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Environmental impact of electric motorcycles: Evidence from traffic noise assessment by a building-based data mining technique

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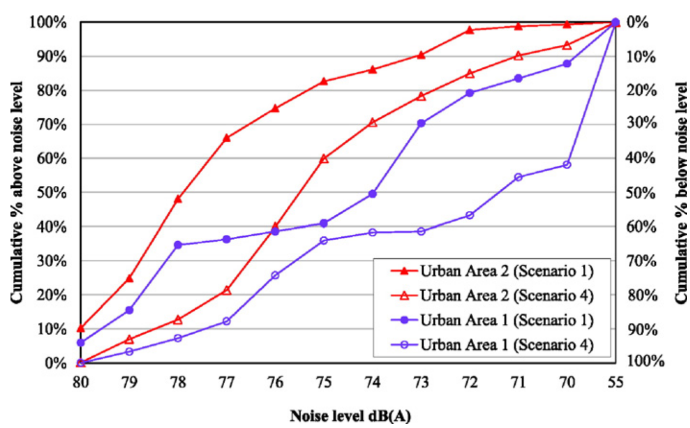
HIGHLIGHTS

- The effects of electric motorcycle on human exposure to traffic noise are assessed.
- The effect is not significant on improving the compliance rate in modern urban area.
- The effect is significant in historical urban area with dominant motorcycle traffic.

GRAPHICAL ABSTRACT



Distributive and cumulative curves of traffic noise level in historical urban area 1 and modern urban area 2 without EMs (Scenario 1) and with EMs (Scenario 4).

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ABSTRACT

This study provided new evidence on the potential adoption of electric motorcycle (EM) as a cleaner alternative to gasoline-powered motorcycle. The effects of EM on human exposure to traffic noise were assessed in different urban areas with different traffic scenarios. The assessment was carried out by a developed building-based model system that took into account the contribution of motorcycle traffic. The results indicated that the EM could be an appealing solution to reduce the risk of human exposure to excessive high traffic noise in a motorcycle city. Particularly, in a historical urban area in which the total traffic volume was lower and motorcycle traffic was dominant, the proportion of noise levels meeting the standard of 70 dB(A) increased significantly from 12.2% to 41.9% when 100% of gasoline motorcycles in the real traffic scenario were replaced by EMs. On the other hand, in a modern urban area in which the total traffic volume was higher and traffic noise levels at majority of sites were higher than 75 dB(A), the proportion of noise levels above 75 dB(A) decreased significantly from 82.6% to 59.9%. Nevertheless, the effect of EM on improving the traffic noise compliance rate in the modern urban area was not significant and other policies or measures need to be sought.

1. Introduction

Motorcycles are a fundamental mode of transportation in many Asian cities due to their low cost, flexibility, and adaptability to road conditions. They are particularly attractive in a compact city with

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narrow streets and high traffic density, together with the need to overcome the problem of city traffic congestion. Table 1 shows the percentages of motorcycles in total vehicles in different countries and regions (International Road Federation, 2012; Phan et al., 2010; Chang et al., 2011; ASEAN-JTSB, 2013; DSEC, 2013). It is observed that motorcycles account for over 50% of local transportation in many Asian countries/regions such as Vietnam, Myanmar, India, Sri Lanka, Bangladesh, Taiwan, Thailand, China, Philippines and Macao. Particularly in Vietnam, motorcycles comprised >90% of all registered motor vehicles. In contrary, developed countries such as United States, United Kingdom, Australia, Japan, Netherlands and Germany have low percentages of motorcycles (<10%).

One acoustic survey in Hanoi and Ho Chi Minh City (Phan et al., 2010) revealed that in cities of a developing country, environmental noise levels due to traffic were notably higher than those in a developed country such as Japan. High traffic noise exposure levels in Hanoi and Ho Chi Minh City in Vietnam were mainly due to the large number of motorcycles and frequent horn sounds. A study in Taiwan (Chang et al., 2011) also showed that the dominant source of traffic noise was motorcycles in central Taiwan, where registered motorcycles comprised 68% of all registered motor vehicles and 48% of the people in Taiwan used motorcycles for transportation. Motorcycles produce additional annoyance for the population living in the urban area. Studies in the Netherlands and United Kingdom showed that motorcycles were among the most annoying noise sources in the country even though motorcycles were not largely used (Paviotti and Vogiatzis, 2012).

Electric two-wheelers (ETW) (e.g. electric bicycles, electric scooters or electric motorcycles) may be an alternative to alleviate the severe noise pollution problems caused by gasoline-powered motorcycles in urban areas. The popularity of ETW has grown in recent years, particularly in China (Weinert, 2007; Weinert et al., 2007; The Economist, 2010; Bento, 2012). In contrast to the sales of electric four-wheelers (e.g. passenger cars) which have lagged far behind the optimistic projections all over the world, it was estimated that 40–50 million Chinese people used ETWs in 2007 (Asian Development Bank, 2009a; Cherry et al., 2009). The ETW sales have grown from 0.15 million in 1999 to 21 million in 2007 and then to 35 million in 2014 (Cherry et al., 2009; Wuyang-Honda, 2015). A growing literature has focused on the environmental impacts of ETW, including the positive aspects such as reduction of emissions and the negative aspects such as lead pollution (Tzeng and Chen, 1998; Cherry, 2007; Meszler, 2007; Asian Development Bank, 2009a,b; Cherry et al., 2009; Kamakaté and Gordon, 2009; Ji et al., 2012; Trappey et al., 2012; Van der Kuijp et al., 2013; Lelong et al., 2014).

Table 1
Comparison of number of motorcycles in different countries and regions.

Country or area	Year	Total vehicles (1000 units)	Motorcycles (1000 units)	Percentages of motorcycles (%)	Sources
Vietnam	2010	20,830	20,000	96.02%	a
Myanmar	2010	2225	1881	84.54%	b
India	2009	103,602	82,402	79.54%	b
Sri Lanka	2010	3630	2630	72.45%	b
Bangladesh	2010	1442	976	67.68%	b
Taiwan	2010	21,700	14,800	68.20%	c
Thailand	2012	31,440	19,169	60.97%	d
China	2010	177,781	100,564*	56.57%	b
Philippines	2010	6317	3482	55.12%	b
Macao	2013	228	119	52.19%	e
Malaysia	2010	19,695	9442	47.94%	b
Pakistan	2010	4329	1284	29.66%	b
Turkey	2010	13,655	2389	17.50%	b
Singapore	2010	902	147	16.30%	b
Italy	2010	47,619	6526	13.70%	b
Spain	2010	30,021	2707	9.02%	b
Germany	2010	50,639	3828	7.56%	b
Netherlands	2010	9387	636	6.78%	b
Hong Kong	2010	582	38	6.53%	b
Japan	2010	78,801	3502	4.44%	b
Australia	2010	16,166	670	4.14%	b
United Kingdom	2010	33,504	1234	3.68%	b
United States	2010	254,876	8212	3.22%	b

Note: Source a: Phan et al., 2010; Source b: International Road Federation, 2012; Source c: Chang et al., 2011; Source d: ASEAN-JTSB, 2013; Source e: DSEC, 2013.
* The data was only for gasoline motorcycles.

The present study aims to provide new evidence on the environmental impact of electric motorcycle (EM). The effects of EM on pedestrian exposure to traffic noise are assessed in different urban areas with different urban forms. Two typical urban areas, i.e. historical and modern urban areas, are considered. The traffic noise assessment is carried out by a developed building-based traffic noise model system. The system integrates a traffic noise model with a Geographic Information System (GIS) that enables automatically processing a large amount of complex geographically referenced data such as street configuration, road gradient and road surface nature. The developed GIS-based traffic noise modeling system has a high spatial resolution down to individual buildings along both sides of the street, and therefore can support spatial analysis of traffic noise in a compact city with complex traffic conditions and urban geometries. Particularly, the traffic noise model proposed in this study takes into account the effect of significant motorcycle traffic and therefore, can be applied to assess traffic noise in a compact city with high motorcycle traffic.

In the next section, the building-based traffic noise model system is introduced in detail. In Section 3, model validation is presented. In Section 4, the effects of EM on pedestrian exposure to traffic noise are discussed based on a large-scale traffic noise assessment conducted by applying the present modeling system. Moreover, the effects of EM are investigated in two typical urban areas, i.e. historical and modern urban areas which have different urban forms. Finally the conclusions are given in Section 5.

2. Model development

2.1. Establishment of a traffic noise model for motorcycle city

Many popular road traffic noise prediction models have been developed in the literature, such as the Federal Highway Administration (FHWA) model in United States (Anderson et al., 1996; Dai et al., 2014), the Calculation of Road Traffic Noise (CoRTN) model in United Kingdom (Delany et al., 1976; Department of Transport Welsh Office, 1988), the RLS-90 model in Germany (Steele, 2001), the ASJ model in Japan (Koyasu, 1978; Yamamoto, 2010), and the Nordic prediction model in Sweden (Bendtsen, 1999). Among these, the FHWA model and the ASJ model have included motorcycles in the calculating equations, however, they cannot be directly applied to estimate road traffic noise levels in a city with significant motorcycle traffic because motorcycles only comprised 3.22% and 4.44% of registered motor vehicles in United States and Japan, respectively (International Road Federation, 2012). In the CoRTN model and the Nordic prediction model, motorcycles are simply counted into light vehicles and heavy vehicles, respectively, and their effects are not considered separately.

Significant motorcycle traffic may lead to inaccuracies when applying the aforementioned models to assess traffic noise in a motorcycle city. In this light, Chang et al. (2012) has developed a modified Nordic prediction model to map road traffic noise in Taichung City of Taiwan which has significant motorcycle traffic. While in the present study, the CoRTN model is selected to be modified because it has been widely used in the United Kingdom, Australia, New Zealand and the neighboring city of Hong Kong. Particularly in the United Kingdom and Hong Kong, the CoRTN model is the sole instrument for the assessment of road traffic environmental impacts by local authorities. Some researchers have studied the reliability of traffic noise prediction using the CoRTN model and the performance of the CoRTN model was found to be different under different prevailing conditions (Steele, 2001). In Australia, Samuels and Saunders (1982) reported that the mean