

Construction Noise Management: Hong Kong Reviews and International Best Practices

Morgan Cheng, Wilson Ho, Max Yiu, Dragon Tsui, Wylog Wong, Yasir A. Naveed, C. S. Loong, Richard Kwan, K. C. Lam, Hannah Lo, C. L. Wong

Abstract—Hong Kong is known worldwide for high density living and the ability to thrive under trying circumstances. The 7.5 million residents of this busy metropolis live primarily in high-rise buildings which are built and demolished incessantly. Hong Kong residents are therefore affected continuously by numerous construction activities. In 2020, the Hong Kong Environmental Protection Department (EPD) commissioned a feasibility study on the management of construction noise, including those associated with renovation of domestic premises. A key component of the study focused on the review of practices concerning the management and control of construction noise in metropolises in other parts of the world. To benefit from international best practices, this extensive review aimed at identifying possible areas of improvement in Hong Kong. The study first referred to the United Nations “The World’s Cities in 2016” Report and examined the top 100 cities therein. The 20 most suitable cities were then chosen for further review. Upon further screening, 12 cities with more relevant management practices were selected for further scrutiny. These 12 cities include: Asia – Tokyo, Seoul, Taipei, Guangzhou, Singapore; Europe – City of Westminster (London), Berlin; North America – Toronto, New York City, San Francisco; Oceania – Sydney, Melbourne. Subsequently, three cities, namely Sydney, City of Westminster, and New York City, were selected for in-depth review. These three were chosen primarily because of the maturity, success, and effectiveness of their construction noise management and control measures, as well as their similarity to Hong Kong in certain key aspects. One of the more important findings of the review is the importance of early focus on potential noise issues, with the objective of designing the noise away wherever practicable. The study examined the similar yet different construction noise early focus mechanisms of these three cities. This paper describes this landmark, worldwide and extensive review on international best construction noise management and control practices at the source, along the noise transmission path and at the receiver end. The methodology, approach, and key findings are presented succinctly in this paper. By sharing the findings with the acoustics professionals worldwide, it is hoped that more advanced and mature construction noise management practices can be developed to attain urban sustainability.

Keywords—Construction noise, international best practices, noise control and noise management.

I. INTRODUCTION

FOR pursuing a better quality of life, noise arising from different construction activities at construction sites and renovation activities at domestic premises has become a

concerning topic for the citizens living in metropolitan cities characterised by high population density and high-rise residential towers. In Hong Kong, according to the Quarterly Report of Employment and Vacancies at Construction Site in the second quarter of 2010 and 2018 [1], [2], the number of construction sites has increased over 50% from 2009 to 2018. About 70% of the construction sites are expected to be building sites and most of them are located in areas with relatively dense population. In other words, construction sites have a high probability to become one of the main sources that may adversely affect the citizen’s quality of life. Proper construction noise management is needed to meet the increasing demand for a better living environment. To tackle potential noise problems from construction sites and domestic premises, the Environmental Protection Department (EPD) of Hong Kong SAR commissioned a feasibility study (hereafter “the Study”) on construction noise which was completed in 2020. The Study comprised gathering and comparing information on construction noise management practices from 12 international metropolitan cities including Tokyo, Berlin, City of Westminster, Melbourne, Sydney, Toronto, San Francisco, New York City, Guangzhou, Seoul, Taipei and Singapore [3], plus Hong Kong to explore possible options of construction noise management or management measures.

The Study explored and revealed international best practices to manage construction noise logically and systematically. In this paper, international best construction noise management practices of these cities at source, along transmission path and at receiver are holistically reviewed to provide a comprehensive view on the relevant regulatory and non-regulatory practices, experiences and rationale behind the systems in tackling construction noise in these cities.

II. CONSTRUCTION NOISE MANAGEMENT PRACTICES AT SOURCE

Construction noise sources can be categorised into two groups, noise from construction sites and noise from domestic premises. It is noted that the sources of noise from these two groups include both Powered Mechanical Equipment (PME) as well as the construction sites or domestic premises themselves.

Morgan Cheng is with Wilson Acoustics Limited, Hong Kong SAR, PRC (phone: 852-3188-1170; fax: 852- 3422-8117; e-mail: mcheng@wal.hk).

Wilson Ho was with Wilson Acoustics Limited, Hong Kong SAR, PRC (Corresponding author, phone: 852-3188-1170; fax: 852- 3422-8117; e-mail: who@wal.hk).

Max Yiu, Dragon Tsui, Wylog Wong, Yasir A. Naveed, C. S. Loong and Richard Kwan were with Wilson Acoustics Limited, Hong Kong SAR, PRC (e-

mails: max.yiu@wal2.hk, dragon.tsui@wal2.hk, wwong@wal.hk, yanaveed@gmail.com, cs.loong@wal2.hk, richard.kwan@wal.hk,).

K. C. Lam is with the Chinese University of Hong Kong, Hong Kong SAR, PRC (e-mail: kinchelam@cuhk.edu.hk).

Hannah Lo and C. L. Wong are with the Environmental Protection Department, Hong Kong SAR, PRC (e-mail: cwlo@epd.gov.hk, clwong@epd.gov.hk).

Source management tools such as labelling system, daytime machine operation restriction and early planning measure can be applied to both construction sites and domestic premises. Moreover, managing noise source through a combination of best practicable means, absolute noise limit at a distance from the source and site management are commonly used in construction sites only.

A. Labelling System

1. Hong Kong – Noise Emission Label

In 1992, Noise Emission Label (NEL) was introduced as a statutory framework in Hong Kong to regulate the operation of noisy construction equipment [4]. The framework imposed a Hong Kong wide ban on sale, purchase and use of the machines included in the list of NEL applicable machines unless if they received the NEL from EPD and displayed it at all times. According to the regulation, NEL would only be granted to a machine if it meets at least one of the following criteria:

- EEC type-examination certificate; or
- An EC Declaration of Conformity, and relevant documentation under the Directive 2000/14/EC of the European Union (EU); or
- A noise testing report certifying compliance of noise emission standards as stipulated in relevant noise laws.

Since launch, two PME's have been included in the scheme:

- Hand-held breakers that are over 10 kg, and
- Air compressors that are over 5 bar (500 kPa) operating pressure.

NEL clearly defines the weight or capacity of the applicable machines. Hand-held breakers that matches or exceeds the threshold mentioned in the said regulations can only be sold, imported and/or used in Hong Kong only if the relevant noise standard is complied with. This could be a possible incentive for construction contractors to use smaller PME's and avoid using heavy machinery unless really necessary.

In addition, the law also empowers the authority to specify the conditions/mode of operation of PME's to prevent tampering after NEL approval. Contractors are required to display the NEL certificate on PME at all times during operation and ensure compliance with the conditions/mode of operation as specified by the law. Failure to do so is an offence under Hong Kong law.

The authority has the right to require inspection, measurement or test of the machine if there is information regarding potential exceedance beyond the noise level stated in the NEL.

It is worth noticing that both of these PME's are commonly used in essential works including utilities work and road works which are usually conducted during nighttime to avoid causing serious traffic disturbance. It was common that over half of the approved Construction Noise Permits (CNP's) were related to essential works at sensitive hours and the NEL system has helped in regulating noise generated by these two PME's at source.

2. Hong Kong – Quality Powered Mechanical Equipment

Further to the control of noisy machines through the NEL

system, there is also an administrative system in Hong Kong. The Quality Powered Mechanical Equipment (QPME) label was introduced in 2005 to promote the use of 15 types of PME's that are new, high-tech, quiet and well maintained [5]. The 15 types of PME's that satisfy EC Directive 2000/14/EC and Japan MLIT "Low-noise" label are eligible to apply the QPME label [6], [7]. The label is only valid for a maximum of 6 years, subject to the age of the PME at the time of label application. The authority, EPD, generally would not consider renewal of QPME unless re-measurement as well as maintenance report is provided to show the machine is well maintained with no deterioration in noise and operation performance.

To encourage the use of QPME, there is no application fee for QPME labels. Furthermore, an incentive scheme was introduced in 2008 according to which the capital expenditure on QPME can be deducted from the Profits Tax over 5 years by the buyer company. The advantage of using QPME for construction companies is not only financial reason. In fact, construction companies can use the noise level stated on the QPME label (usually lower than the noise level of conventional PME) for noise calculation in the application for a CNP, and therefore facilitate a successful CNP application. Moreover, if a construction company wants to apply for a CNP, they do not need to conduct a specific noise measurement which helps to save time and money consistently throughout the duration of QPME label validity.

Generally, QPME has a lower Sound Power Level (SWL) than comparable PME's, e.g., mobile crane with 100-ton operating weight has a SWL of 112 dB(A) as stated in EPD's relevant Technical Memorandum, whereas for an equivalent QPME the SWL is 104 dB(A). It is evident that QPME labelling system contributes well in decreasing noise generated at source from specific machines and improves the quality of machines being used on site throughout the service life of the QPME.

3. Sydney

A similar control method like NEL exists in Sydney for noise management at source. The scope of Sydney's machine labelling system includes 7 PME's and, unlike Hong Kong, it is compulsory for all machines in Sydney to apply, obtain and display the label on machine if it is intended to sell in retail. PME's included in Sydney's labelling system are hand-held breaker, mobile air compressor, chainsaw, domestic air conditioner, grass-cutting machine, pump (including heat pump water heater) and mobile garbage compactor. In addition, according to Protection of the Environment Operations (Noise Control) Regulation 2017, there is also a provision for the chainsaw being required to conform to the EU Directives (with a label) at the retail point [8].

Sydney does not have the exact control system as the NEL system in Hong Kong. There are two major differences. Firstly, the Hong Kong NEL system only includes major construction equipment while the Sydney's system is applicable to other domestic use machines as well e.g., air-conditioner, grass cutting machine). Secondly, the Hong Kong system controls non-compliant machines during operation whereas the Sydney system only regulates the labelling without any in-use

requirement. The machine labelling regulation in Sydney enables consumers to make an informed decision before they buy or use the product.

4. Seoul

The machine labelling system in Seoul covers six PMEs: excavator above 19 kW, air compressor, tracked loader, wheeled loader, non-vibratory compactor and vibratory compactor. A common theme among all of these PMEs is that they are used in road works. However, similar to the labelling system in Sydney, it is compulsory for manufacturers to place labels on these machines but there is no threshold noise level similar to NEL which places a ban on machines that produce noise above the threshold level.

It should be noted that specified construction works are defined as those involving works with these six machines. Since contractors have to report on the noise levels of these machines in order to get a permit, it enables the authority to monitor whether sites are actually using the specified machines or not.

Apart from statutory labelling, administrative labelling was also introduced in Seoul, which is called Eco-label [9]. It is a similar system to Blue Angel of Berlin in which the scheme consists of various products for different aspects of environment. There are 22 types of construction equipment eligible for Eco-label. Those PMEs with Eco-label are exempted from the noise inspection.

5. Berlin

In addition to labelling systems that are part of the law and enforced as a statutory measure, some places have labelling systems that are non-statutory or do not directly stem from legal framework of a country/province/city. One of such labelling schemes is the EC Directive 2000/14/EC which is a set of specific instructions to countries in the European Union [6]. It is not part of the legal framework of any of the countries, but it

has to be implemented. The EU member countries are required to follow the Directive otherwise there would be consequences, for EC Directive 2000/14/EC the PMEs without the CE marking shall be excluded to the EU market. Currently amongst the cities of interest, Berlin is obligated to follow this Directive. Although all EU countries are obligated to execute such instruction, manufacturers or companies could also report on such violation. Hence this Directive could also be market-regulated. There are 53 types of PMEs required CE marking as well as a label showing the guaranteed SWL.

On the other hand, Berlin has another labelling system in addition to EC Directive 2000/14/EC: Blue Angel [10]. Blue Angel is to benchmark the products with greater environmental friendliness. It also provides information and assistance to consumers in their purchase decisions from which suppliers may gain competitive advantage. The scheme consists of various products in different aspects of environment, one of which is construction machinery related to noise emission. There are 33 types of PMEs eligible for Blue Angel Label. The criteria are generally 1-3 dB(A) lower than the criteria stated in EC Directive 2000/14/EC.

6. Tokyo

In Tokyo there are “Low Noise” and “Super Low Noise” labelling systems for 22 types of PMEs [7]. They are the labelling systems introduced by Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan. The aim is to benchmark quiet PMEs for use at construction sites that are located in areas requiring exceptionally quiet environments. Both labels have the same standard, with “Super Low Noise” is eligible for PMEs that measured 6 dB(A) below the criteria of “Low Noise”.

Table I summarizes the major legislative and administrative source control tools in different cities.

TABLE I
SUMMARY OF SOURCE CONTROL IN DIFFERENT CITIES

	Regulation		Administration	
	Description	No. of PME	Description	No. of PME
Hong Kong	NEL (Label)	2	QPME (Label)	15
City of Westminster	EC Directive 2000/14/EC (Label)	53	-	-
Sydney	Labelling (Label)	7	-	-
Berlin	EU Directive 2000/14/EC (Label)	53	Blue Angel (Label)	33
Tokyo	-	-	“Low Noise” and “Super Low Noise” (Label)	22
Seoul	“Noise Inspection” (Label)	6	Eco-label (Label)	30
Melbourne	Designated Sound Level (noise limits for respective machines)	-	-	-
Guangzhou	Prior Registration Required	-	-	-
Taipei	-	-	Construction Noise Control Project	-
Singapore	-	-	Quieter Construction Fund	-
Toronto	General machine noise limit (a noise limit for any machines)	-	-	-
San Francisco	Noise limit at certain distance	-	-	-
New York City	Specific machine noise limit (noise limits for respective machines)	-	-	-

B. Restriction on Daytime Machine Operation

1. Hong Kong

The percussive piling machines operation in Hong Kong requires a permit in advance. Subject to the noise impact, the piling period could be granted for 3, 5 or 12 hours at specific time frames. At minimal, one percussive piling machine could be operated for 3 hours per day.

2. Singapore

Singapore does not have a statutory restriction on machine operation system for general construction works, but they do have a system to restrict use of machines during domestic renovation works under the ambit of Housing Development Bureau (HDB). The contractors are restricted to use maximum 2 machines simultaneously in a domestic premises during renovation works at the same time. There is a list of approved hand-held power tools for contractors to follow.

3. Tokyo

Several works have been classified as specified construction works by the Tokyo authority depending on the machines being used and the level of noise being generated from the works. A contractor must obtain permit from the authority before commencement of such works.

4. San Francisco

Machines that emit more than L_{eq} 80dB(A) at a distance of 100ft are not allowed to be used at any time and place in the city except for percussive machines which can be used if a muffler of 5 dB(A) or higher noise reduction capability is installed.

C. Best Practicable Means

1. City of Westminster

Best Practicable Means (BPM) is a distinct feature of the noise policy in City of Westminster such that there are no explicit criteria specifying what mitigation measures and noise limit are acceptable for a noise consent application.

It is hereby highlighted that in the City of Westminster, there are sets of agreed standards and guidelines to follow for implementation of BPM, such as BS5228-1:2009 Code of practice for noise and vibration control on construction and open sites, and Best Available Technology not Exceeding Excessive Cause (BATNEEC) [11]. These standards and guidelines provide an objective framework for BPM.

2. Hong Kong

BPM is required for construction works that must be conducted during restricted hours of 1900 to 0700 due to unavoidable constraints, e.g., road works, where prior assessment indicates an exceedance of the noise requirement for granting a permit. During early planning process of Environmental Impact Assessment stage of Designated Project, BPM will also be considered.

D. Absolute Noise Limit at a Distance from Machine

1. San Francisco

According to the San Francisco Police Code (SFPC) Article 29 - Regulation of Noise, it is unlawful to operate any PME that emitting over 80 dB(A) at 100 ft distance or an equivalent sound power level at other distance for any construction company. [12]. However, some certain equipment is exempted from this regulation as long as it is advised by the manufacturers thereof and approved by the Director of Public Works or the Director of Building Inspection as best achieving maximum noise depletion. This equipment includes:

- Impact tools and equipment with intake and exhaust mufflers;
- Pavement breakers and jackhammers equipped with acoustically attenuating shields or shrouds;
- All construction equipment needed in emergency work which is defined as any necessary work to restore property to a secure condition following a public tragedy or work required to avoid persons or property from an inevitable exposure to danger or work by private or public services when recovering utility service.

2. Singapore

Any contractor is required to submit a noise management plan to the authority and obtain advance permission before construction at sites which are within 150 m distance of a residential premises. In this plan, appropriate noise mitigation measures have to be installed in discussion with the authority. These may include perimeter noise barriers, noise enclosures, etc.

3. Toronto

According to Toronto Municipal Code, sound emitted from any equipment shall not exceed an Equivalent Sound Level (L_{eq}) of 85 dB(A) when measured 20 metres from the source over a five-minute period. This provision is used in special circumstances where multiple complaints from the same construction site have been received.

E. Site Management

1. City of Westminster

Prior consent must be obtained for Level 1 and Level 2 projects as well as for all construction outside core working hours [13]. The contractor shall conduct baseline monitoring and submit noise assessment results, together with proposed noise mitigation measures in the application. The consent will specify the plants which are or are not to be used, the hours during which the works may be carried out and the level of noise which may be emitted.

- Level 1 projects: involving the creation of 100 or more new or additional residential units or the creation / change of use of 10,000m² or more floorspace.
- Level 2 projects: involving the creation of 10 or more new build residential units, or buildings where the new build floorspace to be created is 1000m² or more, or any basement developments.

2. Guangzhou

In Guangzhou, prior registration is required for construction, demolition and renovation works using PMEs. The contractor is to register the said works 15 days prior to works commencement with the local noise management authority.

3. Melbourne

All contractors in Melbourne engaged in construction works valued more than Australian \$5,000 or demolition and removal of buildings and structures (regardless of the work value) are required to submit and get approval for Construction Management Plan (CMP), which contains Noise and Vibration Mitigation Plan (NVMP), from the Melbourne City Council at least 48 hours before construction work begins [14]. The plans include expected data for noise production during construction work. If the authority deems any machine or process too noisy, they can instruct the contractor to not proceed with the machine/process or comply with limited number of operation hours as directed by the authority. Once the NVMP is approved, authority expects the contractor to submit periodic noise data voluntarily but if there is a complaint then this becomes a compulsory requirement [14].

4. Singapore

Since 2012, Singapore's NEA has required builders of construction/demolition projects located within 150 m of residential and sensitive premises, and above \$50 million in project value, to submit their Noise Management Plan (NMP) to improve their noise monitoring programme, check for proper locations of noise monitoring system, siting of noisy equipment, public engagement programme and provide advice on noise mitigation measures [15]. The NMP includes controlling the noise source with the use of newer machines and properly maintained machines; proper scheduling of work with restricting the duration of noisy activities and factor work no to be conducted on Sunday and public holiday; place stationary noise sources, e.g., generators, further away from noise sensitive premises; employing noise barrier and enclosure; and remind or educate workers on good practices.

5. Sydney

Any construction or demolition work undertaken in Sydney is subject to control under the Protection of the Environment Operations Act and the Environmental Planning and Assessment Act. An environmental noise impact assessment is necessary to propose mitigation to minimize impact to the surrounding, and the authority could impose further mitigation where necessary.

In addition, a permit from local council of Sydney is necessary before commencement of construction works. To get the consent from local council, the applicant is required to negotiate the terms of the planning agreement with the council. The draft planning agreement would be exhibited to public for submissions when necessary. The public submissions would be considered in the application assessment to form a development consent with conditions. The condition of consent usually required an approved construction methodology report

prepared by acoustic consultant and construction professional to suggest all reasonable and feasible measures to reduce the environmental noise impact. Respite period may be applied to the noisy equipment such as pile driver and hydraulic hammer.

F. Early Planning Stage Measures

1. Singapore

As mentioned in previous section, for projects larger than Singaporean \$50 million and located within 150 m distance of a residential building, the contractors need to submit a Noise Mitigation Plan (NMP) to the authority and obtain approval before construction begins [15].

There is a nighttime noise criteria in Singapore, and a permit is required in advance to start overnight work. The authority considers these cases based on their compliance with nighttime noise criteria and decision to grant the nighttime permits are made on a case-by-case basis - usually emergency cases - as, in practice, nighttime work is usually avoided by contractors in Singapore.

Regarding domestic renovation works, Singapore has made it compulsory for renovation contractors to obtain a permit from the HDB before commencing any demolition or hacking of walls. In addition, a neighbourhood notification system is established in which at least two neighbours have to be informed about the renovation works 3 days in advance. Although this is not a statutory system, it serves to improve communication among residents which is one of the most critical factors in neighbourhood noise management.

2. Berlin

In Berlin, it is compulsory for contractors to obtain permit from national noise management authority before commencing work on infrastructure projects such as construction of railroads, public roads, railways, magnetic suspension railways and tramways, etc. [16].

3. Melbourne

As stated in previous section, Construction Management Plan (CMP) is required to proceed construction work valued more than Australian \$5,000 (roughly equal to HK\$30,000) or demolition and removal of buildings and structures (regardless of the work value) [14].

In addition, Melbourne considers general construction works and road works separately because of the noise produced and schedule of construction. The restricted hours of these two types of works are different as road works are usually required to be conducted in non-peak hours due to traffic congestion. It must be noticed that the restricted hours for road works are 1 hour less on weekdays and 5 hours less on Saturdays as compared to general construction works. Also, road works are prohibited on Sundays and public holidays while general construction works are allowed for a definite time period. This distinction in restricted hours is important because any work done within the restricted hours must be done with a valid permit from the government which naturally means that road works are more likely to need a permit than general construction works.

Renovation works involving demolition or external works also require a “out-of-hours” permit for works outside the restricted hours (e.g., 07:00 to 19:00 on a normal weekday). During the application process, the authority may direct the owner to send a letter to neighbours or erect a sign on-site to advertise the permit application such that neighbours can have the opportunity to object.

4. Toronto

Toronto has a Preliminary Plan Review (PPR) system for projects involving use of pile drivers, hoe rammers and/or percussive piling machines such that any projects using this equipment must submit a PPR to the authority and obtain approval for use in advance [17]. The PPR requires contractors to prove that no other method is applicable on this site and that adequate measures have been adopted to ensure minimal disturbance to nearby public.

Toronto also has a nighttime construction permit system but it is mainly for emergency work or unavoidable constraints. For other projects, the decision to grant a permit to work outside allowed hours is made on a case-by-case basis and contractors have to submit an application beforehand. Contractors are required to prove that the sound emitted by all construction equipment employed on site does not exceed $L_{eq} 85dB(A)$ when measured 20m from the source over 5 minutes. In certain cases, active real time noise monitoring would be conducted by the authority who would be physically present on site.

In Toronto a renovation project with total project cost including labour and material exceeding Canadian \$50,000 or more is considered a general construction work.

III. CONSTRUCTION NOISE MANAGEMENT PRACTICES ALONG TRANSMISSION PATH

Noise management along the transmission path is defined as noise mitigation between source and receiver such as inserting a control element between them. From perspective of construction noise, construction site itself can be categorized as a source. Therefore, the transmission path here is defined as the area from outside the construction site boundary to façade of the residential premises (or other noise-sensitive premises).

In general, constructing noise barrier at site boundary or a particular noisy machine is common in construction site that is known as the noise management along transmission path. Most of the cities execute this management in a project-by-project basis with consideration of construction tender requirement and addressing concern of noise-sensitive premises through administration means instead of legislation means. The study finds that noise management along the transmission path is not the option with the first priority for construction noise management in majority of reviewed cities.

There are relatively few examples of management practices along the transmission path among the reviewed cities. Seoul is

one of the most distinct examples that require contractors to put up noise barriers around construction site boundaries.

1. Seoul

Noise management system in Seoul is one of the unique examples of a control system for tackling construction noise through statutory control in transmission path. In Seoul, it is compulsory to install proper noise barriers around the construction sites. Mobile noise meters are also installed to measure noise levels between construction site and residential buildings to ensure the noise level is within the noise criteria.

Different types of noise barriers are made for each site based on site area. For construction site that cover less than 1,000m², although they are exempted from preliminary register requirement, the contractors are obliged to erect sheath plastic steel (effective in reducing 25dB) when applying for construction permit. If the site covers 1,000m² or more, noise barrier made of aluminium or polypropylene soundproof material (effective in reducing 26~30dB) has to be constructed before applying for construction permit. Additional removable or sealed soundproof wall is needed if the process includes heavy noise pollution work such as drilling and blasting.

In addition to that, more proactive noise management actions have been conducted throughout the city. For example, 4 mobile noise meters are installed at various locations and noise measuring networks to measure noise emissions from construction sites on a random basis. The meters will periodically record and report data to the Korean Ministry of Environment to ensure the law is properly followed.

IV. CONSTRUCTION NOISE MANAGEMENT PRACTICES AT RECEIVER

Construction noise management practices at receiver could be accomplished through regulating restricted hours, noise control zones and noise criteria as well as going through early planning and community liaison. Restricted hours, noise control zones and noise criteria are widely used in both general construction works and domestic renovation works. Besides, in-depth discussion from the Study stated that early planning are mainly used in general construction, but community liaison is generally used in domestic renovation works.

A. Restricted Hours

Restricted hours in each city are based on lifestyle of people and social norms. While this is the case is out of scope for this paper, an important point to note, however, is that only two out of the 12 cities have established special restricted hours for renovation noise and the other 10 cities have defined renovation work as part of general construction works. Table II is a general summary of the restricted hours adopted in different cities, without showing the details for exceptional situations or the practices for holidays etc. other than Sundays.

TABLE II
SUMMARY OF RESTRICTED HOURS FOR GENERAL CONSTRUCTION AND RENOVATION WORKS ACROSS DIFFERENT CITIES

City	General Construction	Domestic Renovation
Hong Kong	Allowed: Monday to Saturday 07:00 to 19:00 (percussive piling requires a permit) Otherwise not allowed (unless permit granted; percussive piling prohibited)	Same as general construction
Tokyo	Allowed: Monday to Saturday 07:00 to 19:00 Not allowed (unless exceptional cases): Sunday all day.	Same as general construction
Guangzhou	Allowed: Monday to Saturday 06:00 to 22:00 Not allowed (unless exceptional cases): Sunday all day.	No restricted hours. Practice is to stop work from 12:00 to 14:00.
Seoul	Allowed: Monday to Friday 07:00 to 18:00 Not allowed (unless exceptional cases): Saturday and Sunday all day.	Same as general construction
Taipei	Allowed: Monday to Saturday 08:00 to 22:00 Not allowed (unless exceptional cases): Sunday all day.	Same as general construction
Singapore	Allowed: Monday to Saturday 07:00 to 19:00 Not allowed (unless exceptional cases): Sunday all day. Friday 19:00 to Monday 07:00 prohibited for construction sites within 150 m distance of residential premises	Same as general construction
Berlin	Allowed: Monday to Friday 07:00 to 18:00 Not allowed (unless exceptional cases): Sunday all day.	Same as general construction
Melbourne	Allowed: Monday to Friday 07:00 to 19:00 Saturday 07:00 to 13:00 Not allowed (unless exceptional cases): Sunday all day.	Allowed: Monday to Friday 07:00 to 19:00 Saturday 08:00 to 18:00 Sunday 09:00 to 18:00
Toronto	Allowed: Monday to Friday 07:00 to 19:00 Saturday 09:00 to 19:00 Not allowed (unless exceptional cases): Sunday all day.	Same as general construction
San Francisco	Allowed: Monday to Saturday 07:00 to 20:00 Not allowed (unless exceptional cases): Sunday all day.	Same as general construction
City of Westminster	Allowed: Monday to Friday 08:00 to 18:00 Saturday 08:00 to 13:00 Not allowed (unless exceptional cases): Saturday all day restriction on earthwork, piling & demolition. Sunday all day.	Same as general construction
Sydney	Allowed: Monday to Saturday 07:00 to 19:00 Not allowed (unless exceptional cases): Sunday all day.	Allowed: Monday to Saturday 07:00 to 20:00 Sunday 08:00 to 20:00 Not allowed (unless exceptional cases):
New York City	Allowed: Monday to Saturday 07:00 to 18:00 Not allowed (unless exceptional cases): Sunday all day.	Same as general construction

B. Noise Control Zones

Noise control zones are established in many cities as geographical administrative units comprising buildings of various types. These zones are usually established in city planning stage where clusters of similar buildings are established. Many cities have outlined special noise criteria for each zone. It is to be noticed here that not having a zone does not mean that there are no distinctions of applicable noise law among different building types. In cases where noise zones are not available, the authorities may have different mechanisms to manage noise impact.

1. Hong Kong

Although the terminology of “noise control zone” is not used in Hong Kong, there is a concept of acknowledging the need of more protection for different locations by virtue of the nature of the place in concern and the prevalent uses and noise climate. During the assessment of CNP applications, the authority will establish the criteria (or Allowable Noise Level, ANL) for a noise sensitive receiver (NSR), based on the type of area that a NSR is located, e.g., urban or rural areas, and surrounding factors, e.g. highway and industrial area, that would influence the background noise at the NSR façade. An Area Sensitive Rating (ASR), in the form of A, B and C, for the NSR will be determined by a matrix of considerations given under the relevant Technical Memorandum (TM) [4].

Further to the ASR, Designated Areas (DAs) were established for built-up areas where specified PME would require compliance with more stringent noise criteria and tighter control on noisy manual construction works, or Prescribed Construction Works (PCW), e.g., hammering handling of rubble, wooden board and steel bar, during restricted hours [4].

2. Berlin

Noise control zones in Berlin are established in four categories starting from the least sensitive to the most sensitive in descending order [16]. The division in Berlin is unique in the sense that where other cities establish zones based on residential and highly sensitive areas, Berlin has divided residential areas into 3 sub-categories, namely commercial facilities and residential, predominantly residential and only residential. The decision to categorize an area has been left in the hands of authority and no maps are provided such that liaison with the authority is expected to be necessary. The final decision to determine which area belongs to which category is left to the authority, and the difference in allowed noise level is 5dB between different categories which means that if an area is classified as commercial facilities with residential and another area is classified as predominantly residential, there will be a difference of 5dB in allowed noise level.

3. Melbourne

The noise control zones in Melbourne are based on a Designated Sound Level (DSL) system which is the maximum noise level allowed at 1.5 m distance from a building façade that is closest to a construction site [18]. But the zoning system

of Melbourne is interesting such that an area is considered to be within the sensitive zone based on certain pre-specified types of building within a specified radius of the construction site in a specified time range. The noise control zone system is based upon the time of the day. In this system, a building or a group of buildings will be considered within a noise sensitive zone based on the “typical sensitive periods” established by the authority and DSLs will be enforced within the “likely area for consideration”. For example, if there is a residential premises within 200m radius of a site boundary, the authority would enforce 75dB(A) $L_{eq,30mins}$ criteria at the façade of this residential premises. For all other buildings outside this radius, there would be no DSL applicable.

4. Taipei

There are 4 noise control zones (known as classes) in Taipei that are divided based on noise sensitivity. Areas with highest sensitivity such as hospitals, nature reserves, etc. are grouped into Class 1 and other areas with decreasing sensitivity are arranged in descending order as shown in Section 4.4. The noise criteria are respectively more stringent in more sensitive areas. This zoning system is complemented by a special zoning mechanism in which the authority can designated any location, property or group of properties as special class zone with 5dB lower criteria applicable than the originally applicable criteria within maximum radius of 50m from the location. Taipei considers 4 zones of different classes with different noise criteria for different noise sensitivities. Special zone provision could be demarcated by the authority to ensure added safety for noise prone premises, by assigning a more stringent noise criterion. [19].

Different regulations can be made for different zones, not just for the noise criteria but for other factors as well such as restricted hours.

C. Noise Criteria

1. Hong Kong

Noise criteria in Hong Kong are established based on the area in which the work is being done, for example the areas defined in Technical Memorandum on Noise from Construction Work other than Percussive Piling include the following:

1. Rural area, including country parks or village type developments;
2. Low density residential area consisting or low rise or isolated high-rise developments;
3. Urban area;
4. Area other than those above.

Each of the above types of areas combined with Influencing Factors (IFs) have specific applicable criteria for evening (19:00 to 23:00) and night (23:00 to 07:00) hours. The same methodology of determining applicable criteria is used for DAs, however, the applicable criteria in DAs is 15dB lower than non-DAs only for operation of five types of Specified Powered Mechanical Equipment (SPME).

A contractor has to ensure the noise compliance of both regular PMEs and SPMEs separately in order to obtain a Construction Noise Permit inside a DA.

Daytime noise criteria, according to the EIAO, are established in many situations at 75dB(A) as measured at identified NSRs façade, or 65dB(A) in exceptional conditions such as hospitals and schools during examinations. As mentioned before, EIAO is applicable to infrastructure projects which are considered as Designated Projects (DPs) [4].

2. Seoul

Noise criteria in Seoul is based on similar philosophy as Hong Kong i.e., the criteria are provided for noise measured at the nearest building façade such that the impact of noise on general public can be measured. The noise criteria is given in Section 4.3 which includes noise levels to be complied with throughout the day i.e. Seoul has criteria for early morning, morning, evening and nighttime.

A special feature of this criteria is that it is adjustable for shorter durations of work, thus catering for short term noisy works. The criteria are adjustable up to +10dB(A) when the working time of a machine or equipment is less than 3 hours per day and adjustable up to +5dB(A) when the working time of a machine or equipment is more than 3 hours and less than 6 hours per day. Advance notification to the mayor's office is necessary otherwise no special provisions are applicable.

3. Toronto

The noise criteria in Toronto follows the Environmental Noise Guideline for the Ontario province, which classifies all areas into classes with specific regulations for each class. Toronto falls into Class 1 (area typical of a major population centre) and Class 2 (area with characteristics representative of both rural area and Class 1 area). The outdoor noise criteria based on $L_{eq,1hr}$ is 50 dB(A) for Class 1 area, and 50 dB(A) (07:00-19:00)/45 dB(A) (19:00-23:00) for Class 2 area [17].

4. Sydney

The noise criteria in Sydney is based on a noise limit relative to the background noise level (BGL). The unique feature of noise criteria in Sydney is that, say for a normal weekday, there is a criterion of "BGL + 5 dB(A)" for a narrow timeslot in the early morning hours (7 am to 8 am) which allows contractors to start work early in the morning. An allowance of further +5 dB(A) is possible (i.e., "BGL + 10 dB(A)" as the noise limit) depending on site situations such as nearby urban setting and impact on them in daytime hours (8 am to 7 pm). The criteria is lower for evening time ("BGL + 3 dB(A)", 7pm to 11pm) and night works ("BGL + 0 dB(A)", 11pm to 7am).

D. Community Liaison

In addition to above technical aspects of noise management at the receiver, some cities also have non-technical management methods such as community liaison. The consultant has found that these measures are mostly early interventions to address public concerns. It may include facilitation of dialog between community and construction contractors for better understanding, or providing useful information to contractors and members of public.

1. Tokyo

Citizens of Tokyo can register their complaints with the representative offices of Tokyo Metropolitan Government in each ward through direct approach, telephone call or emails provided on the website. Upon receiving the complaint and understanding the details provided by complainant, the location, type and source of noise are determined, possible improvement measures are evaluated, responsible parties at noise source are instructed some steps for improvement of the situation, a report is sent to the complainant after the improvements are completed, further follow up checks and verifications are conducted on noise source site to ensure that the problem is fixed, and finally the complaint data with relevant improvement actions are recorded in the government database.

2. New York City

One of the main responsibilities of the Community Boards (CB) office is to receive complaints from community residents including noise complaint against domestic renovation. Although CBs are not legally binding, it has persuading power in handling noise complaint.

The NSR could ask CB for assistance via chairperson of environmental protection committee, community board meetings or even CB's District Manager. CB will assign their members to follow the renovation and contact the neighbour. The CB member will launch meeting with both parties. In the meeting CB member will request the neighbour to schedule the renovation work to fit for the life style of the affected NSR. Finally, both parties need to sign agreement or contract with legal power. This is the most effective way to control noise from domestic renovation in NYC.

It is vital to note that community boards cannot order any City agency or official to operate any task while they serve as proponents for their neighborhood. Despite this limitation, boards usually succeed to deal with the problems they address.

3. Sydney

The guidelines of negotiating with the community are provided in document "Our approach to engaging the community". According to the community engagement framework, there are three levels of community engagement. The levels are inform, consultation and active participation. Informing, as known as low level of engagement, occurs when a decision has already been made or action is mandatory, and those affected needs to be noticed of the facts by the City of Sydney. Consulting occurs before part of the project or decision is proceeded when some input, feedback or advice is required. Active participation (high level of engagement) involves the collaboration between the City of Sydney and specific stakeholder groups or the community to develop a to-do list and to work out solutions that are integrated into decision making. All engagement processes are necessary to inform, majority of them will require some level of consultation and some will involve active participation.

Engagement activities include:

- a dedicated online consultation portal -

sydneyoursay.com.au which includes surveys, polls, mapping, and online forum workshops and community meetings, stakeholder meetings and roundtables

- deliberative processes including 21st century town hall meetings and citizens' juries
- public seminars including CityTalks
- creative workshops with children
- community and stakeholder reference groups
- Advisory panels and groups including the Aboriginal and Torres Strait Islander Advisory Panel; Public Art Advisory Panel; Retail Advisory Panel –information on the City of Sydney websites and advertised through traditional and social media channels

These activities are evaluated into four areas such as process, appropriateness, reach and outcomes. Process includes the quality of design and implementation of the engagement. Appropriateness determines whether the engagement is appropriate as well as the acceptance of the public and stakeholders. Reach is to find out whether the representative of those affected by the decision are reached. Outcomes decides the achievement of expected outcomes. The evaluation results are used to inform recommendations for the next stage of the process and future projects.

4. Seoul

The community liaison system in Seoul is perhaps the most active and comprehensive system among other cities in terms of two-way communication between the authority and community [8].

Firstly, a noise monitoring network is established throughout the city and locations are informed to the public. Public access is also allowed to the data obtained from these measurement stations through a website. The mayor is also required to submit yearly report on progress of noise management measures in each Gu and disclose it to public through the internet.

To provide most up to date information on construction works, the Seoul Metropolitan Government maintains an interactive website where all construction works in each Gu are updated on a map of Seoul [8]. This provides the citizens a chance to know the duration of construction works and access site specific information such as starting date, target end date, type of work and exact location of the work which can help to understand the impact of noise from construction works on the citizens nearby. It must be noted that the website does not provide any information regarding the noise emission from the site.

Also, the city government engages in effective communication campaigns with the public to ensure that views and grievances related to noise complaints are swiftly handled. Various media, Facebook, Twitter, telephone line, etc. are used to disseminate useful information to the public and collect feedback.

V.CONCLUSION

This paper reviews the international best practices in managing construction noise at source, focusing on the transmission path and at the receiver end. The results from 13

international cities show that noise management at source and at receiver end are undertaken in the form of legislation targeting noise from construction sites and domestic premises. The study recommends noise management at source as a preventive and early planning approach to encourage the construction industry (including project proponents and contractors) to choose quieter construction machines for both general construction works and domestic renovation. On the other hand, the Study also suggests that the community approach can also be applied to general construction works; but also domestic renovation. Such community approach may be further developed for tackling noise from domestic renovation in Hong Kong.

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