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Effect of the Green Deck on Local Noise Environment

(Final Report)

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Effect of the Green Deck on Local Noise Environment (Prof. SK Tang)

Noise levels at various locations on PolyU podium and entrance facing the Cross Harbour Tunnel toll gate areas are simulated using a ray-tracing algorithm. The present simulation results confirm the potential of high noise levels on PolyU podium facing the proposed Green Deck. The noise level at PolyU entrance will increase by 8 dBA, while some locations along the PQ, CD and DE cores will receive a noise level ~ 5 to 6 dBA above the present figures. The noise levels underneath the deck will also be very high. A 12 dBA increase in the noise level is obtained under the deck.

It is proposed to use louvres together with micro-perforated sound absorbers and powerful sound absorbers as the noise mitigation measure. The lourves and the sound absorbers are proposed to be lined along the Green Deck's near edge (along Hong Chong Road) while the other sound absorbers are proposed to be lined beneath the deck and on the wall of Hung Hom Station (along Hong Chong Road). The noise level at PolyU entrance, which will be the worst location affected by the Green Deck in term of noise, is estimated to be ~5.4dBA higher than the current condition in the absence of the noise mitigitation. However, with the proposed noise mitigation measures, the Green Deck would be able to reduce the current traffic noise problem to PolyU and the surrounding by at least 1.5 - 2dBA in general, which the noise levels under the Deck remain nearly unchanged.

Content

SUMMARY

The effect of the proposed Green Deck on the nearby noise environment is studied. As the Green Deck, as it is currently designed, does not fully cover the area between the Hung Hom Railway station and PolyU, the noise trapped inside the cavity below the proposed deck will radiate out through all the openings. Some of these openings are next to PolyU and some of them form horn-like structures which could radiate sound effectively to the surrounding. The exceptionally high noise level underneath the deck because of the reverberation will also have adverse effect to the users of the toll area. The major objectives of this study are to estimate the effect of the Green Deck as it is currently proposed and to explore appropriate noise mitigation measure.

The work was carried out in two stages. The first stage consisted of a noise measurement for a rough understanding on how the Green Deck, under the current design, would affect the noise levels nearby, especially the podium and entrance areas of PolyU. The second stage was detailed numerical simulations. A noise mitigation measure is proposed. Without any noise mitigation measure, the noise level at PolyU entrance is likely to increase by 8 dBA, while some locations along the PQ, CD and DE cores would be ~ 5 to 6 dBA above the present figures. A 12 dBA increase in the noise level is likely to be found under the deck.

The proposed noise mitigation measure consists of a transparent lourves with micro-perforated panels and strong sound absorption materials. Louvres with 50% opening are proposed to be installed along Hong Chong Road. Sound absorbers are added to the bottom of the deck and on the external wall of Hung Hom Station facing Hong Chong Road. Footbridges linking Hung Hom Station, the cavity under the Deck and PolyU are proposed to be fully enclosed. With this proposal, the Green Deck would be able to reduce the current traffic noise level at PolyU by ~3dBA on average. The noise levels under the Deck remain nearly unchanged. The noise reductions at locations nearby the Hunghom MTR station and the Hong Kong Coliseum would be within 3 to 20 dBA.

I. INTRODUCTION

Recently, there is a proposal on the building up a Green Deck which will cover the toll area of the Cross Harbour Tunnel. The proposed deck is large and is expected to be able to foster strong connectivity between various areas surrounding the toll area. The current conceptual design of the Green Deck is shown in Figure 1.

Figure 1 : Conceptual Design of the Green Deck

In principle, the deck will cover the traffic within the toll area of the Cross Harbour Tunnel and will provide some acoustical protection to the surrounding building if one sticks to the principle of noise reduction due to obstruction of the direct-line-of-sight [2]. However, this deck tends to tunnel the sound sources, resulting in the accumulation of acoustical energy under the deck. This energy will then radiate out of this semi-enclosed under-deck cavity at the openings. These openings then act as large horns which radiate sound powerfully into the surroundings [3]. Such radiation can be so powerful to result in significant rise in noise levels at locations even several kilometres away. It appears that some openings are directed towards PolyU and/or near to PolyU, the MTR station and the buildings flanking Hong Chong Road (and even Austin Road). Such accumulation of sound energy also results in very high noise level under the deck. This will affect all the vehicle drivers in this area.

The major objectives of this study are to estimate the effect of the Green Deck as it is currently proposed and to explore appropriate noise mitigation measure. Since the design of the deck is not in its final stage, the mitigation measure proposed later in this report is indicative and can be used as a reference for the final design.

II. EXISTING ROAD TRAFFIC NOISE AND PROJECTIONS

An estimation of the effects of the proposed Green Deck on the noise levels around PolyU is done in the first place in order to understand the possible change of noise environment after the Green Deck is built based on the current design.

Noise measurements were carried out around the areas of PolyU facing Hong Chong Road connecting to the toll area of the Cross Harbour Tunnel. Figure 2 illustrates their locations. The purpose of the measurements is to obtain an understanding on the current noise levels around the most influenced regions of PolyU. This measurement will provide data for the estimation of the likely sound power of the traffic for the estimation of the noise levels after the toll area is covered by the Green Deck.

Figure 2 : Locations of measurements (A, B, C and D)

The measurements were performed using standard procedure [4]. During each measurement, the microphone of the sound level analyser B&K2270 was located 1 m away from the podium/roof-top façade. Each measurement lasted for 1 hour with traffic condition recorded using a video camera. Figure 3 shows the views of Hong Chong Road at Points B and A.

Figure 3 : Photographs taken at measurement locations (Left : Point B, right : Point A)

Table 1 summarizes the measured noise data, distances of measurement points from road (according to CRTN [5]) and the traffic conditions during the measurements. It can be seen that the average vehicle speed along Hong Chong Road was not high, probably because of the toll area and the large traffic volume. Vehicles in the near lanes were in general moving faster than those in the far lanes during the measurements.

Pt.	Slant Distance (m)	Date	Period	Noise Levels (dBA)		Traffic Condition		
				L_{A10}	L_{Aeq}	No. of Vehicles/hr	Speed (km/hr)	% Heavy Vehicle
A	23.0	18/11/13	16:42 – 17:42	75.4	73.7	9439	42	30.3
B	12.5	21/11/13	11:14 – 12:14	80.2	78.1	7900	27.8	23.0
C	12.5	13/11/13	15:57 – 16:57	78.9	76.5	7445	35	21.5
D	31.2	20/11/13	15:24 – 16:24	77.9	76.0	9120	11.1*	17.2

Table 1 : Noise measurement results
**Traffic jam on far lanes (Island bound)*

The measured noise levels are high, even in the case of a far-lane traffic jam. Point D is located at the near lane exit of the toll area where vehicles should be accelerating under relatively free-flow condition and thus producing strong noise. The number of vehicles running along the near lanes during the measurement at Point A was not so high (Fig. 2), resulting in a lower noise level measured at Point A.

Road traffic is usually regarded as a line source with the sound intensity varies reciprocally with the slant distance, d [5]. Its power per unit length, W, can then be estimated for simplicity as

W = Intensity $\times$ $2\pi d$.

From the data in Table 1, the maximum W is that associated with the measurement at Point D, which reaches ~99 dB (based on the L_{Aeq}). The curve length of the proposed Green Deck is 540 m and that of its side adjacent to MTR Hunghom station is 500 m. The average length of the Deck is thus assumed to be 520 m (L). The level of the total sound power that will be generated underneath the proposed Green Deck will thus be 126 dBA. This is a very high value and thus noise mitigation must be done within the future toll area.

The proposed Green Deck will cover the whole toll area. For a quick analysis on the effect of the Deck on PolyU, it is assumed that the region below the Deck will be reverberant as there is no indication of any noise control measure underneath the Deck [1]. All the sound power will then be radiated out through all the openings uniformly. The architect has provided two section views of the Deck. One section shows a deck height of 10.2 m and the other 15.4 m. For simplicity, it is assumed that the average deck height above ground is 12.6 m. The total area A for sound radiated out of the space underneath the deck will then equal

$A = 12.6 \times (540 + 16) = 7005.6\ m^2$,

assuming that noise cannot go into the rail platform. Sound intensity at openings will be *WL/A* which in term of decibel is 87.6 dBA. Since the average deck height is slightly higher than the podium level of PolyU, noise levels in term of L_{Aeq} at PolyU entrance, along PQ podium (or even that of QT) and at the PolyU library façade can be over 85 dBA after the completion of the proposed Green Deck. It is expected that the noise levels at higher height levels are reduced by the proposed Green Deck.

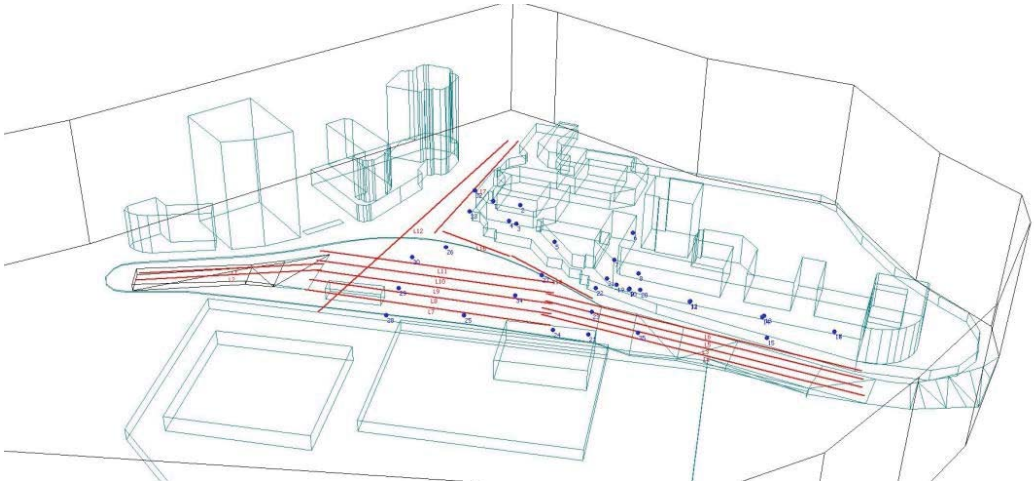
III. NUMERICAL SIMULATIONS OF GREEN DECK'S EFFECT ON NOISE

3.1 Numerical Ray-tracing scheme

The site in concern is too big so that the finite-element or boundary-element methods are not applicable because of computer resources constraint. The ray tracing method [6] is commonly used in this circumstance.

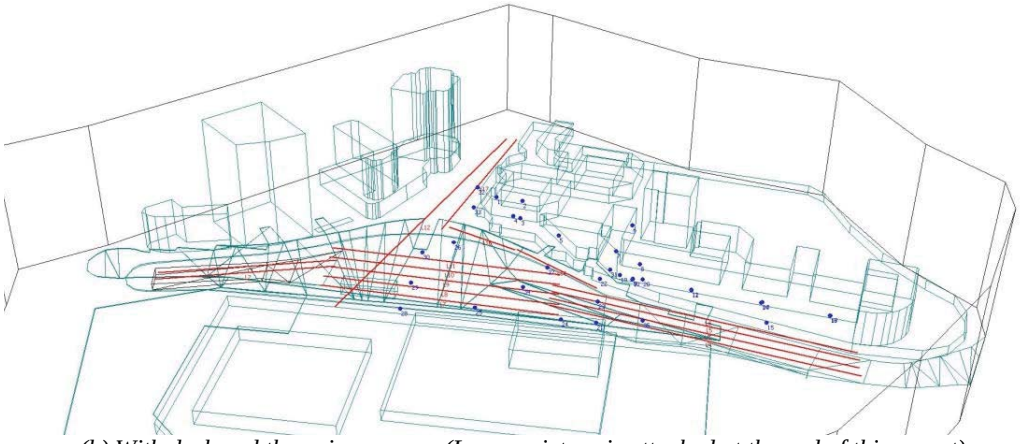
In this study, numerical modelling using ray tracing algorithm implemented in ODEON v.8 was carried out for the octave bands from 125Hz to 4kHz (Traffic noise frequency range). The ray-tracing technique is originally used in optics. In acoustics computation, the sound energy radiated out from a source is assumed to be carried by rays which move in a straight line until they hit a reflecting surface. The energy of a ray will be reduced according to the sound absorption properties of the surface it hits. Each ray has an initial energy which is the total sound energy emitted by the source divided by the number of rays used for computation. ODEON is a piece of software which combines the ray-tracing algorithm with image source methods for more reliable results and faster calculation (hybrid model). In ODEON v.8, the reflection based scattering method and the oblique Lambert are adopted for better handling of scattering.

Figures 4a and 4b show the computational models in the ODEON for the cases without and with the Green Deck respectively. The numbered blue dots represent the check points where noise levels are calculated.



(a) Without deck

Figure 4 : Computational models in ODEON



(b) With deck and the noise sources (Larger picture is attached at the end of this report)
Figure 4 : Computational models in ODEON

For simplicity, the traffic, which is the major source of sound, is assumed to be made up of a number of line sources of finite length (5 m each), but of different powers because of the differences in the traffic flow volume and expected average vehicle speed. Tables 2 and 3 summarize the input data to ODEON. The data in Table 2 look a bit arbitrary, but this is no big problem as we are predicting the noise level difference between the cases with and without the Green Deck.

Source	Location	Sound Power (dB)
L1	At Cross Harbour Tunnel Entrance	120
L2	At Cross Harbour Tunnel Entrance	120
L3	Hong Chong Road towards Ho Man Tin	100
L4	Hong Chong Road towards Ho Man Tin	100
L5	Hong Chong Road towards Ho Man Tin	100
L6	Hong Chong Road towards Ho Man Tin	100
L7	Cross Harbour Tunnel Toll Gate Area	98
L8	Cross Harbour Tunnel Toll Gate Area	98
L9	Cross Harbour Tunnel Toll Gate Area	98
L10	Cross Harbour Tunnel Toll Gate Area	98
L11	Cross Harbour Tunnel Toll Gate Area	98
L12	Hong Chong Road towards Toll Gate	98
L14	Hong Chong Road (near lane to PolyU)	98
L15	Hong Chong Road (near lane to PolyU)	98
L16	Hong Chong Road (near lane to PolyU)	98
L17	Hong Chong Road (near lane to PolyU)	98

Table 2 : Traffic Noise Powers (constant for all frequencies)

Surface	Material	Sound Absorption Coefficient					
		125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
Roads, outdoors	Rough concrete	0.02	0.03	0.03	0.03	0.04	0.07
Windows, Curtain wall	Glass, large panes of heavy plate glass	0.18	0.06	0.04	0.03	0.02	0.02
External wall, PolyU tiles	Marble or glazed tiles	0.01	0.01	0.01	0.01	0.02	0.02
Buildings façade	smooth painted concrete	0.01	0.01	0.02	0.02	0.02	0.05
Poly podium ceiling	smooth concrete painted or glazed	0.01	0.01	0.02	0.02	0.02	0.02

Table 3 : Sound Absorption Coefficients of Surfaces

3.2. Change of Noise Levels due to the Green Deck

In order to make the noise reduction relevant to traffic noise, the normalized traffic noise spectrum in EN1793-3 [7] is adopted to produce a single A-weighting rating. This is a common method to study the performance of frequency-sensitive noise attenuating devices [8,9]. Table 4 illustrates the rise in noise levels after the installation of the Green Deck. Negative figures devote noise reduction.

Check Point	Location	Noise Level Increase (dB)						
		125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	Weighted*
1	CD podium	4.4	4.1	4.0	3.9	3.5	2.4	3.4
2	DE courtyard	5.9	5.6	5.7	5.9	5.8	5.0	5.5
3	DE podium	4.9	4.6	4.6	4.5	4.1	3.0	4.0
4	DE façade	6.3	5.8	5.7	5.5	4.8	2.7	4.8
5	Library façade	2.6	2.2	2.2	2.0	1.4	0.3	1.5
6	Library entrance	-0.3	-0.8	-0.8	-0.7	-0.8	-0.8	-1.0
7	Library	5.5	4.5	4.3	4.0	2.8	0.4	3.2
8	Lawn	3.3	2.6	2.5	2.3	1.7	0.5	1.8
9	P Podium	9.3	8.3	8.1	7.8	6.6	3.6	6.9
10	P Façade	1.4	0.8	0.7	0.5	0.0	-0.7	0.1
11	PQ podium	9.8	8.5	8.2	7.6	5.9	2.5	6.4
12	PQ façade	1.8	1.5	1.4	1.2	0.8	-0.1	0.8
13	QT podium	6.2	5.2	5.0	4.5	3.4	0.8	3.7
14	QT façade	1.5	1.2	1.1	1.0	0.7	0.3	0.6
15	QT podium	2.7	2.3	2.0	1.7	1.0	0.2	1.2
16	TU Podium	4.1	3.6	3.4	3.0	2.0	0.5	2.4
17	TU façade	1.2	0.8	0.5	0.2	0.2	0.2	0.1
19	Entrance to podium, around security desk	9.8	8.5	8.2	7.7	6.0	2.7	6.5
20	P podium	9.1	8.0	7.7	7.3	5.8	2.9	6.3
21	Footbridge	13.6	12.7	12.4	12.0	10.5	6.9	10.8
22	PolyU Entrance, Bridge	10.3	9.5	9.3	9.0	7.8	5.1	8.1
23	Footbridge	10.8	9.9	9.6	9.2	7.7	4.9	8.2
24	Bus stop area	14.9	13.9	13.6	13.2	11.5	7.2	11.8
25	Bus stop area	16.1	15.1	14.9	14.4	12.7	7.9	12.9
26	Bus stop area	11.9	11.1	10.9	10.5	9.3	6.5	9.6
27	Bus stop area	10.9	10.0	9.8	9.4	7.9	4.5	8.3
28	MTR Exit D bridge	14.2	13.3	13.1	12.9	11.9	9.5	12.1
29	MTR Exit D bridge	13.6	12.6	12.3	12.1	10.8	7.7	11.1
30	MTR Exit D bridge	11.7	10.8	10.6	10.3	9.0	6.4	9.4
31	Entrance to podium, around security desk	3.3	2.5	2.4	2.2	1.7	1.0	1.8
32	Hong Tai Path	2.1	1.9	1.7	1.6	1.1	0.4	1.2
33	Hong Tai Path	4.6	4.2	4.0	3.9	3.3	1.9	3.4

Table 4: Rise in Noise Levels after Installation of Green Deck
**Weighted by normalized traffic noise spectrum [7,8,9]*

The highlighted check points in Table 3 are within PolyU. One can observe that there is a considerable level of noise level increase at locations on PolyU podium facing the proposed Green Deck. Overall, the presence of the Green Deck, as it currently designed, will increase the noise levels on PolyU podium by ~ 5dBA on average, which agrees with the conclusion

of the empirical approach in Section 2. At location at PolyU entrance landing connecting to the footbridge (Check point #22), the noise level will increase by 8 dBA. Under the Deck, the noise level increase can be above 12 dBA. The corridor connecting PolyU and the HungHom MTR station needs careful design to shield off noise.

IV. NOISE MITIGATION MEAUSRE PROPOSAL

To reduce the noise level, it is proposed to add louvres and sound absorption to the Green Deck and surroundings. Louvres with 50% opening are proposed to be installed along Hong Chong Road. Conventional porous sound absorbers, like fibreglass, are not so suitable to be used in this region because of the high large particulate concentration. Micro-perforated panel absorbers are proposed as they can be cleaned if necessary and are transparent. Sound absorbers are added to the bottom of the deck and on the external wall of Hung Hom Station facing Hong Chong Road. Footbridges linking Hung Hom Station, the cavity under the Deck and PolyU are proposed to be fully enclosed so as to further reduce the noise intruding into PolyU podium level.

In the Odeon model, louvers are added along the edge of the Green Deck along Hong Chong Road from Cheong Wan Road to the deck's ending near Core Q (Fig. 5). The louvers drop from the bottom of the deck to 9.8 m level. Figure 6 shows the schematics of the proposed noise mitigation measure. The MPAs are located on the inner side of the louvers along the deck. Table 5 shows the absorption coefficients of the metal louvres and MPA with 50mm air spacing adopted in the simulation.

Surface	Material	Sound Absorption Coefficient					
		125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
Roads, outdoors	Rough concrete	0.02	0.03	0.03	0.03	0.04	0.07
Windows, Curtain wall	Glass, large panes of heavy plate glass	0.18	0.06	0.04	0.03	0.02	0.02
External wall, PolyU tiles	Marble or glazed tiles	0.01	0.01	0.01	0.01	0.02	0.02
Buildings façade	smooth painted concrete	0.01	0.01	0.02	0.02	0.02	0.05
Poly podium ceiling	smooth concrete painted or glazed	0.01	0.01	0.02	0.02	0.02	0.02
Micro-perforated panel absorbers (MPA)	Micro-perforated member mounted with 50mm air gap with attaching surface	0.00	0.05	0.15	0.50	0.60	0.40
Fibreglass, 2-inches thick	2 inches thick 48kg/m^2 fibreglass blanket without backing	0.17	0.86	1.00	1.00	1.00	0.98

Table 5 : Sound absorption coefficients of material surfaces in the simulation of noise mitigation measure

In addition, 2-inch thick fibreglass panels are proposed to be installed as the sound absorbers under the proposed Green Deck and on Hung Hom Station external wall next to the cavity under the Green Deck. Sound absorption material that have the equivalent absorption coefficients, can be used in construction. Further, the footbridges linking PolyU, the cavity under the Green Deck and the Hung Hom station are enclosed by rigid walls in the simulation model.

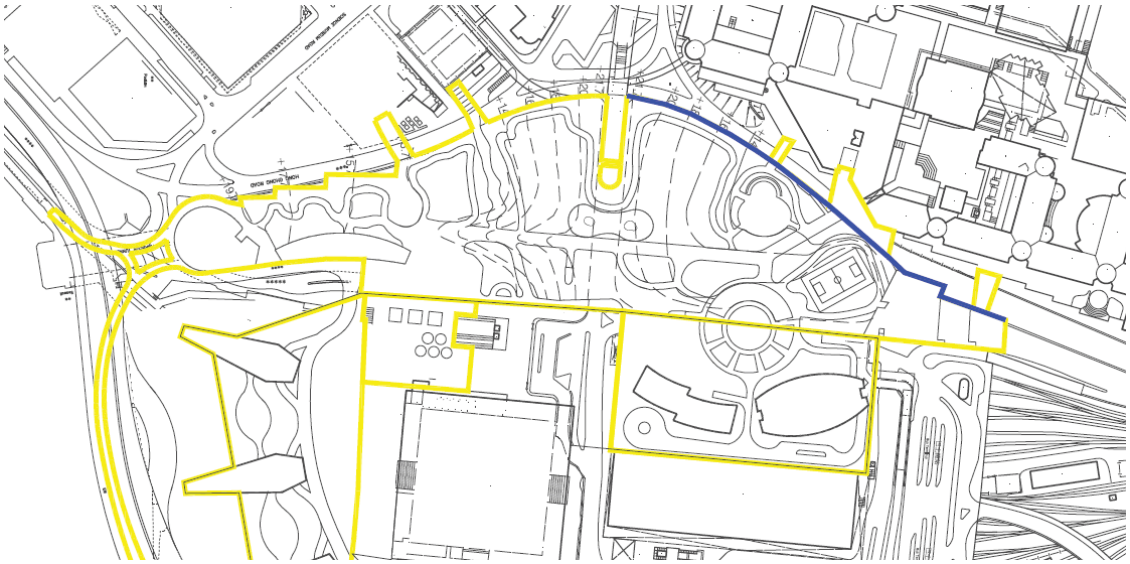


Figure 5: Mark-up plan of Green Deck and vicinity.
(yellow line – Green deck, Blue line – louvres and MPAs)

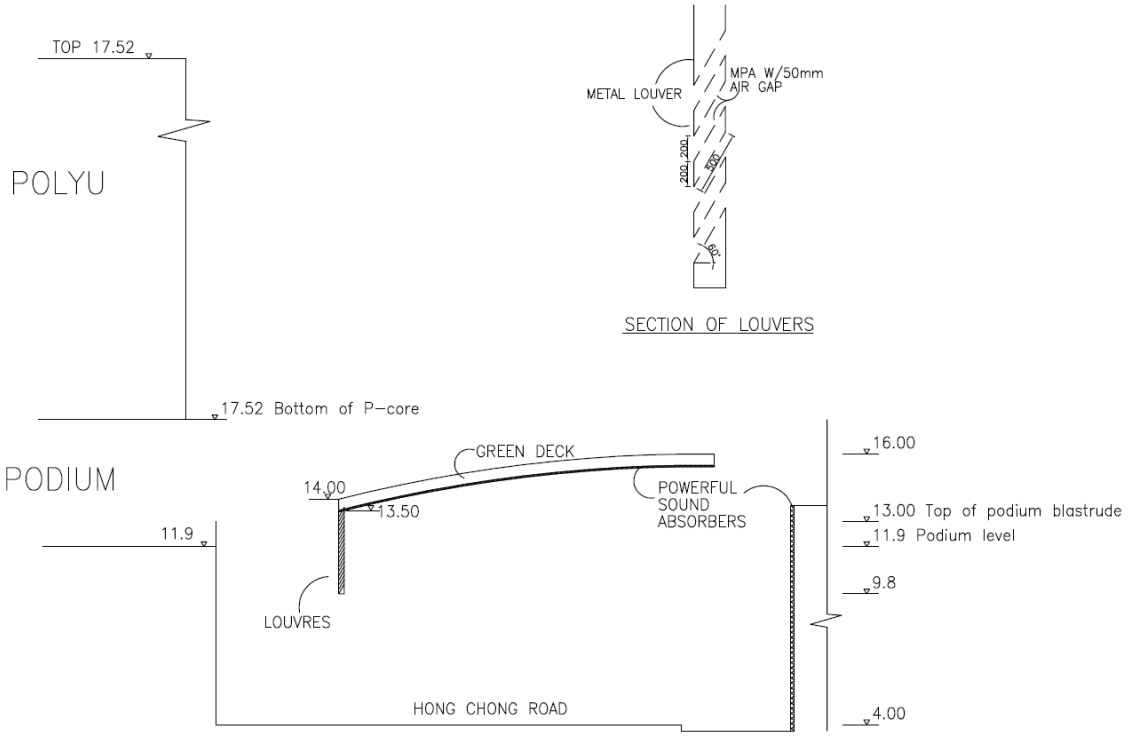


Figure 6: Schematics of the proposed noise mitigation measure

More checkpoints are added in order to understand the noise levels at higher levels of the PolyU façades and the areas near to the Hunghom MTR station and the Hong Kong Coliseum. Figure 7 illustrates all the checkpoints adopted.

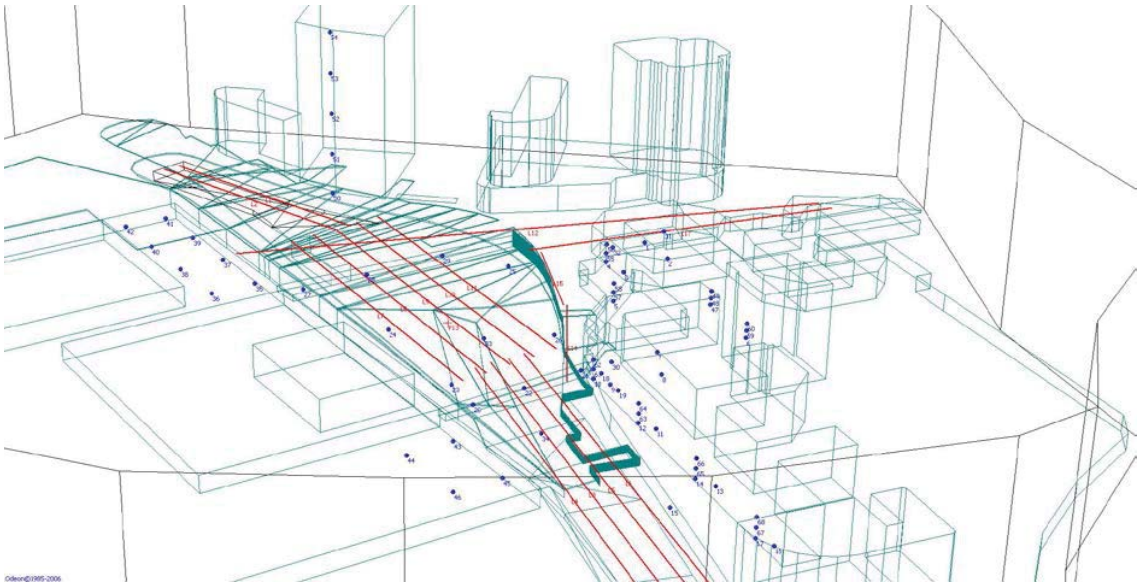


Figure 7 : Additional checkpoints on PolyU façades and at open area around Hunghom station

Table 6 compares the rise in noise levels after the installation of the Green Deck with additional ventilation louvers with and without MPA and sound absorbers under the deck and on the external wall of Hung Hom Station along Hong Chong Road. Again, negative figures denote noise reduction.

Check Point	Location	Noise Level Increase (dB)						
		125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	Weighted*
1	CD podium	2.1	0.4	-0.2	-0.1	-0.1	0.1	0.0
2	DE courtyard	2.7	0.4	-1.5	-1.4	-1	-0.3	-1.0
3	DE podium	-4.9	-6.8	-7.9	-8.2	-8.1	-6.9	-7.8
4	DE façade	-1.1	-4.1	-5.4	-5.2	-4.6	-2.7	-4.8
5	Library façade	-1.6	-5	-6	-6	-5.3	-3.2	-5.5
6	Library entrance	-1.7	-3.9	-4.5	-4.5	-4.5	-4.3	-4.4
7	Library	1.3	-3.2	-3.9	-4.1	-4.1	-4.1	-3.9
8	Lawn	0.2	-3.4	-4	-4.1	-3.7	-2.7	-3.7
9	P Podium	5.1	1.6	0.6	-1.6	-2.4	-2.2	-1.2
10	P Façade	-2.7	-4.8	-5	-4.8	-4.3	-3.2	-4.6
11	PQ podium	3.8	-2.7	-4.1	-4	-3.4	-1.6	-3.5
12	PQ façade	-2.1	-3.7	-3.7	-3.3	-3.1	-2.4	-3.3
13	QT podium	2.9	-3.4	-4	-3.8	-3.1	-1.7	-3.4
14	QT façade	-0.9	-1.6	-1.7	-1.6	-1.1	-0.4	-1.4
15	QT podium	-0.4	-0.7	-0.7	-0.6	-0.4	0	-0.5
16	TU Podium	-0.1	-3.2	-3.9	-4	-3.2	-0.8	-3.4
17	TU façade	-1.5	-1.9	-1.7	-1.4	-0.7	0.2	-1.3
19	Entrance to podium, around security desk	-0.2	-6.4	-7.3	-7.6	-7.3	-6.5	-7.2
20	P podium	2.6	-3.1	-3.8	-3.8	-3.1	-1.8	-3.3
21	Footbridge	> 20	> 20	> 20	> 20	> 20	> 20	> 20
22	PolyU Entrance, Bridge	> 20	> 20	> 20	> 20	> 20	> 20	> 20
23	Footbridge	> 20	> 20	> 20	> 20	> 20	> 20	> 20
24	Bus stop area	10.1	3	0.2	0.2	0.3	0.4	0.6
25	Bus stop area	11.9	3.3	0.1	0.2	0.4	0.3	0.6

26	Bus stop area	8.9	2.6	0.4	0.3	0.5	0.6	0.7
27	Bus stop area	7.2	1.2	-0.2	-0.2	-0.1	0.2	0.1
28	MTR Exit D bridge	-8.2	-9.6	-11.5	-14.5	-15.6	-19.8	-14.8
29	MTR Exit D bridge	-8.4	-10.4	-12.6	-14.9	-15.9	-19.4	-15.0
30	MTR Exit D bridge	-9	-9.3	-9.9	-11	-11.9	-14.3	-11.2
31	Entrance to podium, around security desk	1.1	-6.1	-7.2	-7.2	-6.5	-5.1	-6.7
32	Hong Tai Path	1.3	0.2	0	-0.1	0	0.1	0.0
33	Hong Tai Path	2.6	0.8	0	0.1	0.1	0.1	0.2
34	New East Ocean Centre, ground	8.9	2.4	0.1	0.1	0.2	0.2	0.5
35	New East Ocean Centre, ground	4.6	0.6	-0.1	-0.1	0	0.1	0.1
36	HK Coliseum Podium 15m from road	-6.4	-14.4	-19.6	-20.1	-19.8	-19.9	-19.4
37	HK Coliseum Podium 40m from road	-5.8	-11.5	-16.4	-16.7	-15.9	-15.2	-15.9
38	HK Coliseum Podium 15m from road	-6.6	-11.4	-15.3	-15.8	-15.7	-16.1	-15.3
39	HK Coliseum Podium 40m from road	-2.8	-7.7	-12.3	-12.6	-11.6	-10.9	-11.7
40	HK Coliseum Podium 15m from road	-5	-13.2	-18.6	-19.2	-18.9	-20.4	-18.6
41	HK Coliseum Podium 40m from road	3.5	-1.7	-5.8	-6.2	-5.3	-4.7	-5.4
42	HK Coliseum Podium 15m from road	-2.9	-9.1	-15.2	-15.9	-15.1	-15.2	-15.0
43	HK Coliseum Podium 40m from road	7.9	1.2	-3.6	-3.9	-2.9	-1.6	-3.0
44	Hung Hom Station Bus Station 15m from road	-5.5	-10.8	-12	-12	-11.7	-10.7	-11.6
45	Hung Hom Station Bus Station 40m from road	-2.4	-5	-5.3	-5.3	-4.8	-3.9	-5.0
46	Hung Hom Station Bus Station 15m from road	-5.2	-7.8	-8.3	-8.1	-7.5	-6.1	-7.8
47	Hung Hom Station Bus Station 40m from road	-1.5	-3.1	-3.3	-3.1	-2.5	-1.3	-2.8
48	Library Entrance podium	-2.2	-3.7	-4.5	-4.5	-4.2	-3.2	-4.2
49	Library Entrance 3-4/F	-9.5	-10.4	-11	-11.3	-11.7	-12	-11.3
50	Library Entrance 5/F	-5.1	-5.8	-6.1	-6.1	-5.9	-4.8	-5.9
51	Hotel Icon Facade, G/F	5.6	1.8	0.3	0.3	0.3	0.4	0.5
52	Hotel Icon Facade, 6-7/F	-5.2	-8.9	-11.5	-11.7	-12	-12.3	-11.5
53	Hotel Icon Facade, 13-14/F	-7.3	-12	-15	-15.2	-15.5	-16.1	-15.0
54	Hotel Icon Facade, 20-21/F	-8.3	-13.1	-15.9	-16.2	-16.5	-17.3	-16.0
55	Hotel Icon Facade, Roof	-8.6	-13.4	-16.1	-16.4	-16.8	-17.7	-16.2
56	DE façade 3-4/F	-1	-3.8	-5.2	-5.4	-4.8	-2.9	-4.8
57	DE façade 5-6/F	-0.1	-3.3	-4.3	-4.2	-3.6	-2.2	-3.8
58	Lib façade 3-4/F	-1.3	-4.3	-5.5	-5.5	-4.9	-3.2	-5.0
59	Lib façade 5/F	-1.6	-4.8	-5.8	-5.6	-5	-3.3	-5.2
60	Library and M-core entrance 3-4/F	-2.8	-4.6	-5	-5.1	-5	-4.5	-4.9

61	Library and M-core entrance 5-6/F	-4	-5.5	-5.9	-5.9	-5.7	-5.1	-5.7
62	P façade 3-4/F	-3	-4.8	-5	-5	-4.5	-3.5	-4.7
63	P façade 5-6/F	-3.6	-5.3	-5.5	-5.4	-5.1	-4.1	-5.2
64	PQ façade 3-4/F	-2.4	-3.8	-4	-3.9	-3.3	-2.2	-3.6
65	PQ façade 5-6/F	-2.2	-4	-4.1	-3.9	-3.4	-2.4	-3.7
66	QT façade 3-4/F	-0.9	-1.5	-1.5	-1.4	-1	-0.5	-1.3
67	QT façade 5-6/F	-0.9	-1.6	-1.6	-1.5	-1.1	-0.6	-1.4
68	TU façade 3-4/F	-1.8	-2.1	-2	-1.7	-1.1	-0.4	-1.6
69	TU façade 5-6/F	-1.4	-1.8	-1.7	-1.4	-0.7	-0.1	-1.3

*Table 6 : Rise in Noise Levels after Installation of Green Deck with the proposed noise mitigation measure. *Weighted by normalized traffic noise spectrum [7,8,9]*

With the proposed mitigation measure, the noise levels at checkpoints in PolyU are at least not worse than those the 'no deck' condition. The sound absorbers under the deck are reducing the sound energy from under the deck, resulting in a slight decrease in the noise level to all check points under the deck. At higher height, the noise reduction can be as high as 16 dBA. The noise reductions at the checkpoints nearby the Hunghom MTR station and the Hong Kong Coliseum range from 3 to 20 dBA.

The footbridges between Hung Hom Station Exit A and PolyU are now enclosed and thus isolated from the cavity under the Green Deck, resulting in a very impressive reduction of noise levels at those checkpoints.

V. CONCLUSIONS

Noise levels at various locations on PolyU podium and entrance facing the Cross Harbour Tunnel toll gate areas are simulated using a ray-tracing algorithm. The present simulation results confirm the potential of high noise levels on PolyU podium facing the proposed Green Deck. The noise level at PolyU entrance will increase by 8 dBA, while some locations along the PQ, CD and DE cores will receive a noise level ~ 5 to 6 dBA above the present figures. The noise levels underneath the deck will also be very high. A 12 dBA increase in the noise level is obtained under the deck.

It is proposed to use louvres together with micro-perforated sound absorbers and powerful sound absorbers as the noise mitigation measure. The lourves and the sound absorbers are proposed to be lined along the Green Deck's near edge (along Hong Chong Road) while the other sound absorbers are proposed to be lined beneath the deck and on the wall of Hung Hom Station (along Hong Chong Road). The noise level at PolyU entrance, which will be the worst location affected by the Green Deck in term of noise, is estimated to be ~5.4dBA higher than the current condition in the absence of the noise mitigation. However, with the proposed noise mitigation measures, the Green Deck would be able to reduce the current traffic noise level at PolyU by ~3dBA on average, while the noise levels under the Deck remain nearly unchanged. The noise reductions at locations nearby the Hunghom MTR station and the Hong Kong Coliseum are found to be within 3 to 20 dBA.

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