Global trends in environmental noise control for a smarter city

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Abstract: It is well-known that environmental noise can make people anxious, difficult to fall asleep and even increase the chance of having heart attack. It is important for people to build a smart city on thinking how to protect our environment and reduce noise pollution, while we are looking for a high standard of living and good economic benefits. In this paper, the authors will introduce and summarize how other countries are currently working in order to make their cities smarter. For instance, use of railway transportation as integrated transport system is one of the most popular smart ways to make cities smarter.

Key words: smart city; sustainable urban mobility; railway noise control

1 WHAT IS A SMART CITY？

Definition of smart city varies across the globe and therefore the conceptualization of Smart City, varies from city to city and country to country and it really depends on the level of development, willingness to change and reform, resources and aspirations of the city residents.

Picture of a smart city contains a wish list of infrastructure and services that describes citizen's aspiration. To provide for the aspirations and needs of the citizens, urban planners ideally aim to develop the entire urban eco-system, which can be represented comprehensive development-institutional, physical, social and economic infrastructure. This can be a long term goal and cities can work towards developing such comprehensive infrastructure incrementally, adding on layers of 'smartness'.

Core infrastructure provides a decent quality of life, a clean and sustainable environment to its citizens through application of 'Smart' Solutions. The core infrastructure elements in a smart city can include adequate water supply, assured electricity supply, sanitation, solid waste management, robust IT connectivity and digitalization, sustainable environment, sustainable mobility and public transport.

This paper will discuss various Smart City initiatives being implemented across the globe with focus on Sustainable Urban Mobility.

Received: Sept. 19, 2016; **Revised:** Nov. 25, 2016

2 GLOBAL INITIATIVES

Sustainable Urban Mobility can be defined as the ability to meet the needs of society to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or environmental values today or in the future.

There are goals for improving the sustainability of mobility[1], which includes the reduction of conventional emissions from transport to levels where they do not constitute a significant public health, reduce transport-related noise as well as mitigate traffic congestion, preserve and enhance mobility opportunities available to the general population. 3 tiers approaches will be discussed in this paper:

- **Tier 1 -** City level
- **Tier 2 -** Project level
- **Tier 3 -** Technology & innovative controls

We will illustrate the sustainable urban mobility through those initiatives being implemented in China, Hong Kong, Thailand and United Kingdom.

2.1 City Level-Thailand

World Business Council for Sustainable Development (WBCSB) was established in 1995. Approximately 200 top managements of global companies aim to establish sustainable development as a core value of the management. WBCSB had developed Sustainable Mobility Project 2.0 (SMP2.0) – Bangkok Task Force "Sathorn Model"[2] and concluded in November 2014. The aim of the SMP2.0, mainly are:

- Integrating and demonstrating holistic approaches addressing the aspects of sustainable mobility
- Advocating the policy accelerators and framework conditions
- Developing a detailed roadmap for sustainable mobility
- Formulating sustainable mobility indicators that measure the state of mobility in city
- Fifteen companies were participated in the pilot, where the sustainable mobility indicators and solution tool box were developed. The SMP2.0 process was comprehensive, where mobility performance and identification of city priorities were analyzed through survey and data collection from the key stakeholders then to formulate priority indicators.

Mobility enhancement solutions were formulated and roadmap towards mobility plan was developed with a defined timeframe, area of deployment, infrastructure / policy behavior enabler as well as the financing mechanism.

Sothorn Road in Bangkok was selected in the pilot project given that Sothorn Road is one of the most congested roads in Bangkok with good access to existing mass-transit transportation, existing of multinational companies and schools.

Sustainable Urban Mobility Indicators were developed through survey undertaken with the key stakeholders and indicators included affordability, accessibility for impaired, air pollution, noise hindrance, fatalities, access, functional diversity, travel time, economic opportunity, public finance, space usage, GHG, congestion, energy efficiency, active mobility, intermodal integration, comfort and pleasure as well as security.

This pilot model targets to improve traffic congestion at the Sathorn Road, such as expansion of current road & Mass-Transit transportation capacity as well as shift traffic demand from vehicle to other. Model also included the review of the spread time of traffic demand, such as flexible working time and way to improve traffic flow through mitigate traffic bottleneck.

2.1.1 Details of the Initiatives

Top-management of 69 companies committed to participated in the SM2.0 Project, where various initiatives were put into action:

- Park & Ride using parking of shopping mall
- Shuttle bus for BCC school and shortened the cycle time of traffic signal.
- Traffic flow management was also introduced by prohibiting using 3 lanes to drop / pick-up kids as well as shortened the traffic signal cycle.
- Developed mobile application “Link Flow” to provide traffic information to select best mobility option
- Out-reach to change mindset of parent on school / shuttle bus sharing through membership scheme

Multinational companies adopted the flexible working time initiative, these included BP-Castrol (Thailand) Ltd, Hitachi Asia Ltd, Toyota Motor Thailand Co. Ltd, Fujisu System Business Tailand Company Limited, Nippon Parking Development (Thailand) Company Ltd, Sumitomo Mitsun Banking Corporation.

2.1.2 Evaluation of the Pilot Project

Through the 500 participants on the Park & Ride, 150 on the Shuttle Bus initiatives and 13 companies (~2,000 persons) on the flexible working time as well as the bottleneck mitigation, the average travel speed was increased from 17% up to 37% at various sections of Sathorn Road, which had also reduced nuisance from the traffic noise from congested traffic.

2.2 Project Level–Shenzhen, Hong Kong[3], London

By integrating railways into urban planning, it allows railway stations to be within easier reach of more residents. It offers convenience to the public and benefits the society through better utilization of the mass transit system. This in turn reduces the pressure on road-based traffic due to urban development and relieves traffic congestion, thus matching the concept of Sustainable Urban Mobility. By relieving road congestion it minimizes environmental impacts such air pollution and noise impact.

Shenzhen Metro Line 4 (Longhua Line) – Running northward from Futian Checkpoint to Qinghu. The line serves Futian District and the eastern part of Bao’an District (in particular, Longhua Subdistrict) of Shenzhen. The route length of Line 4 is around 21 km with totally 15 stations. Among the 15 stations, 7 are underground, 1 is at grade and 7 are elevated. Shenzhen Line 4 can be interchanged to Shenzhen Line 1, 2, 3 and China High Speed Railway.

Hong Kong is currently expanding its railway network and these projects are being completed between 2015 and 2021. Upon completion, the total length of railways in Hong Kong will be increased to more than 270 km. There will be 99 railway stations and 68 light rail stations, serving areas inhabited by more than 70% of the local population and forming an easily accessible mass transit network. It is anticipated that the rail share of local public transport trips will increase to 43%, which further underlines our policy of using railways as the backbone of our passenger transport system (see Fig.1).

London is building an east-west rail line known as Crossrail (Fig.2). When the new central London section of the system opens at the end of 2018 it will make a significant difference to the metro area’s public transport system.

Europe’s largest current infrastructure project, Crossrail is expected to cost £14.8 billion – twice as much as the city’s 2012 Olympics. No one denies that the additional rail capacity is desperately needed; the city’s population is growing rapidly, increasing the strain on existing and new lines with more people travelling on London’s Tube than ever before[4].

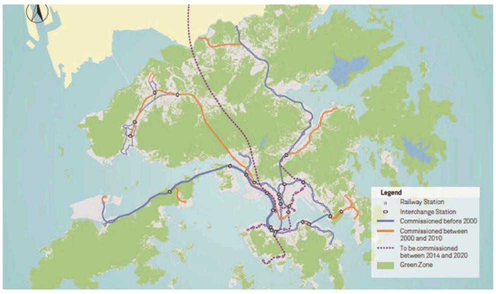

Fig.1　Backbone of passenger transport system in HK

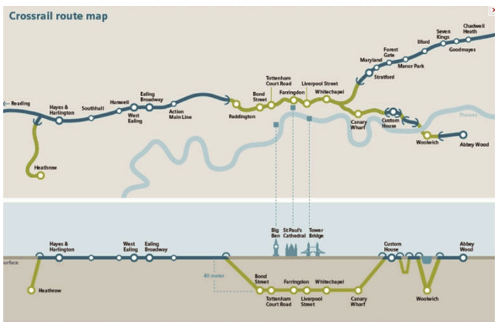

Fig.2　Crossrail network, UK

2.2.1　Noise Controls Initiatives

Development of railway project requires impact assessment to assess their environmental acceptability. For a long term impact evaluation, efforts will focus on the railway noise control. Various noise mitigation measures have been designed and implemented in various projects across the globe, the followings will highlight the details and summarized in Fig.3 & Table 1.

Airborne Noise

Noise emissions from electrical railway system are predominantly causes by the rolling contact of steel wheels on steel rails. Other noise sources on electric passenger trains (such as air-conditioning plant and air compressors) are generally insignificant in noise level when compared with the wheel rail interaction, unless the train is travelling at a very low speed or is stationary. Railway noise is mainly controlled through at source and/or at noise paths.

Control at Source - Balance between airborne noise and structure-radiated noise controls, rail dampers can achieve reduction up to 4 dB(A) on airborne noise. At locations, benefit can reduce to around 2 dB(A) to 2 - 3 dB(A).

Control at Noise Path

- Noise barriers 5 metres in height, located at-grade is predicted to give typically between 6 and 10 dB(A) reduction in net noise to existing eight-storey medium raise building around 50 metres to 100 metres on a proposed at-grade alignment[5].
- Typical semi noise enclosure of about 7 metres in height, which are at-path control measure, located at-grade is predicted to give typically at least 15 dB(A) reduction in net noise to existing over twenty-storey building in less than 50m from a proposed at-grade alignment[6].

As with rail dampers, the benefit of noise barriers is reduced at locations where structure-radiated noise dominates. Once the airborne noise level is reduced to below the structure-radiated noise, further reductions in airborne noise will not significantly reduce the overall noise levels. To be effective, noise mitigation efforts will therefore focus on the dominant noise source.

Groundborne Noise

Rail vibration is generated by dynamic forces at the interface of the rail head and train wheels and can transmit into adjacent buildings via the tunnel structure and intervening ground. If the levels of vibration are sufficiently high (*i.e.* in buildings very close to rail tracks), then this vibration can be felt as tactile vibration by the occupants of nearby buildings.

Noise enclosure

Noise enclosure

Floating slab track

Noise barrier

Noise barriers during installation

Noise reducer

Fig.3 Typical rail noise control measures

Table 1 Noise controls being implemented across other regions of Shenzhen, Hong Kong and London

Area	Projects	Operation Status	Background	Noise Control Measures
Shenzhen, China	Line 4	Since 2011	Approx. 21km between Futian Checkpoint and Qinghu Station	• Low Vibration Trackform • 1m High Noise Barrier • 6m High Noise Barrier • Noise Reducer
Hong Kong, China	West Rail Line[7]	Since 2003	Approx. 35.4 km of railway between Hung Hom and Tuen Mun	• Noise Enclosure • Lower Vibration Trackform : Resilient Baseplated Trackform and Floating Slab Track
	Ma On Shan Line[8]	Since 2004	Approx. 11.4 km of railway between Tai Wai and Wu Kai Cha	• 7.4m High Cantilever Barrier • 2m High Noise Barrier • 2m High Noise Barrier (above 2.1m parapet wall) • Noise Enclosure • 3m High Noise Barrier (above 2m containment wall) • 1.5m High Noise Barrier (above 2.1m parapet wall)

Continued Table 1

Area	Projects	Operation Status	Background	Noise Control Measures
	Lok Ma Chau Spur Line[9]	Since 2007	Approx. 7.4km railway extending from existing East Rail Network at North of Sheung Shui to Lok Ma Chau	• Absorptive Cantilevered-typed Noise Barrier, 5.8m High Vertical Panel above rail head and a 3.6m long incline on top at 60º • Absorptive Noise Barrier with a height of 5m above rail head and 300 m in length
	West Island Line[10]	Since 2014	Approx 3km underground railway, including Sai Ying Pun Station, University Station and Kennedy Town Station	• Medium Attenuation Baseplate • High Attenuation Baseplate
	South Island Line (East)[11]	2016	Approx. 7km of partly underground and partly viaduct railway alignment from South Horizons to Admiralty	• 6m Semi Enclosure • 2.2m Vertical Noise Barrier (above parapet wall) • 2.4m Vertical Noise Barrier (above parapet wall) • Low Vibration Trackform: Resilient Baseplated Trackform
	Hong Kong Section of the Guangzhou－Shenzhen－Hong Kong Express Rail Link[12]	2018	High speed rail link connecting Hong Kong to the National High-speed Railway Network, with a major terminus in West Kowloon (26km)	• 8m High Noise Barrier • 5.5m High Noise Barrier • 13m Noise Absorptive Panels • Low Vibration Trackform: Isolated Slab Trackform (IST) & Vanguard
	Shatin to Central Link (SCL): Tai Wai to Hung Hom[13]	2019	Approx. 11km of partly underground and partly viaduct railway alignment from Tai Wai to Hung Hom	• 2m High Noise Barrier • 3m High Noise Barrier • 7m High Noise Barrier • Low Vibration Trackform: Resilient Baseplated Trackform and Float Slab Track
	SCL – Mong Kok East to Hung Hom Section[6]	2019	Approx. 1.2 km realigned and modified railway from Portal 1A near Oi Man Estate to the new ventilation building in Hung Hom Station	• Natural Ventilated Absorptive Noise Enclosure
	SCL – Stabling Sidings at Hung Hom Freight Yard[5]	2019	Stabling Sidings at Hung Hom Freight Yard	• 7m High Semi-enclosure • 5m High Noise Barrier
London	Crossrail	• 2015 (initial section under “TfL Rail” brand) • 2018 (new central London section) • Late December 2019 (Heathrow Airport to Liverpool Street)		• Lower Vibration Trackform

After entering a building, this vibration may cause the walls and floors to vibrate faintly and hence to radiate noise, which is commonly termed ground-borne or regenerated noise. If it is of sufficient magnitude to be audible, this noise can have a low frequency rumbling character.

Mitigation of ground-borne noise and vibration in buildings near railway lines is usually achieved through the track form design, by the insertion of a resilient (rubber) layer between the rail and tunnel foundation. The resilient layer may take the form of resilient rail fasteners, booted sleepers, floating slab track or a combination of approaches. The following trackforms are typically adopted internationally:

Standard Attenuation Track – incorporating hard resilient baseplates and can be used in areas with low sensitivity to groundborne noise and vibration impacts.

High Attenuation Track – incorporating medium resilient baseplates with attenuation of about 5 to 10 dB(A), high attenuation baseplate or booted dual sleepers with attenuation of about 10 to 15 dB(A)[6]. This trackform can be used in sensitive areas where the standard track is not sufficient to meet the design objectives and a higher performance track is required.

Very High Attenuation Track – incorporating soft resilient baseplates or floating mini slab track with attenuation of about 20 to 30 dB(A)[6]. This track can only be required in very sensitive areas where the depth of the tunnel is particularly shallow.

These measures are deployed at the noise source to decrease the total sound level dispersed from railway operation. The track path of the railway line considerably affects rail noise generation and propagation. The propagation path between the noise source and receiver is treated in these ways helping to reduce total sound level travelling along the path.

2.3 New Trends in Environmental Noise Management and Heading Towards

2.3.1 Noise Management Combining Sound Technology and ICT

The first large-scale Automatic Noise Data Management E-system (ANDANTE) is being deployed in the Hong Kong Section of Guangzhou-Shenzhen-Hong Kong Express Rail Link project. ANDANTE is an innovative web-based noise monitoring system that alerts users automatically for any breaches on noise level which had greatly facilitated prompt follow-ups. In order to have more efficient and more detailed measurement on noise monitoring, the system is designed on a continuous noise monitoring at more than one site, which provides continuous noise data for monitoring purpose(See Fig.4~Fig.5).

2.3.2 Extending Sound Technology Smart Rail Maintenance

A big proportion of the expenses related to operating a railway are related to replacing wheels and rails, as a result of friction between the wheel and rail interface. Especially wheels that have cracks or faults on them may cause significant wear. These wheels will have to be replaced, may be cause to replacing parts of the rail track itself, or in worst case be the

Fig.4 ANDANTE's system architecture

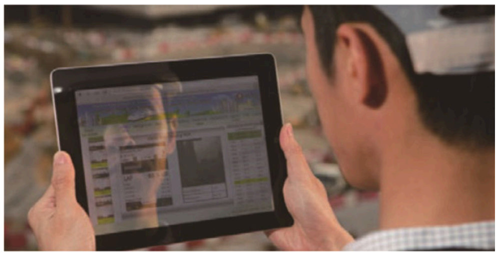

Fig.5 Mobile version of ANDANTE

underlying factor for derailing a train.

Identifying faulty wheels may not be a trivial task, where each wheel may have to be manually inspected for errors during which time the train is out of operation.

Automatic system based on an acoustic beamforming technology has been developed as the next generation of rail maintenance tool for future adoption by railway operators. It identifies acoustic signature of train wheels from different trains in motion, to detect faulty train wheels.

The underlying assumption is that a faulty, or unhealthy, wheel sounds differently than a wheel that is not damaged. This may be in terms of a higher sound pressure level (SPL) as to compare to other wheels on the same train, differences in frequency content within different frequency bands or time frames, and so forth. These differences may be called acoustic signature. By placing an array of microphones next to a railway track, beamforming methods can be used to listen to a single point on the track, thus filtering out sounds from different wheels as the train passes by(See Fig.6).

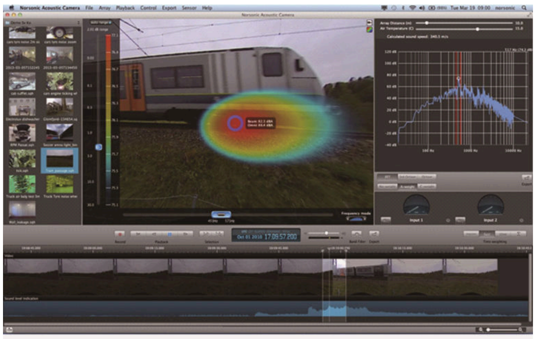

Fig.6 Using beamforming methods to listen a single point on the track

2.3.3 Collaborative Noise Management – Shared goals for smart performance

In the UK, the Crossrail scheme deployed eight tunnel boring machines to construct 42 km of new tunnel below a dynamic urban environment that mixes historic buildings - with strong legal protections - and more modern, but no less sensitive receptors. The scheme deployed a number of customized noise controls including: floating slab track - to mitigate railway groundborne noise and vibration, the installation of special trackform - related to proximity to noise sensitive buildings, and the realignment of some track designs to avoid / reduce noise impacts.

Given Crossrail's proximity to very historic protected buildings, such as the Grade 1 listed Paddington Station, and other noise sensitive buildings, the project gave assurances that the temporary construction railway needed to deliver materials to site would meet specified acoustic performance requirements. To deliver this, perhaps the greatest step forward in Crossrail's approach to noise management was not only in the application of noise technology, but also within the contracting process. This was achieved through the use of a smart and shared approach to managing noise risks between the Crossrail project and its construction contractors.

The project deployed a Performance Assurance Framework (PAF) across its supply-chain to provide an objective assessment and benchmark of performance across the portfolio of works required to deliver the project as a whole. The PAF covered all aspects of construction including the management of noise and vibration; with the purpose of: driving performance across the Crossrail supply-chain; generating innovation; sharing good practice and connecting those delivering it; and creating the knowledge base that drives a legacy of such good practice into future projects.

In relation to noise and vibration the PAF scored and measured each contractors performance on a four point scale from 0 (non-compliant) to 3 (world class), with three contractors delivering sufficiently high performance to merit the award of a level 3 grading. The detailed case studies behind this work are still in development at this time, but will be available to review and disseminate by the end of September as part of the Crossrail Environmental Learning Legacy.

This demonstrates another key role for major infrastructure development's that wish to deliver a smarter city - the sharing of knowledge to generate collaborative shared knowledge that helps ensure the next project learns and performs better than the last. This is a planned and resourced legacy, which is specifically designed to share innovation and learning to both local and global audiences through a project's construction and operational phases. Crossrail's learning legacy provides learning on Noise and Vibration, wider environmental learnings from air quality to resource management, and on to project management, health & safety, and information management and technology learnings (http://learninglegacy.crossrail.co.uk).

3 CONCLUSION - HOW TO ENHANCE THE DEVELOPMENT OF SMART CITY IN THE REGION

Technology will not only change the face of urban transport, but our lives. Technology will not only solve every problem, but also is a part of every solution. Smart Cities will transform the face urban transport and here are some key points:

Smart cities are real-time: information feedback is built into the city systems

Technology promotes transformation. Government transforms how it interacts with citizens using technology

So what does it mean for rail? It means that everything around us is becoming programmable. Software is integrated into every aspect of human nature. Apps, markets, plans and places are all programmable. We need to think really broadly about automation, think about different scenarios. What is possible? How can it influence transport? What if it all collapses? What constraints do we have? We need to think about how cities will be re-organized around the transformed world and what opportunities it opens for rail.

While citizens of smart cities wish to enjoy the potentials brought about by smart mobility via railway, the operators and relevant authority put extra effort to manage the potential noise impacts due to construction and operation phases. The prevailing practices and emerging new innovations presented in this paper aim to provide a good reference for the region on their journey towards building a smarter city.

References

[1] Daniel Augello (Director, Transportation Policy Delegate, Renault, Special Advisor to ITS EUROPE CEO IMPACTCS), International Conference, Seattle July 1, 2005 [C]//The Sustainable Mobility Project 2030, Meeting the challenges to sustainability.

[2] Mr. Okayama, Sustainable mobility project in Bangkok: Sothorn Model by at IAIA16 Conference, Nagoya, Japan, 12 May 2016.

[3] Transport & Housing Bureau, Highways Department, Review and Update of the "Railway Development Strategy 2000", Stage 1 Public Engagement - Consultation Document.

[4] Andreas Kleinschmidt, How cross rail will communicate, http://www.siemens. com/innovation/en/home/pictures-of-the-future/infrastructure-and-finance/smart-cities-crossrail.html.

[5] MTR Corporation Limited, EIA Report for Shatin to Central Link - Shatin to Central Link - Stabling Sidings at Hung Hom Freight Yard..

[6] MTR Corporation Limited, EIA Report for Shatin to Central Link - Mong Kok East to Hung Hom Section.

[7] KCR Corporation Limited, EIA Report for West Rail.

[8] KCR Corporation Limited, EIA Report for Ma On Shan Rail.

[9] KCR Corporation Limited, EIA Report for Lok Ma Chau Spur Line.

[10] MTR Corporation Limited, EIA Report for West Island Line.

[11] MTR Corporation Limited, EIA Report for South Island East.

[12] MTR Corporation Limited, EIA Report for Hong Kong Section of Guangzhou - Shenzhen - Hong Kong Express Rail Link.

[13] MTR Corporation Limited, EIA Report for Shatin to Central Link - Tai Wai to Hung Hom Section.

[14] MTR Corporation Limited EIA Report for Shatin to Central Link - Hung Hom to Admiralty Section.

智慧城市–环境噪声控制的全球趋势

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摘要：众所周知，过量的环境噪声会令人失眠、焦虑、或引发心脏病等。根据世界卫生组织报告, 全球各国都有一定数量的人已达至这水平，很多人是受环境噪声的影响。当大家在追求提高经济效益及生活质素的同时，各国为了建立智慧城市，有着不同的思维和构思去改善环境噪声，其中利用轨道交通工具作集体运输被各国视为一石二鸟的聪明出行方法。文章旨在分享全球在这方面的现状和趋势。

关键词：智慧城市；创建宜行环境；铁路噪声控制

中图分类号：TB533 **文献标识码**：A **文章编号**：1000-3630(2016)-06-0563-08

DOI 编码：10.16300/j.cnki.1000-3630.2016.06.013