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Transportation Research Part D 12 (2007) 437–448

TRANSPORTATION
RESEARCH
PART D

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High-speed maglev noise impacts on residents: A case study in Shanghai

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Abstract

High-speed maglev trains offer competitive journey-times to automobile and air transport in markets of 60–1000 miles but they have potentially adverse noise impacts. This paper considers the noise characteristics of the Shanghai Maglev Train on residents within 300 m to the track. It shows that the system is about 4–8 dBA quieter than other high-speed systems at comparable speeds with their guideways at a similar distance. One of the train's noise characteristics is that L_{ASmax} drops 7–10 dBA as distance from the guideway doubles. The onset rate within 30 m-distance to the maglev track is more than 20 dB/s, and 86.5% of respondents complained they had been startled when traveling beneath the guideway when it was in use. High speed maglev noise annoyance is not found to be strongly related to demographic variables, other than that home owners are more annoyed than renters. The linear dose-response relationships between HA% and L_{ASmax} is developed to evaluate the impacts of high-speed rail systems, with the finding that L_{ASmax} is more appropriate than calculated L_{Aeq} to as a descriptor of noise level and limit boundary.

Keywords: High-speed maglev; Noise measurement; Social survey; Noise annoyance; Onset rate

1. Introduction

Magnetic levitation (maglev) is a technology in which magnetic forces lift, propel, and guide a vehicle over a, usually, elevated guideway. Utilising electric power and control systems it eliminates physical contact between vehicle and guideway permiting cruising speeds over 400 km per hour (kph), somewhat higher than conventional high-speed rail. In terms of speed this makes it competitive with automobile and air transportation the 60–1000 mile travel markets (US Federal Railroad Administration, 2001).

Maglev technology has been researched and developed since the 1960s, especially in Japan and Germany. The German Transrapid International Maglev System has a design based on a long stator linear synchronous motor with conventional electromagnets in an attractive magnetic force configuration, whereas the Japanese

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doi:10.1016/j.trd.2007.05.006

Railway Technical Research Institute's MLU-series system, has a design based on superconducting magnets in an electro-dynamic repulsive system and set a speed record of 581 kph in December, 2003 (RTRI, 2004).

The latest German Maglev System TR08 has been used in the Test Facility Emsland in Germany and Shanghai Maglev Train (SMT) in China, as well as selected by for other systems, such as the Pennsylvania and Maryland Maglev Projects in the US (US Federal Railroad Administration, 2001), the Zuyderzee Maglev Project in Netherlands (Holties, 2001) and the Shanghai–Hangzhou Maglev Project.

The maglev train produces high noise levels at speeds of more than 250 kph that may affect the health and well-being of residents near the line. Noise characteristics of TR08 in Emsland have been evaluated by the US Federal Railroad Administration (2002), and sound exposure level (SEL) at a distance of 30.5 m from the line 100 dBA was recorded when the train's speed reached 400 kph. Project Group of Zuyderzee Maglev Line conducted laboratory tests (Vos, 2003) where they presented twelve listeners with various sound fragments and the annoyance levels were rated. It was found that the annoyance caused by the maglev train was significantly higher than that caused by the intercity trains and hardly different from road traffic, provided that the outdoor A-weighted SEL was constant. The limitations of this works, however, are that the sample size is small and the sound employed was just a recording of TR08 in Emsland. Finally the respondents were in the maglev "sound environment" just for a few hours rather than several years.

The paper does several things. First it measures the noise character of high-speed SMT to help establish a cleared annoyance borderline for residents. Second, it compares SMT noise levels with other high-speed train system. Third it develops the dose-response relationship between noise level and annoyance of residents in the vicinity of the SMT.

2. The shanghai maglev train

The SMT employing Transrapid International Maglev System Technology is the world's first high-speed maglev commercial commuting system. The 30 km elevated double-track project with prototype concrete guideway connects Shanghai Pudong International Airport (SPIA) and the Longyang Road Station, a downtown metro station (Fig. 1). Most of the SMT parallels the Yingbin Expressway that is heavily trafficked throughout the day. Construction of the project began in March 2001, tested on December 31, 2002, and opened on March 29, 2004. Its cost is about 10 billion RMB ($1.2 billion).

Fig. 1. SMT route.

The SMT carried 2.18 million passengers in 2004, and about 7500 passengers now use it each day. Passengers are mainly of tourists and users of the SPIA terminal. Recently discounted SMT tickets were offered for passengers with airline tickets to attract passengers and increase revenues. Two German made trains operate on the line, each 126.3 m long grouped with five carriages. They run at 15–20 min headway from 8:30 am to 17:30 pm with a top speed of 430 kph. It takes 7 min and 20 s for 30 km trip. It takes about 2 min and 15 s to reach 300 kph, about another 70 s to reach its peak speed that it maintains for about 55 s, and then decelerates gradually. The maglev technology and the specially designed windows make the riders feel comfortable and quiet even at its maximum speed.

A 300 m width greenbelt runs along the track to limit noise and creates an acceptable landscape in Shanghai Pudong area. Thousands of residents live within 300 m of the line and hundreds very close to the line, within 50 m.

3. The measurement of maglev noise

3.1. Basic framework

The total wayside noise generated by a high-speed pass-by train consists of several independent noise generating mechanisms, each with its own characteristics of source location, strength, total train length, frequency content, directivity, and speed dependence. These noise sources can be generalized into three major regimes:

- Regime I: propulsion or machinery noise,
- Regime II: mechanical noise resulting from wheel/rail interactions and/or guideway vibrations, and
- Regime III: aerodynamic noise resulting from airflow moving past the train.

For a conventional train with 200 kph or so maximum speed, propulsion and mechanical noise are sufficient to describe the total wayside noise. The aerodynamic noise component begins to be the dominant factor when the train speed exceeds about 250 kph. For high-speed maglev, aerodynamic noise sources include the flow separation on the front and rear ends, vortex shedding from the antennae, flow interactions in the gap between the vehicle and guideway, the wake generated at the trailing end, and the turbulent boundary layer. Aerodynamic noise level increases with train speed much more rapidly than does propulsion or rolling noise level, with typical governing relationships of 60–70 times the logarithm of speed (US Federal Railroad Administration, 1998). The lasting duration of noise increases with the total length of train, and noise lasting duration together with the noise level determine the degree of noise influence on concerned residents.

Fig. 2 shows the noise level measured on a comparable basis for various high-speed rail and maglev systems (US Federal Transit Administration, 2002), and the spectral frequencies of SMT noise is shown on Fig. 3 with a clear feature for aerodynamic noise.

A feature of the noise derived from high-speed maglev is peculiarity of the onset rate of the sound signature. The intensity of sound waves produces a sound pressure level (SPL) that is generally measured in decibels. Onset rate is the average variance rate of increasing SPL in decibels per second (dB/s) during a single noise event. The rapid approach of a high-speed train is accompanied by a sudden increase in noise for those near the track. Sounds of approaching vehicles carry a sense of convergence and cause greater annoyance than receding sounds (US Federal Railroad Administration, 1998). Moreover, sounds with fast onset rates are more annoying than those that emerge more slowly or steady noise with the same maximum noise level. The US Air Force looking at the effects of the onset rate from aircraft noise found that people are increasingly annoyed by onset rates greater than 15 dB/s, and tend to be startled when the onset rate exceed about 30 dB/s.

Our noise measurements were carried out on October 23 and 24, 2004. Depending on the time of the day, temperatures during the measurement were between 16 °C and 20 °C, typical sunny days in autumn in eastern China. Two directions of SMT were measured in case of differences in noise levels by direction. Each site was measured at least 3 times for each direction and the average values applied.

To consider the noise issue at the maximum speed of the train and, because it takes about 205 s for SMT to reach this speed, locations for surveying are at least 205 s away from the two terminals. Fig. 4 shows the distance–speed relationship, and the speed variance at the same site for two directions is no more than 20 kph.

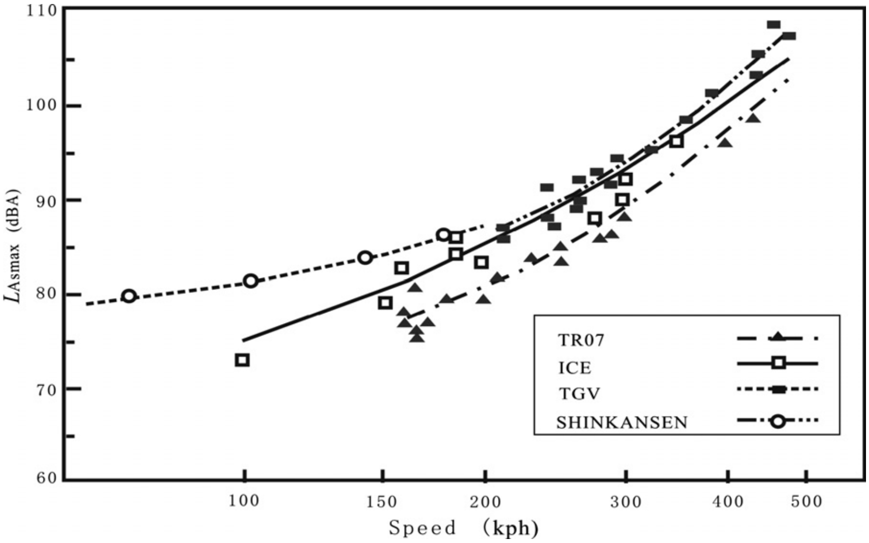

Fig. 2. L_{Asmax} from high-speed rail system at 30.5 m to centerline.

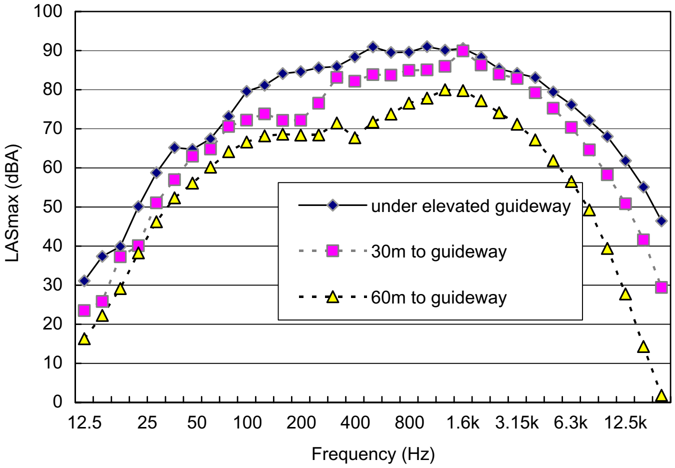

Fig. 3. Spectral frequency of the A-weighted SPL at speed of 430 kph.

Site 2, almost in the middle of the section with the maximum speed, is the best site for measurement at this speed.

Typical noise characteristics correlate with distance from the sound's origin and the distance effect of noise distribution within 300 m is focused on. Five different points at site 2 were measured in a line perpendicular to the track to analyze the effect of distance on noise levels (Fig. 5). Point 1 is beneath the 15 m elevated maglev track with the distances between points 2, 3, 4, 5 and the centerline of the guideway being 30 m, 60 m, 120 m, and 240 m, respectively. All measured points are at the same height above ground level (1.2 m) excluding point 5. Point 5 was located as far as 240 m to the line with a height of 5.2 m to avoid the trees shield.

Additionally, the YingBin Expressway contributing about 81.9 dBA of roadside noise is located 60 m to the south of SMT at Site 2. Therefore, all points were arranged to the north of SMT to allow for the disturbance of noise emitted by traffic on the Expressway, and the values of background noise of points 1, 2, 3, 4, and 5 are 62.5 dBA, 55.6 dBA, 54.2 dBA, 53.7 dBA, and 51.8 dBA, respectively.

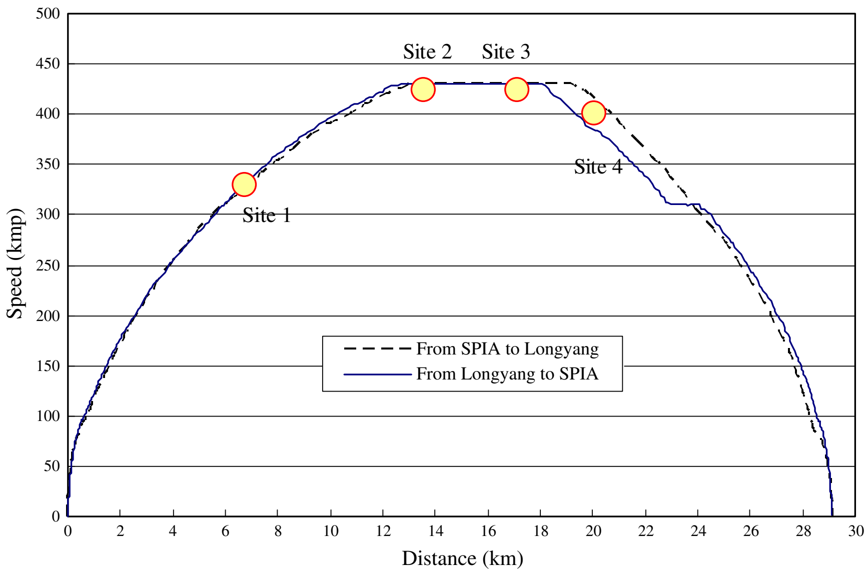

Fig. 4. SMT distance–speed relationship.

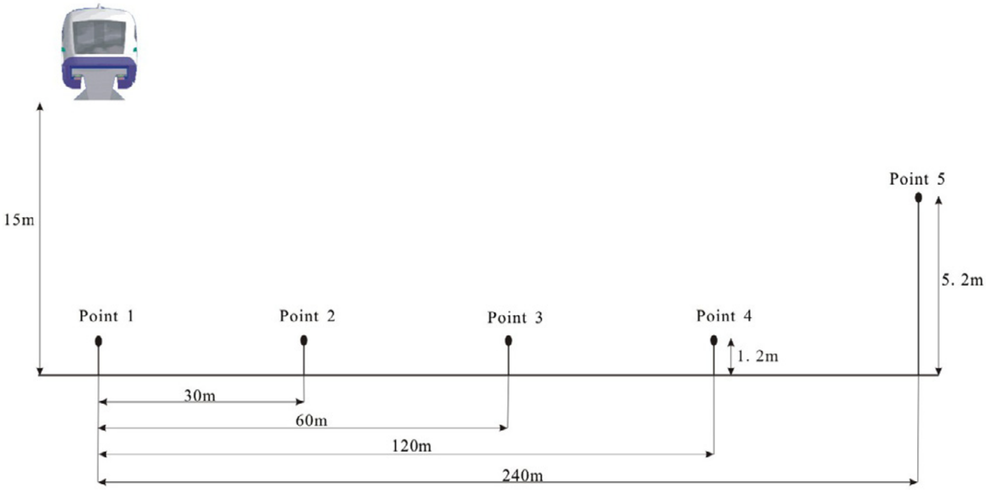

Fig. 5. Location of measurement points at site 2.

The A-weighted method that is designed to reflect the acuity of the human ear to sound is used to scale SPL.[1] The descriptor for cumulative 1-h sound exposure is the Equivalent Sound Level by A-weighted method, abbreviated here as L_{Aeq}, with which all of the time-varying sound energy in the measurement period are included. The maximum A-weighted sound level during the sound event is expressed with the maximum level (L_{Amax}), describing short-term noise events for the general assessment of noise impacts. It is usually more appropriate to use the “slow” setting to measure the noise, where the sound level is averaged over a 1 s period. L_{ASmax} abbreviated from L_{Amax} (slow) gives a better representation of sound energy of an event, and therefore the data of sound level meters on “slow” setting is used.

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[1] The measurements used in the analysis complies with *GB/T 5111-1995 Acoustics – Measurement of noise emitted by railbound vehicles* which is similar to *ISO 3095:2005 Railway applications – Acoustics – Measurement of noise emitted by railbound vehicles.*

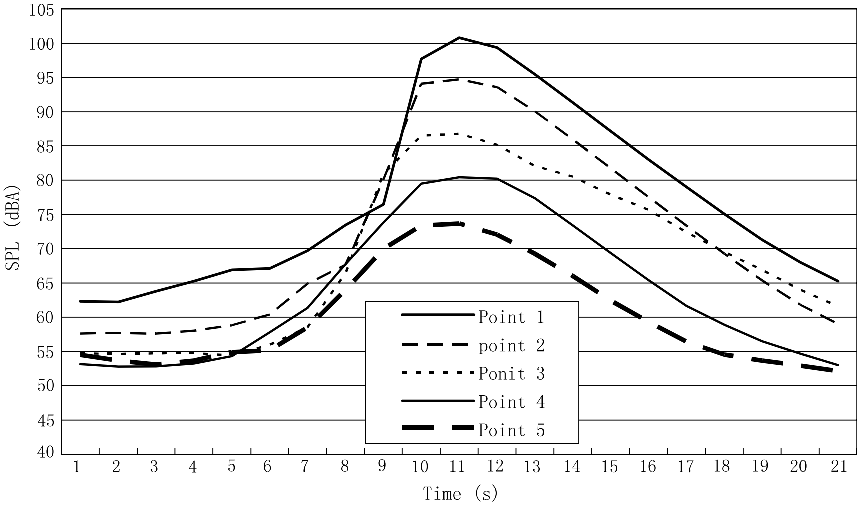

Fig. 6. Time history of the A-weighted SPL at speed of 430 kph.

In the analysis we use, L_{Aeq} and L_{ASmax}, denoting sound levels in different procedures, although, the L_{Aeq} of the SMT is still calculated. Because most of background noise levels are higher than the calculated L_{Aeq} found in preliminary trial calculation, real L_{Aeq} produced by the SMT can only be obtained by calculation.

Eq. (1) based on Rathe's model is used to relate L_{ASmax} to L_{Aeq} under reference conditions because aeroacoustic mechanisms can be modeled as having simple monopole directivity (US Federal Railroad Administration, 1998).

$$L_{\text{Aeq}} = L_{\text{ASmax}} + 10\log\left(\frac{len}{v}\right) - 10\log(2\alpha) + 10\log(V) - 32.3 \tag{1}$$

where L_{ASmax} is reference L_{ASmax} under reference conditions, dBA, *len* is reference source length, *m*, *v* is reference train speed, kph, α is $\tan^{-1}(\frac{len}{2y})$, radians, *y* is reference observer distance from track centerline, metre, and *V* is hourly volume of train traffic, in trains per hour.

In addition, considering the "startle effects" at places close to maglev track, time histories of maglev pass-by noise were specially measured.[2]

3.2. Results

Time histories of the A-weighted noise level at 430 kph at five points are shown in Fig. 6. It is seen that as the train approaches, passes by, and then proceeds into the distance, sound levels rise, reach a maximum, and then fade into the background noise. The sound increase phases in the five curves are steeper than in the decrease phases, especially for points 1, 2 and 3. The curve tends to be flatter when the measurement point is farther from the sound source. The onset rate at maximum speed is about 20 dB/s at point 2, and 30 dB/s or so at point 1, which is similar to TR08 Maglev System in Emsland (US Federal Railroad Administration, 2002).

Objective simultaneous noise measurements were performed at all points. The L_{ASmax} values at different distances are seen in Fig. 7a with values of 94.7 dBA, 86.8 dBA, 80.4 dBA, and 73.7 dBA for 30 m, 60 m, 120 m and 240 m from the track showing that distance exerts a significant influence on the sound level. L_{ASmax}

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[2] A B&K 2250 hand-held analyzer had been employed for the measurement, manufactured by Brüel & Kjær. It loads three application software modules that are taken in broadband statistics, frequency analysis and logging of statistics by a storage card. B&K 2250 has 120 dBA dynamic range and sound levels up to 140 dBA with supplied Microphone Type 4189. The measurement instruments were kept into stable state when continuous noise measurements were conducted.

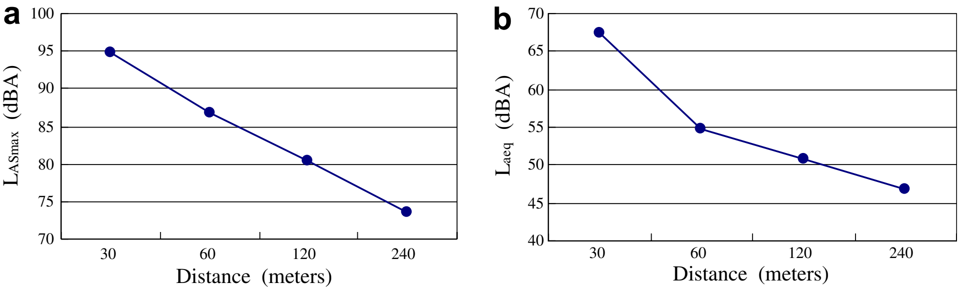

Fig. 7. SMT noise dependence on distance to maglev centre-line at speed of 430 kph.

drops about 6 to 8 dBA as distance doubled. It is known that the attenuation from point sources is 6 dBA per doubling of distance, and 3 dBA per doubling of distance attenuation is exhibited by line sources. Thus the attenuation feature of the SMT demonstrates that the maglev train at high-speed behaves acoustically more like a point sources than a line source.

Compared with L_{ASmax} values produced by other high-speed systems at their greatest speed the same distance from the guideway centre (US Federal Railroad Administration, 2002), the SMT is lower at 4–8 dBA. The lower noise probably results from atmospheric absorption, ground absorption and obstacles such as trees. At a distance of 300 m to the maglev line, L_{ASmax} for the SMT is lower than that from vehicles on nearby roads, which is about 75 dBA. Hence the noise annoyance produced by the SMT is indistinguishable from road noise 240 m from the rail line, and residents beyond 240 m were not interviewed.

Japan High-speed Rail Noise Limits (Table 1) depends on land use categories, with L_{ASmax} required to be below 70 dBA in the case of residential land and 75 dBA for non-residential land. It suggests at least 240 m for the noise limit boundary when a maglev operates at 430 kph. The calculated L_{Aeq} based on Eq. (1) is shown as Fig. 7b. The very low noise level of the SMT is a consequence of a low V value in the equation.

For the German Magnetic Levitation Noise Standards (Table 2), 59 dBA L_{Aeq} is the upper limit allowed near residential land. It seems that about 50 m should be used as the noise limit boundary for residential land here when the maglev operates at 430 kph speed. The substantial difference in the boundary limits derived from Japan and German standards is due to the different noise descriptors.

Table 1
Japanese Shinkansen noise limits

Land use category	Maximum sound level, L_{ASmax} (dBA)
I: Residential	70
II: Non-residential	75

Source: Japanese Ministry of the Environment, 2002.

Table 2
German magnetic levitation noise standards

Land use category	Hourly equivalent sound level, $L_{\mathrm{Aeq,1h}}$ (dBA)	
	Day	Night
I: Hospitals, schools, spas, retirement homes	57	47
II: Residential	59	49
III: Core, village, mixed-use	64	54
IV: Industrial	69	59

Source: US Federal Railroad Administration, 2002.

4. Survey analysis

4.1. Approach

To examine people's responses to noise, the international 5 point rating scale ("not at all annoyed", "slightly annoyed", "moderately annoyed", "very annoyed", and "extremely annoyed") used by the International Organization for Standards amongst others is applied. HA% is the percentage of highly annoyed responses for "very annoyed" and "extremely annoyed", which is a general indicator to scale the nuisance (Fields, 1997).

Differential noise level cause different nuisance effects that can be quantitatively expressed by the Schultz (1978) curve that synthesised pervious analyses of community-level noise effects. A recent update of the original research, containing several additional rail, road, transit and street traffic noise surveys, confirms the shape of the original curve. The updated Schultz curve suggests that HA% is approximately 0 at 45 dBA (L_{Aeq}), and at 10% around 60 decibels, HA% increases quite rapidly to approximately 70% at around 85 dBA (Fidell, 2003). The day–night average sound level (L_{Aeq}) is employed in Schultz curve to measure the degree of annoyance, and is also regarded as the key indicator when evaluating the HA% for daytime periods (Lambert, 1996).

However, as shown the L_{Aeq} seems unreasonable because the limits of residential land use beyond maglev lines would be too narrow uisng German standards. L_{ASmax} is also a conventional descriptor when evaluating noise and is supported in the Japanese Shinkansen Noise Limits. Therefore, the relationship between L_{Aeq} and significant annoyance as well as the relationship between L_{ASmax} and significant annoyance are both developed to further identify the appropriate descriptor.

Residents living in the vicinity of the maglev line are unevenly distributed. At four sites – Qiantang (site 1), Huanglou (site 2), Tangjia Garden (site 3) and Xizhou (site 4) – there are more residents than at others and less affected by other noise sources, such as vehicles and planes. Site 1 covers sub-regions at both sides of the maglev track while sites 2, 3 and 4 cover only one side opposite of the Yingbin Expressway that runs parallel with the maglev track in these areas. These four sites are each composed of several independent sub-regions with similar maglev noise exposure and distance to the maglev track. There are 33 sub-sites identified in all.

4.2. Survey method and results

For each sub-region L_{ASmax} represents the noise level that all residents suffer in the sub-region to avoid the laborious work to measure L_{ASmax} for each resident. In terms of sub-region sizes, the range of estimated noise exposure levels within sites were fluctuates at most 2 dBA with respect to the noise level at measurement points.

Although L_{Aeq} values in some sites are measured, the L_{Aeq} values of the SMT are largely subsumed by other sounds making it difficult to isolate the L_{Aeq} of SMT. In addition, measuring the L_{Aeq} of all sub-regions would be excessively time-consuming. Thus the L_{Aeq} of the SMT is found by calculation rather than measurement to develop the relationship between L_{Aeq} and noise nuisances. The L_{Aeq} of SMT is calculated using Eq. (1).

Post-graduates interviewers explained the survey to respondents when necessary and outlined each item of the questionnaire before starting the questioning. A two part questionnaire was used (see Appendix). Information was gathered on gender, age, education, duration of residence, and types and property of houses in part one, to help to analyze whether demographic variables impact residents annoyance to maglev noise. Questions related to general annoyance, sleep disturbance, interference with daily activities, physical symptoms, and psychological symptoms were included in part two to help explore the relationship between the noise index and annoyance and further identify whether $L_{\mathrm{Aeq}}/L_{\mathrm{ASmax}}$ is a proper indicator to appraise high-speed rail noise.[3]

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[3] Earlier studies were reviewed to ensure that no key variables were omitted and that similar questions were asked to allow comparisons with those studies (Lambert, 1996; Fields, 1997; Fields et al., 2001; Fidell, 2003).

Table 3
Characteristics of inhabitants among noise levels and HA%

Items	Categories	Noise levels L_{ASmax} (dBA)						Total	HA%
		70	75	80	85	90	95		
Sex	Female	33.3%	53.0%	44.8%	53.5%	47.5%	0.0%	45.6%	52.1%
	Male	66.7%	47.0%	36.7%	46.5%	52.5%	100%	54.4%	44.8%
Age	16–25	16.7%	17.0%	36.3%	9.3%	23.7%	0.0%	15.3%	36.7%
	26–35	25.0%	27.0%	51.6%	14.0%	28.8%	50.0%	25.0%	36.3%
	36–45	0.0%	25.0%	60.0%	32.6%	15.3%	0.0%	20.0%	51.6%
	46–55	41.7%	15.0%	53.1%	27.9%	13.6%	25.0%	18.8%	60.0%
	56–65	8.3%	6.0%	60.0%	7.0%	10.2%	0.0%	10.0%	53.1%
	>60	8.3%	10.0%	45.7%	9.3%	8.5%	25.0%	10.9%	60.0%
Education	Primary school	58.3%	35.0%	48.4%	48.8%	25.4%	25.0%	36.3%	45.7%
	High school	41.7%	61.0%	59.1%	37.2%	67.8%	75.0%	56.9%	48.4%
	Advanced education	0.0%	4.0%	52.8%	14.0%	6.8%	0.0%	6.9%	59.1%
Home ownership	Renter	16.7%	33.0%	11.1%	7.0%	27.1%	25.0%	27.8%	58.4%
	Owner	83.3%	67.0%	66.7%	93.0%	72.9%	75.0%	72.2%	21.0%
Numbers		12	100	102	43	59	4	320	

Besides, the feeling of residents at the time when they encountered maglev pass-by noise beneath the guide-way they were also questioned to allow evaluate of the effects of onset rate on nuisance.

Relationships between demographic variables and maglev noise annoyance are seen in Table 3.

The L_{ASmax} ranges from 65 dBA to 100 dBA in the study, but only 70–95 dBA is shown in the table. Normally the noise level in the highly annoyed analysis is scaled by 5 dBA intervals, but the respondents with some noise level are too small for useful statistical analysis. The L_{ASmax} values are clustered in 5 dBA intervals with the clustered L_{ASmax} values are in a 2 dBA range.

Nonparametric tests show no distinct difference between HA% by sex suggests that noise annoyance is not significantly related to gender – finding common with Miedema and Vos (1999). A slightly higher level of noise annoyance is found if residents have higher education – again similar to the findings of Miedema, although the differentials are slightly weaker in that study. Home owners are more annoyed by noise than renters. This differs somewhat from Miedema, who concluded that the effect of house tenure was small and is not substantially affected by taking the age of the respondent into account. One reason for the difference may be that many renters are outsiders who are generally used to a lower quality of because of their relatively low income. Age is an important factor affecting but less so if housing tenure is taken into account and particularly since actually 82% of those over 55 years stay at home for more than 10 h daytime (8:00am to 8:00pm).

The L_{Aeq} beneath the elevated maglev bridge was 65 dBA, equal to roadside traffic noise level. Most of those affected by this noise level are not seriously disturbed according to Schultz curve. Most of those surveyed, however, complained that they had been startled when they went beneath the guide-way when a train was passing. Some even claimed they were afraid to approach the track because of the sudden noise effect. To the question of "When you walked under elevated maglev line or nearby maglev line, what is your response if a maglev train is passing by?", 75% stated "startled and heart beaten", and 13.5% complained of "headache or severe headache" whereas a small number (mainly those over 60 years old) stated that they had not experience any effect because the noise was so bad that they avoided the area.

The relationship between HA% and L_{ASmax} is examined using linear regression analysis. Extreme noise levels under 70 dBA are excluded, because L_{ASmax} lower than 70 dBA, together with other occasional noise sources, are difficult to discern by interviewees. In addition, since locations with 95 dBA dataset are rare, such observations are also excluded. The resultant curve is seen in Fig. 8a, using L_{ASmax} is divided by 5 dBA intervals and based on Eq. (2). The HA% increases by 2% when L_{ASmax} rises by 1 dBA.

$$\mathrm{HA\%} = -108.31 + 1.94L_{ASmax}, \quad R^2 = 0.94 \tag{2}$$

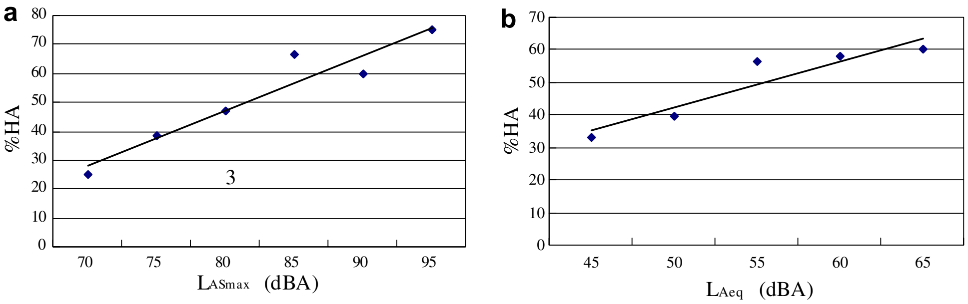

Fig. 8. Relationship between noise description and HA%.

It was suggested that at least 240 m should used as the noise limit boundary when SMT operates at 430 kph, however, there is 25% HA% at the points 300 m away from the track where the train is operating at maximum speed suggesting a stricter limit boundary for SMT than the Japanese standard is needed.

The relationship between HA% and accounted L_{Aeq} is based on

$$\mathrm{HA\%} = 7.13L_{\mathrm{Aeq}} + 28.06, \quad R^2 = 0.88$$

The relationship is seen in Fig. 8b. Compared with the Schultz curve, this data demonstrate that the noise from the SMT could cause more severe annoyance for those resident close to the line: the HA% is approximately 0, 5 and 15 at 45 dBA, 55 dBA and 65 dBA (L_{Aeq}) in Schultz curve, compared to the levels of 35, 55 and 60 seen in Fig. 8b. The HA% is, overall 20 higher than that produced by the TGV at the same L_{Aeq} (Lambert, 1996). In addition, considering that 5–10 HA% is generally used as the upper limit for tolerable noise levels, 55 dBA L_{Aeq} could be regarded as baseline limit for residents area in terms of the Schultz curve. (In fact, 59 dBA L_{Aeq} is stipulated as the upper limit in German standard.) Even so, 5 dBA is added to adjust the noise nuisance by to accord with a proposed criterion for high-speed rail systems in the US (Hanson, 1996). Even taking the onset rate effects into account, the 55 dBA L_{Aeq} base could be increased to 60 dBA, and the 57% HA% for 55 dBA L_{Aeq} would still be unacceptable for residents. Therefore, it seems that the L_{Aeq} is not a good descriptor of limits in noise evaluations of maglev systems whether onset rate accounted or not.

5. Conclusions

The analysis looking at the noise problems associated with the new Shanghai Maglev Train found that the system is quieter than conventional high-speed rail for comparable distances from the track but that there are significant onset effects at a train sudden approach. The latter is found, from survey data, to be a particular concern for residence, and especially so for more elderly people. This leads to the conclusion that noise nuisance factors based upon maximum speeds rather an average measure are a more relevant measure for noise containment policies covering this mode of transportation.

Acknowledgement

The authors appreciate many graduate students' contribution for their involving in survey and measurement of the study. Specially, we greatly thank anonymous reviewers and editors for their valuable advices. However, the authors are responsible for the data results and conclusions.

Appendix. Questionnaire for social survey

1. Are you male or female?
   (1) Male; (2) female

2. How many persons are there in your household?
   (1) 1; (2) 2; (3) 3; (4) 4; (5) 5; (6) more than 5
3. How many years have you lived in the present house?
   (1) Less than 3 months; (2) less than 1 year; (3) less than 3 years; (4) less than 5 years; (5) more than 5 years
4. How old are you?
   (1) 16–25; (2) 26–35; (3) 36–45; (4) 46–55; (5) 56–65; (6) more than 66
5. What's your highest education degree?
   (1) Primary school; (2) high school; (3) advanced education
6. The number of stories of the building including your house is:
   (1) 1; (2) 2; (3) more than 5; (4) other: ( )
7. Type of your living house:
   (1) Detached house; (2) apartment house; (3) other: ( )
8. Do you own the house?
   (1) Yes, we own the house; (2) no, we are just the renter
9. In your opinion, which one is the most important environmental issue in your neighborhood?
   (1) Maglev noise; (2) aircraft noise; (3) noise from road traffic; (4) noise from the neighbor
10. Thinking about the past 12 months or so, when you are at home, how much does noise from maglev bother, disturb or annoy you?
    (1) Not at all; (2) slightly; (3) moderately; (4) very; (5) extremely
11. In which way are you annoyed by maglev noise?
    (1) the sound is a little annoying, but not so serious
    (2) the sound is irritating
    (3) the sound disturbs listening to telephone, TV, or radio
    (4) the sound disturbs working or reading
    (5) the sound disturbs conversation
    (6) the sound disturbs sleep
    (7) other: ( )
12. If the noise from maglev bothers, disturbs or annoys you, have you done anything to reduce the nuisance?
    (1) Placed my bedroom away from the side of maglev line; (2) put in double-glazed windows; (3) set up a baffle; (4) thought about/tried to move to get away from the noise; (5) done nothing; (6) other: ( )
13. When you pass through maglev line, what is your response if a maglev train is passing by?
    (1) Startled and heart beaten (2) headache or severe headache (3) too worried to trip

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