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Original Research Paper

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Development and Mapping of Noise Risk Zones in Neighbourhoods Along Saensaep Canal: Revealing the Public Health Burden of Water Transport in Bangkok

Vasim A. Khatik†, Rattanathorn Intarak and Tewelde G. Foto

Faculty of Public Health, St. Theresa International College, 1 Moo 6, Rangsit-Nakhonnayok Road, Klong 14, Bungsan, Ongkarak, Nakhonnayok 26120, Thailand

†Corresponding author: Vasim A. Khatik

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ABSTRACT

In this study noise pollution from public transport boats in the Saensaep canal was investigated and questionnaire surveys were performed to assess the impact of noise. The spatial noise measurements were conducted inside the boats and surrounding neighbourhoods. On the basis of the results, noise-risk zone map was developed. It shows the settlements located between 0 to 15 meters from canal fall under high to moderate risk zone and the settlements located from 15 to 20 meters fall under tolerable noise zone. The measurements conducted in different sections of the boats show wide noise variations ranging from 75.2 db(A) in the forward sections to 91.3 db(A) at the rearward section. These values clearly exceed all categories of permissible limits recommended by American Public Transit Association (APTA). The questionnaire surveys performed in the noise affected areas along the canal revealed the issues of sleep disturbance, conversation hampering, and annoyance attributed to the noise originating from passing boats. On the basis of this study, three major recommendations are forwarded. First, the households exposed to boat noise should install noise cancellation devices, sound barriers and insulators. Second, boat transportation authorities need to execute proper noise control approaches to reduce excessive noise from boat operations. And lastly, to avoid excessive noise exposure, passengers are recommended to prefer seats in the forward section over middle and rear sections.

INTRODUCTION

Saensaep canal is one of the most important routes of water transportation in Bangkok. On a daily basis, about 65,000 people commute with the passenger boat service in this canal (Nopparat 2004). People prefer this boat service because it provides cost effective and time efficient means of access to the downtown areas of the city. Besides that, transportation through Saensaep canal also helps to overcome the problems of frequent traffic jams in the city.

The boat service in Saensaep canal is divided into two sections covering 18 km distance, with a total of 30 stations. There are about 100 boats of 70-90 passengers capacity operating every 5-10 minutes frequency from morning 05:30 to evening 20:30 and 19:30 on weekdays and weekends respectively.

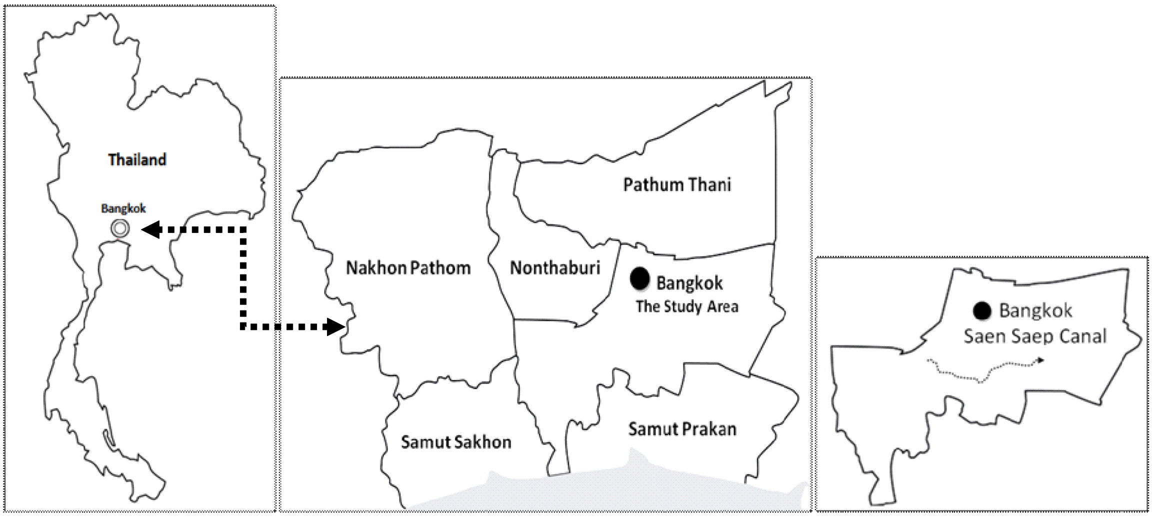
The transportation service operates in the middle of the city intersecting through the highly populated districts of central Bangkok. Starting from the first pier at Sribunruang Temple to the last pier at Bangkapea; the passenger boats pass through the residential and commercial areas ranging from slums, apartments, bungalows and extremely lavish housings to the retail stores, coffee shops, offices, malls and big hotels including silent zones and areas without any development. To sum up, the developmental patterns in the study area represents a mixed noise environment comprised of commercial, mixed and residential areas.

The boats used in the transportation are powered by large (noisy) diesel engines. Because of large engines aided by intensive and continuous operations; boats of Saensaep canal become the source of unwanted noise to the large population residing in proximity of this canal in Central Bangkok (Figs. 1 & 2). This investigation is aimed to produce an insight into the magnitude and extent of noise pollution from boat operations and investigate the resultant impact on the exposed population.

EARLIER STUDIES

From the literature review, it is evident that the road transportation being a primary mode of transit receives frequent attention of researchers for noise pollution investigations (Leong & Laortanakul 2003, Pichai & Chaisri 1999 and Karl et al. 2004). However, water transport systems in Bangkok, despite being a major contributor to the noise environment of the city has been investigated in the only study reported by Velasco et al. (2013).

Velasco et al. (2013) investigated air and noise pollu-



(a) (b) (c)

Fig. 1: Study area (a) Thailand (b) Bangkok metropolitan region (c) Location of Saensaep canal in Bangkok province.

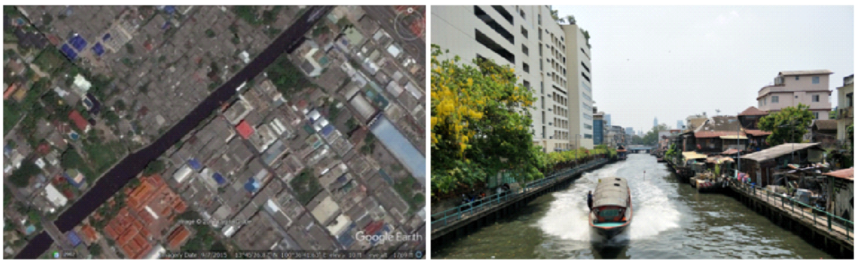


Fig. 2: Aerial view of study area and the passenger boat service in operation.

tion from public transport boats in the Saensaep canal and performed exposure assessments on passengers and by-standing commuters. In this investigation, they studied noise levels inside the boats and surrounding piers. The results indicated that the levels of noise inside the boats were higher than the road traffic noise of Bangkok. And the levels of noise on the piers were similar to the levels of Bangkok road traffic noise.

In their investigation Velasco et. al. (2013), kept their observations limited only up to piers. Therefore, the scope of this study was restricted only up to the passengers and bystanding commuters. However, because of the proximity of residential areas to the canal, noise from passing boats penetrate beyond the piers and invade the nearby residential neighbourhoods also. Therefore, unlike limited exposure of passengers during the travel time, people residing in the neighbourhoods are also exposed to boat noise on a continuous basis from early morning to the late evening hours. This results in a continuous noise exposure from passing boats posing a serious health risk to the population residing along the canal. Therefore, this issue warrants thorough investigation.

MATERIALS AND METHODS

Noise Measurements

The field work and noise sampling were conducted from 17th of April to 29th April 2017. Initial surveys were conducted to understand the nature of settlements and noise environments in the study area. On the basis of settlement patterns the sampling locations were selected in (quieter) residential areas where boats cruised through, at the maximum speed. All the measurement timings were selected during peak traffic hours.

The experiments were carried out with standard procedures using type-II sound level meter (3M™ Sound Examiner- SE-4021061). The measurements were taken as the boats approached and passed by the sampling points.

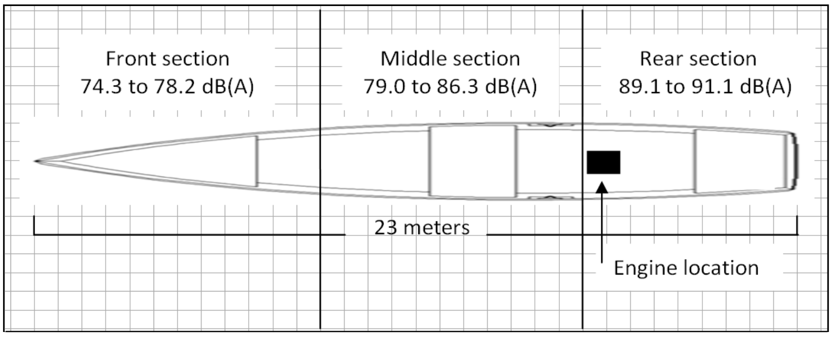


Fig. 3: Noise (Leq) levels in different sections of the boat while cruising.

The noise measurement studies were conducted inside the boats and surrounding neighbourhoods along the canal. For internal measurements, the boat floor was divided into three sections according to the distance from the engine. Namely the middle section, forward section and rearward section where the engine is located. The measurements were taken in these sections while the boats cruised at the highest speed.

For noise measurements carried out in the surroundings of the canal, a total of seven sampling points were selected. At each of the seven sampling points, twelve observations were recorded in one hour monitoring time. The first set of observation was taken close to the engine near the source. The second set of observations were taken at five meters away from the source of noise. The subsequent observations were taken with an incremental distance of five meters from the source up to 30 meters inside the residential spaces where sound intensity was significant.

Table 1: Noise levels with increasing distance from the boat.

Sampling Station	Distance from Boat (in meters)						
	1	5	10	15	20	25	30
Highest (LAF, max)	91.1	85.3	79.6	73.2	67.8	63.0	59.4
Average (Leq)	87.4	82.8	76.0	70.8	65.0	61.9	56.1
Lowest (LAF, min)	81.1	76.9	71.1	66.6	60.0	58.3	54.6
Background noise LA90	52 db						

Table 2: Noise risk zone criteria adopted for the study.

Intensity of noise in dbA	Zones
<66	Safe
66-71	Tolerable
71-76	Low Risk
76-81	Moderate Risk
81-86	High Risk
>86	Extremely High Risk

Noise Mapping

Noise mapping was performed using an online version of ArcGIS. The magnitude and projection of noise were plotted using contour lines fixed on the basis of distance from the source of noise. The contours were plotted in seven bands. Each line of contour indicates a distance of five meters on the ground.

The first circle on the map shows residential areas nearest to the source of noise, whereas every subsequent circle represents the area incrementally outlying five meters from the source. In total, all the six contours on the map covers 30 meters radial area around the source of noise. The colour gradient used in the map indicates intensity and the spatial distribution of noise.

Social Survey

To study the impact of boat noise on residents, questionnaire surveys were performed in the affected neighbourhoods along the canal. A total of 40 respondents were selected for

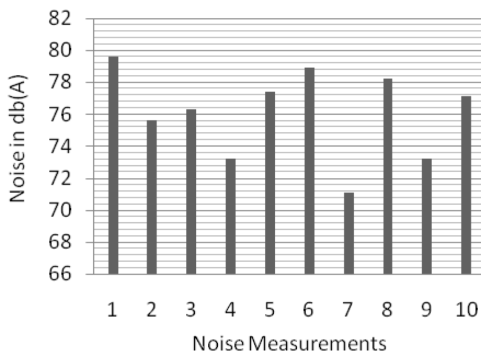


Fig. 4: .Noise variations 10 meters from the

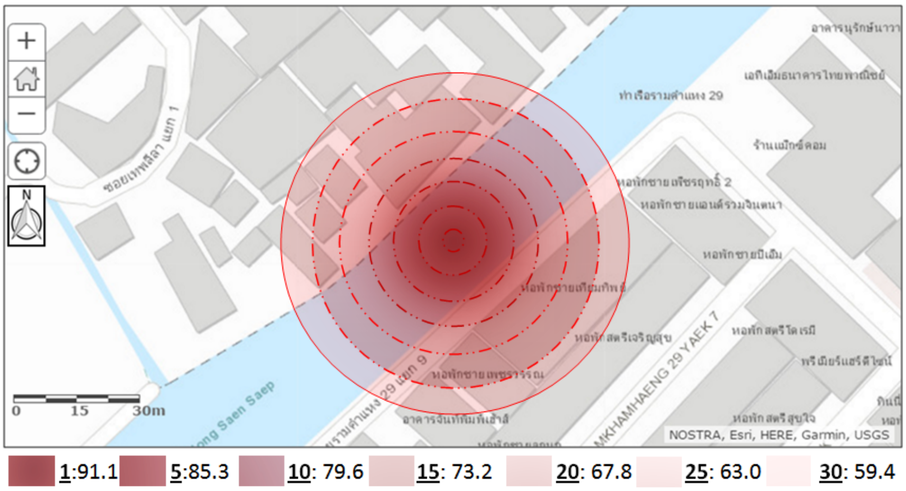


Fig. 5:.Noise map of study area. Underlined values indicate distance in meters and adjacent values indicate noise values db(A).

the survey. The participants included shop owners, students, residents aged from 15 to 45 years. The questionnaires incorporated 6 questions marked numerically from 0 to 5. Number 0 represented the strong disagreement and subsequent numbers up to 5 represented strong agreement. In order to measure the reliability of questionnaire survey, the results were analysed with statistical test Cronbach's alpha.

RESULTS AND DISCUSSION

Noise Measurements

The results of noise measurements are presented in Table 1. The continuous sound levels (LAF, max) ranged from 59.4 db(A) at 30 meters from the source to 91.1 db(A) at the source itself. It is clear that as the distance to the source gets closer, the levels of noise increase with about 4 db(A)/5 meters. Eventually, at the source, the levels of noise are exceedingly high.

The boats used in transportation are about 23 meters long, provided with seating arrangements. The engine in the boat is mounted at the rearward section where it lies isolated from the middle and forward section of the boat. Moreover, the engine is oriented in such a way that the front side (or the noisy components) of the engine face the rear end of the boat and the backside of engine faces the forward end of the boat. Thus, to sum up, the isolated placement and rearward orientation of engine cause significant noise variations between the forward and the rearward sections of the boat. In order to investigate these variations, noise measurements were conducted in the forward, rearward and middle sections of the boat.

Fig. 3 presents a typical floor map of a boat with noise levels in different sections. The levels of noise in the forward and middle sections ranged from 74.3 to 78.2 and 79.0 to 86.3 db(A) respectively. The recorded noise levels at rearward section ranged from 89.1 to 91.1 db(A). It is important to note that the noise levels in the rearward section are considerably higher compared to the other sections. Evidently, the high levels of noise at rearward section are attributed to the placement of the engine in this section.

The noise values observed at different sections of the boat were subjected to statistical analysis with *t*-test. The results of *t*-test show a significant difference (16.8 db(A)) in the variation of noise levels between the forward and rearward ends. To reduce excessive noise exposure passengers are strongly recommended to prefer seats in the forward and middle sections over rearward section.

Fig. 4 shows the levels of noise radiated by boats passing 10 meters from the source. It is surprising that the noise values recorded at the same sampling point are considerably variable ranging from 71.1 to 79.6 db(A). The noise variations can be attributed to factors that include condition of engine, state of repair, passenger load, operator skill, and cruise speed.

It is important to consider, out of all the given factors, the older engines and poor operator skills can be important contributors to the overall noise output and variability. However, the chances of engines being older and drivers being poor operators cannot always be true. Because, Saensaep canal being a busy route, boats are under regular service hence routinely maintained. Secondly, navigating through the narrow spaces of Saensaep canal require operators to be highly dexterous with their job. Thus on the ac-

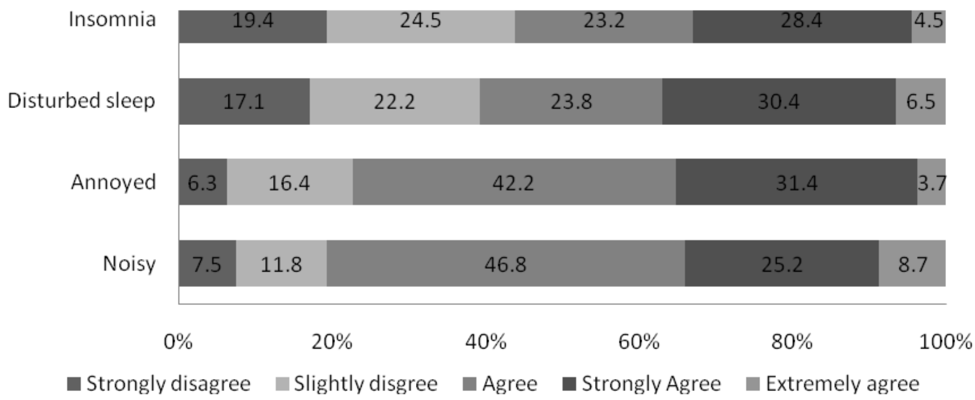


Fig. 6: Results of questionnaire survey.

count of prerequisite of their job, boat operators are naturally dexterous enough to be poor with their skills. Therefore, taken together, the fluctuations and variability of noise can be predominantly explained by varying passenger loads and varying boat speed (due to traffic).

Noise Risk Zone (NRZ) Mapping

In order to study the spatial variations and understand noise distribution in residential areas, the results were plotted on the map of study area as presented in Fig. 5. It is clear from map, that the noise radiated from passing boats measure from 85 db(A) at 5 meters from source to 68 db(A) 30 meters away from the source. This clearly shows that the exposure of residents to boat noise is directly proportional to distance from the canal.

Table 2 gives the noise risk zone (NRZ) criteria as adopted by Banerjee et al. (2008). The noise values on the map were correlated with NRZ criteria. The most significant finding to emerge from this study is that the residential blocks located within 5 to 10 meters from canal fall under high and moderate risk zone. Furthermore, remarkably, the settlements located within 10 to 15 meters from the canal also fall under moderate and low-risk zone. These critical findings clearly indicate the boat transportation service in Saensaep canal is a silent burden to the health of a huge number of commuters and residents living in the neighbourhoods of Saensaep canal.

Further on the other hand, albeit not critical, the housing units within 15 to 20 meters fall under low risk zone to tolerable zone. And lastly as expected, the settlements beyond 20 meters from the canal fall under safe zone according to the NRZ criteria. Even though boat noise levels in this zone are not high enough to pose a health risk. However, when 12 hour Leq values of boat noise are calculated along with prevailing background noise levels, it may exceed the permissible limits.

Comparison with Noise Annoyance Criteria

The American Public Transit Association (APTA) uses the maximum A-weighted sound level (LAmax) of a single vehicle pass-by to describe the noise of vehicles used for transportation. The APTA noise criterion depends on housing density and type. According to this criterion, the residential zones are divided into three groups comprising low, normal and high density housing areas, which is again divided into two types as a single family unit and multiple family unit (APHA 1981).

Table 3 presents maximum A-weighted sound level criterion for a single pass-by vehicle. The noise levels recorded at surrounding neighbourhoods when compared with the maximum allowable criterion by APTA. It was observed that the residential units located between 5 and 15 meters from the canal exceed the limits for both multiple and single family type. Under multiple family type criterion, the noise values were found exceeding the standard for low and normal housing density. Whereas, under single family type criterion the noise values were found exceeding the standard for all the low, normal and high housing density areas.

Further, the internal noise levels in different sections (Fig. 3) of boats were compared with the maximum allowable criterion by APTA. It was observed that the noise levels inside boats clearly exceed all categories of permissible limits described by APTA. Moreover, the housing units located beyond 15 meters from the canal although do not exceed the APTA criteria. Nevertheless, the cumulative noise

Table 3: Maximum A-weighted sound level criterion for a single pass-by vehicle.

Housing density	Residential Zone Description	Maximum A weighted sound level	
		Single family	Multiple family
Low- Residential	Open space, parks, suburban residential or recreational areas; no nearby highways or boulevards	70	75
Normal- Residential	Quiet apartments and hotels, open space, suburban residential, or occupied outdoor areas near busy streets	75	75
High- Residential	Average semi-residential/ commercial areas, urban parks, museums, and non-commercial public building areas	75	80

impact from boats and other sources cannot be ruled out.

Noise Survey

The subjective response collected from 40 respondents from the affected residential areas revealed that out of 40 respondents about 5.8 % disagreed that boat impedes their relaxation, 9.4 % slightly agreed, 44.3 % moderately agreed, 29 % strongly agreed and 11.5 % showed extreme agreement that boat noise impede their rest and relaxation.

The residents on being interrogated with boat noise interference in telephonic conversations, about 3.8 % of respondents strongly disagreed and 8.3 respondents showed slight disagreement. Whereas, rest of other subjects comprising 51.3, 20.5 and 15.6 % showed agreement that boat noise affects their conversations on mobile phones. The Cronbach's Alpha coefficient for survey data was 0.87. This indicates good internal consistency in the surveys. The results of the questionnaire are presented in Fig. 6.

CONCLUSION

From the results, it is concluded that the settlements located between 0 to 15 meters from the canal fall under high to moderate risk zone and the settlements located from 15 to 20 meters fall under tolerable noise zone. The results of noise measurements conducted in different sections of the boats show wide variations with 75.2 db(A) in the forward sections to 91.3 db(A) in the rearward sections. These values indicate a statistically significant difference in the noise levels between the foremost and rearmost sections. The questionnaire surveys performed in the affected areas revealed the issues of sleep disturbance, conversation hampering, and annoyance attributed to the noise from passing boats.

It is important to note that the housing density and pattern along the entire operational section of Saensaep canal is similar to the selected study area. Therefore, entire population residing along Saensaep canal is under the stress of high to tolerable noise risk zones.

On the basis of the findings of this investigation, three major recommendations are forwarded. First, the households exposed to boat noise are suggested to install noise cancellation devices, sound barriers and insulators. Second, boat transportation authorities need to execute proper noise control approaches to reduce excessive noise from boat operations. And lastly, to avoid excessive noise exposure, passengers are recommended to prefer seats in the forward section over middle and rear sections.

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