, and Hui Yan Highway as the main roads of the area, ranks the highest noise level that is approx. 70-80 dB. Amongst these three roads, the Hui Yan Highway's noise level is the highest and then the Bei Tong and Shen Hui road. A noise level of a branch road in the Area is a bit lower compared to the main roads, which is usually around 65-70dB. Apart from the Roads, the inside noise level of a block is further lower with a 60dB less. It is found that the stronger a block enclosed the lower the noise level is. Figure 1 also shows that the worst noise impact is from the Hui Yan Highway with a few buildings around, whereas the most building around is the Shen Hui road. A difference between the Shen Hui and the Bei Tong area is the land use, where the Shen Hui is for residential and commercial use and the Bei Tong is mainly for industrial use.

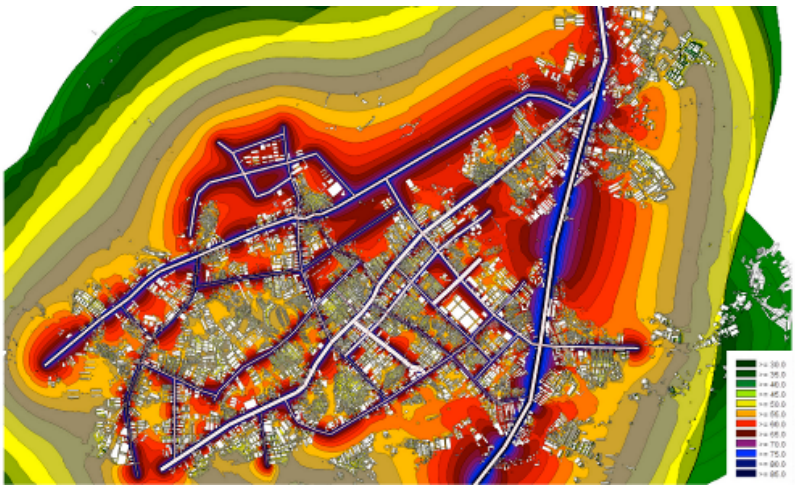


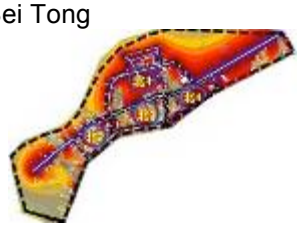
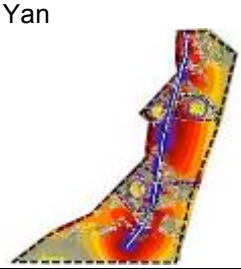
**Figure 1:** A noise map for the current situation

## Current noise influence analyses

Since noise impact is dominated by traffic noise, where the Bei Tong, Shen Hui and Hui Yan are mostly serious, the whole area is divided into three parts namely the Bei Tong, Shen Hui and Hui Yan, to analyse the area's noise environment using either the NNS or the WNIS. For each road area, typical regions have been selected to study noise impact. Four typical regions have been selected for the Bei Tong area, six for the Shen Hui area, and three for the Hui Yan area. A percentage of reached the NNS or WNIS area has been calculated and results are shown in Table 2. It can be seen that approx. 64% typical regions reaches the NNS whereas approx. 55% reaches the WNIS for the Bei Tong area. While approx. 66% reaches the NNS and approx. 59% reaches the WNIS for the Shen Hui area. And for the Hui Yan area, it is found that approx. 60% reaches the NNS but only about 52% reaches the WNIS. A reason might be that the current land-use of the Bei Tong area is industrial mixed residential belonging to a 2 or 3 functional zone according to the NNS that noise limit is 60&65dB for daytime, which is higher than the WNIS's 55dB. Similar as the Bei Tong area, the Hui Yan area belongs to a 2 or 3 functional zone according to the NNS, but with less reached standard areas no matter to the NNS or WNIS, which might be because of a higher noise level from the Hui yan highway. The best noise environment among the three areas is the Shen Hui. A possible reason is that the

area belongs to a 1 or 2 functional zone with a rather lower noise limit as a 55 or 60dB.

**Table 2:** A percentage of reached NNS and WNIS for the current situation.

| Area | | | Functional zone | Reached NNS Ratio | Reached WNIS Ratio |
|---|---|---|---|---|---|
| Bei Tong  | Bei-1 | | 2 | 64% | 56% |
| | Bei-2 | | 2 | 66% | 53% |
| | Bei-3 | | 2 | 65% | 58% |
| | Bei-4 | | 3 | 62% | 52% |
| Shen Hui | Shen-1 | A | 3 | 75% | 60% |
| | | B | 2 | 69% | 56% |
| | Shen-2 | A | 2 | 68% | 58% |
| | | B | 1 | 58% | 58% |
| | Shen-3 | A | 1 | 57% | 57% |
| | | B | 2 | 67% | 57% |
| | Shen-4 | | 1 | 59% | 59% |
| | Shen-5 | | 2 | 68% | 60% |
| | Shen-6 | | 3 | 73% | 60% |
| Hui Yan  | Hui-1 | | 2 | 61% | 54% |
| | Hui-2 | | 3 | 58% | 51% |
| | Hui-3 | | 3 | 62% | 52% |

Generally speaking, noise environment of the whole area at present is not well and noise problem cannot be ignored because there is still nearly 40% area or 50% area cannot reach the NNS or the WNIS. The land-use for the current situation is residential, industrial, commercial, or mixed, belonging to 1 or 2 or 3 functional zone according to the NNS. Based on above section analysis, only 1 functional zone has the same noise limit as the WNIS, whereas 2 or 3 functional zone's noise limit is higher than the WNIS's 55dB, which implies that less areas could reach the WNIS than the NNS, indicating that current national standard cannot exactly match the people's requirement for a noise environment. The result also shows that the worst noise environment is the Hui Yan and the best is the Shen Hui, demonstrating that the traffic amount and vehicle speed has more influence on a noise environment. In addition, the result also presents that a distance of a building to the road and a closure degree of a building block is important to a noise environment too.

## NOISE PREDICTION FOR THE MASTER PLAN

### The master plan noise map analyses

The purpose of the SILCE master plan is to use a diverse of strategies to forge a low-carbon working and living ecological town centre. Environment friendly is then an important aspect and noise environment cannot be ignored as its contribution to acoustic comfort as well as to help nature ventilation implement. Therefore, a noise

environment created by the master plan has to be examined especially at a design stage. Compared to the current situation, more branch roads have been added in the master plan, as an intensive redevelopment needs more transportation. In the master plan, heavy vehicles won't be allowed to pass through the Shen Hui road in order to reduce noise impact to the service area. Also using Cadna/A software, a noise map has been produced for the master plan in order to predict its created noise environment (Figure 2). It can be seen that the Bei Tong, Hui Yan and an added Wai Huan Highway contribute most noises that is about 80-85dB to the entire area according to the master plan. As heavy vehicles are forbidden in the Shen Hui road, its noise level lowers a bit and becomes less serious compared to the Bei Tong, Hui Yan and the Wai Huan. It is clear to see that noise level of the area improves much due to more roads added. For the Bei Tong road, the noise level is about 80dB, which is higher than the current 75dB, whereas noise level of some blocks is about 65dB. For the Hui Yan Highway, the noise level still remains to 80dB as no further traffics added. As more building blocks are added to the Hui Yan area according to the master plan, a noise level of some block inside is going up to 65dB higher than the current situation because of closer to the Highway. However for the Wai Huan Highway, although its noise level is high but as staying a bit far from the SILCE, it has little influence on the entire area's noise environment. For the Shen Hui road, as heavy vehicle is forbidden, the noise level of the master plan is about 70dB that is 5dB lower compared to the current situation. To this area, more branch roads improve the noise level of the entire area, however, for some stronger enclosed block, a lower noise level of 45dB has been found.

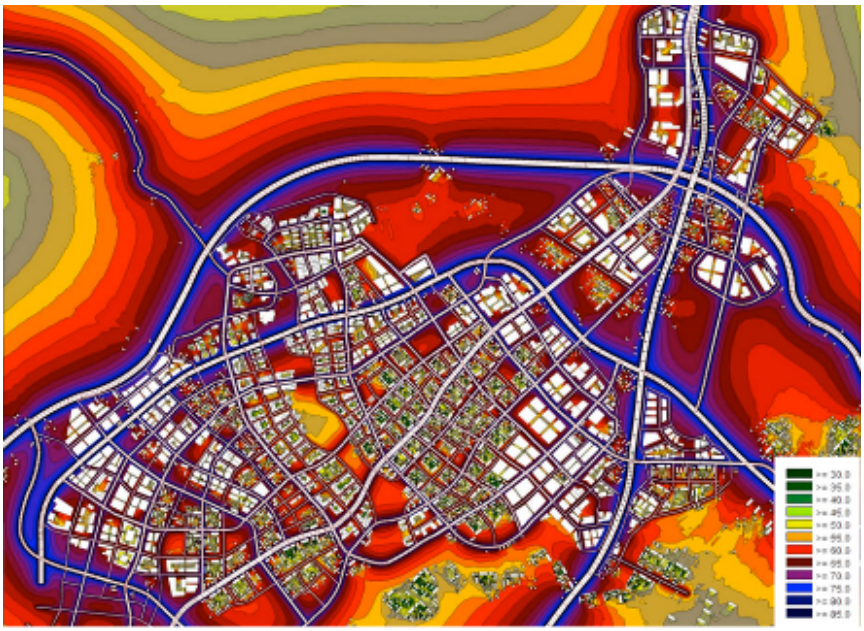


**Figure 2:** A noise map for the master plan

## The master plan noise influence analyses

The same typical regions of the Bei Tong, Shen Hui and Hui Yan area are selected to analyse the noise environment created by the master plan in order to consistent with the noise environment analyses of the current situation. The result is shown in Table 3. It can be seen that 55% area has reached the NNS and 46% reached the WNIS for the Bei Tong area. While for the Shen Hui and Hui Yan area, 56% and 55% has reached the NNS, and 48% and 46% reached the WNIS respectively, indicating that the Shen Hui has the best noise environment than the others. This might be because

heavy vehicle has been forbidden additional north-south roads for diverting the Shen Hui traffic loads to the Bei Tong are not near to any intensive residential block. Generally speaking, the noise environment created by the master plan is worse than that of the current due to an intensive development. However, this is not too worse as a percentage value of the reached NNS or WNIS to the master plan is only a few lower than the current. Nevertheless, improvement has also to be made in order to reach the goal of noise environment created by the master plan better at least not worse than the current situation.

**Table 3:** A percentage of reached NNS and WNIS for the master plan.

| Area | | | Functional zone | Reached NNS Ratio | Reached WNIS Ratio |
|---|---|---|---|---|---|
| Bei Tong | Bei-1 | | 2 | 54% | 47% |
| | Bei-2 | | 3 | 57% | 44% |
| | Bei-3 | | 2 | 55% | 46% |
| | Bei-4 | | 3 | 53% | 42% |
| Shen Hui | Shen-1 | A | 3 | 62% | 48% |
| | | B | 2 | 58% | 46% |
| | Shen-2 | A | 2 | 57% | 47% |
| | | B | 1 | 49% | 49% |
| | Shen-3 | A | 1 | 48% | 48% |
| | | B | 2 | 57% | 48% |
| | Shen-4 | | 1 | 50% | 50% |
| | Shen-5 | | 2 | 56% | 47% |
| | Shen-6 | | 3 | 63% | 50% |
| Hui Yan | Hui-1 | | 2 | 53% | 46% |
| | Hui-2 | | 3 | 51% | 42% |
| | Hui-3 | | 3 | 52% | 45% |

## COMPARISONS AND SUGGESTIONS

### Comparisons of the current and master plan

Compared the noise map of current situation and master plan as shown in Figure 1 & 2, it is obviously to see that noise environment of the master plan is worse. This might be because a rather large amount of transportation bringing more noises. To the Bei Tong area, noise level of the master plan for the most part is around 65dB, whereas it is usually 60dB to the current situation. A comparison of a percentage of reached NNS or WNIS of the current and the master plan shows that less than 9% selected region's area can reach either the NNS or WNIS to the master plan than the current, proving again that the noise environment created by the master plan is worse and a further improvement has to be made. Same as the Bei Tong area, the noise environment of the Shen Hui area is worse too. Comparing the master plan

with the current, it is found that 9% and 10% less area can reach the NNS and WNIS respectively. A similar result is obtained to the Hui Yan too as an 8% less area is found to reach the NNS or WNIS. In total, 8% and 9% less area can reach the NNS and WNIS respectively. Therefore, improvement strategies at the design stage have to be considered. The study demonstrates that the Shen Hui has the best noise environment while the Hui Yan has the worst no matter according to the NNS or the WNIS, which illustrates that a different traffic amount or a different urban form could present a different noise environment for an area. Therefore, a diverse of strategies need be adopted.

### Suggestions

Based on a comparison analysis of noise impact on the current and the master plan, it is found that a worse noise environment created by the master plan, where strategies to noise attenuation as studied by many authors have to be considered at the planning design stage (Pyoung et al. 2007; Hossanet al. 2005; Kang 2006). For the Bei Tong area, a serious noise problem is from a junction of the Bei Tong road and Wai Huan Highway. It is then suggested to design more enclosed blocks for this part. In addition, as the Bei Tong and Wai Huan are rather wider roads with about a 100m width, it is suggested that a distance from 35m to 50m by of a building to the road can mostly reduce noise level as proven in the previous study (Wang 2013). Furthermore, an angle of 15 to 45 degree can also benefit noise attenuation to the Bei Tong area. Although as having enough width, proper landscapes design to use a combined green belt can also the area's noise environment too. Moreover, putting service spaces such as stairwell, toilet towards the road is useful to improve noise environment for the Bei Tong area too. The noise problem of the Hui Yan area is similar as the Bei Tong because of having similar traffic loads as well as industrial blocks. Strategies used to the Bei Tong area are then useful to to the Bei Tong area. Besides, as the Hui Yan is a highway, noise barrier is considered to be an efficient approach to improve the noise environment of the area. A serious noise problem to the Bei Tong and Wai Huan area occurs in the intersection. Noise level of that part can even reach 65dB extremely influencing people's life. A necessary strategy dealing with such a problem is a design approach of mixing noise barrier and landscape method. As the Shen Hui road is not as wide as the Bei Tong and Hui Yan, it is suggested to put a building 35m away from the road as been proven an efficient noise attenuation distance. A different landscape approach used for the Shen Hui from the Bei Tong and Hui Yan is to use rather simple landscape with only two-level green belt, brushes and street trees. A useful planning approach to the Shen Hui is controlling the vehicle type and speed. It is proven usful to forbid heavy vehicles in this area as shown in above section. Furthermore, controlling car-speed and setting pedestrian are also efficient to attenuate noise level. In addition, architectural design strategies such as proper room arrangement, good noise attenuation balcony or shading device, as well as noise protection windows also help to improve noise environment in this area.

## CONCLUSION

In this study, noise impact on the Ping Di, Shenzhen has been studied in order to provide a good noise environment to the SILCE project. The study explored the subjective quietness evaluations based on on-site investigation. It is found that 55dB is a standard for the local people not feeling noise in an environment, which is a rather lower sound level comparing to the national regulation, NNS. Therefore two

standards for noise limit has been used to analyse an area percentage three main roads' area have been made to some typical regions. It shows that a noise environment created by the master plan of the project is worse than that of the current situation due to an intensive re-development. Some strategy such as forbidding heavy vehicles has been adopted in the master plan that makes the master plan having a rather better noise environment. However, more improvement has to be made according to a comparison of noise impact on the current and the master plan, as approximately 9% area less cannot reach the NNS or WNIS if comparing the master plan to the current situation. Eventually, some suggestions have been made to improve noise environment for the master plan at the planning design stage.

## REFERENCES

Fan G, Ma WH (ed) (2011). Low carbon city in action: policy & practice. Bei Jin: Economic Press, China.

UPDIS (2013). A master plan of the Shenzhen international low-carbon eco-city. Unpublished.

Schulte-Fortkamp B (2002). The meaning of annoyance in relation to the quality of acoustic environments. Noise and Health 4:13-18.

Yu L, Kang J. (2008). Effects of social, demographic and behavioral factors on sound level evaluation in urban open spaces. J. Acoust. Soc. Am., 123, 772-783.

CSAQSQ (China State Administration of Quality Supervision and Quarantine) (2008). People's republic of China national standard: environmental quality standard for noise. Bei Jin: Chinese Environment Science Press.

Pyoung JL, Yong HK, Jin YJ, Kyoo DS (2007). Effects of apartment building façade and balcony design on the reduction of exterior noise. Building and Environment, 3417-3528.

Hossan H, Dien El, Woloszyn P. (2005). The acoustical influence of balcony depth and parapet form: experiments and simulations. Applied Acoustics, 533-551.

Kang J. (2006). An acoustic window system with optimum ventilation and daylighting performance. Noise & Vibration Worldwide, 9-17.

Wang C (2013). Design approaches of Shenzhen along-road high-rise residential buildings in terms of traffic noise. Master Thesis: Shenzhen Graduate School HIT.