Empowering traditional house for future noise control based on sound frequency propagation

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Empowering traditional house for future noise control based on sound frequency propagation

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Abstract. Geographical altitude represents tropical environment in Indonesia where the different wind acceleration effects the noise control. The traditional house was designed in the past when the noise was limited in the rural area, and it is changed into the noisy environment in urban space and will potentially be critical in the future. The aim of this study is to evaluate the existing traditional building noise and to upgrade its performance for empowering the future adaptation. The real-time analyzer for sound level meter was fixed in occupant reference height in order to examine the frequency bands effect. MATLAB coding is also conducted in order to evaluate the noise propagation performance. The traditional Javanese houses are the representative case of Indonesia tropical building in both lowland and highland regions. The results are highlighted that by distance and wood or bamboo wall, the sound pressure level is reduced to 20 dB and 15 dB for lowland and highland, respectively. For higher measured frequencies, more than 1 kHz, the road noise gives the major influence to the noise propagation. Meanwhile, the lowest frequency transmission, 125 Hz, has the highest consequence on the noise propagation in the road, but less in the room. It will be the consideration on empowering the local material by its coefficient selection in the future design. The traditional wall has low composite transmission loss; it can reduce insufficient rate.

Keywords: noise control, sound frequency, traditional house, urban space

1. Introduction

In urban environment, noise propagation is determined by the atmospheric absorption, diffraction and ground effect [1]. Those issues are important aside from the role of sound pressure level (SPL) on noise source and distance from noise to receiver which is still the key features. Furthermore, beside the receiver point, the terrain setting such as urban, suburban, rural and the open flat area for site barrier are the essential factors [2]. Currently, the noise environment of traditional tropical houses is affected by the growth of higher human population, building, and traffic density. Perceived noise largely disturbs the urban annoyance. Additionally, non-acoustical aspects have a significant part in the noise annoyance estimation as the response indicator [3].

A tropical environment is represented by the geographical altitude, lowland and highland. Actually, the noise propagation is not affected directly by altitude but by the air movement difference. Hence, the air flow design of the site and building may potentially affect the noise control [4-5]. The noise propagation is not affected directly by geographical setting. The site, buildings differences, and the occupant lifestyle may contribute in the noise controller. The urban thermal map indicates that the urban noise situation is also because the transportation and human movement contain the largest...
module of the heat source, especially in the center of the urban zones as the most crowded activities.

Compared to the similar previous studies, most of those similar findings have also analyzed traditional building performance related to the noise control. However, there were no specific results for the requirements of environment change from its natural environment to today’s adaptation and potential future development [6-9]. Furthermore, most of them have also found the occupants’ adaptation results in the recent environment condition [10-13]. Therefore, this study evaluates the existing traditional building noise and empowers its performance for the detailed future adaptation through potential sound frequency propagation analysis.

2. Methods
This research is located in Surabaya (District of Mulyorejo, altitude 3 m and latitude 7.2 S) as lowland representative and Malang (District of Purwantoro, altitude 475 m and latitude 7.8 S) as highland one. All locations refer to the availability of traditional houses (See Figure 1.). Recently, the both location are in an urban environment, different from the traditional houses in the past which were designed as the optimal model for a lower noise source in the rural environments. The building model for this study has been found in most Javanese houses where the Kampung type as the most used dwelling of traditional people. Actually, the building material and orientation have had many variations, but for the present time analysis, the study evaluates what is the most generally found in urban environment. The traditional Javanese houses have wood which has been used for walls (the transmission loss, TLwood =18 dB, see Figure 2).

This research conducts and sets the traditional building outdoor as noise source position and indoor as occupant receiver noise setting for on-site measurement. The traditional Javanese houses in both lowland and highland areas are 6x7 m² in average based on the initial field observation. The sound level meter was installed for outdoor and indoor evaluation at the equivalent period in order to see the direct result of the noise from main source to the receiver (Table 1). The sample of exposure noise was also taken at the highest traffic density in the weekday-daytime. By this detail measurement, the most critical sound frequency could be detected as a basic idea of future prediction design. Some recommendation for translated building from the traditional to the modern one will also be suggested.

Figure 1. Research site for noise assessment.
Table 2. Traditional building profile.

Table 1. Noise measurement tool.

| Tools                     | Range                      | Location                      | Time                                  |
|---------------------------|----------------------------|-------------------------------|---------------------------------------|
| Sound Level               | - A Weighting              | Main Noise Source             | 7 days:                               |
| Meter for measuring       | - Single dynamic range: 30-137 dB(A) | (Road/Outdoor) and Indoor: 0.6 m to 1.5 m as reference height | Morning (06:00-08:00), Afternoon (12:00-14:00), Evening (17:00-19:00), 24 hours (Weekday/Weekend), and sample for LAeq,1h in weekday-daytime |
| Sound Pressure            | - Real-time frequency analysis (12.5 Hz to 20 kHz) | of occupant’s sitting/standing |                                       |
| Frequency                 |                            |                               |                                       |
| Bands                     |                            |                               |                                       |

3. Discussion
3.1. Noise propagation and building as barrier
The building orientations determine the tropical house zoning in receiving road noise (Figure 3). With road as the main noise source, the distance and building wall, the sound pressure level is attenuated in 20 dB for lowland and 15 dB for highland, respectively. Though the traditional wall has low composite in transmission loss, it can significantly decrease the noise. By average distance, 12 m, and the building itself as a barrier, the noise is controlled in about 8 dBA. It may be reduced by the building barrier with closer distance from its source to the building. With the same distance, the effect of air movement for close propagation is not significant [1]. Both sides of the building receive the same sound pressure level. Meanwhile, the difference occurs at a higher noise source at the lowland environment which has higher noise compared to the highland. In general, this phenomenon applies in all sides of traditional building. Because of blocking effect of building as a barrier, the back sides for both lowland and highland obtain the similar results.
Figure 3. Distance effect on noise propagation.

The noise propagation above prevails for the most sensitive sound frequency for human, 1 kHz. This level is included mid long wave sound which effects not only on noise criteria and its comfort in acoustics environment but also the clarity of human speaking, sound intelligibility. Therefore, the field study with extracted sound frequency by sound analyzer will be discussed intensively.

3.2. Road noise effect on receiver

The high noise disturbance in the lowland site is mainly indicated by the busy traffic movement. The quite close distance to the receiver, approximately 8 m, is the critical location for survival traditional building (see illustration in Figure 4). In a week test and field measurement, the outdoor lowland reaches the peak noise in the early day (morning traffic activities time). The high SPL (around 70.0 dBA) was identified and resulted by the human actions and it is higher than in the afternoon and in the evening which is respectively 66.1 dBA and 67.7 dBA. The high opening people activities in the morning in the urban outdoor environment is the main indicator of this situation. The condition of noise source location in the building outdoor has a direct result to the receiver area where the SPL in 58.9 dBA for the indoor was also perceived in the morning and was higher than other times. The estimated noise in 12 dBA reduction from its source to the receiver is well-attenuated by its natural distance and building envelope.

This study evaluates the existence of tropical traditional building in urban environment using critical WHO recommendation as international standard (35 dB for daytime and 30 dB for night-time) compared to local, Indonesian standard (55 dB for all time) as conducted in the previous studies [5]. From Figure 5, the quadrants adapted to the referred standards can be designated as follows: The A quadrant is the most number of the results of lowland for night-time, highland’s daytime and night-time and the B quadrant is the most dominant and occurred in lowland daytime. Meanwhile, the C quadrant consists of the highland night-time results, but the D quadrant has no results. The leading results on A and B quadrants are the complications in accomplishment for both WHO and Indonesian standards. The dominant indication results in discomfort noise for all time both for lowland and highland buildings reached out all standards even though there are found about 50% which comply with the local standard. Actually, the noise limits by local standard in Indonesia do not provide in detail for indoor or outdoor and daytime or night-time noise condition. It sets the standard based on local allocation for the building purpose.

All conditions above have the simulation setting for the opened door (see Figure 4). Resulted by Matlab calculation, the lowland building at daytime is considered as the most critical condition even it
has less strict noise criteria compared to the night-time requirement. The role of traditional materials has no significant impact to control the environmental noise because of the lightweight and typical porosity of the building material. The road noise source in highland area, particularly for the night-time, almost complies with the Indonesian standard. As the result, the building as the receiver experiences quiet situation, a potential result for WHO limits. Meanwhile, the noise level of the source and the propagation of lowland at night-time compared to highland day-time tend to be similar. In general, the typical single frequency in average as indicated by this section is the representation of the critical sound frequency deliberated in the following discussion.

![Figure 4](image)

**Figure 4.** Effect of road noise on the receiver.

### 3.3. Sound frequency analysis

This section discusses the sound frequency taking on the critical and in the average method explained before. In addition to Prato et al [14], the investigation of low-frequency noise has become very important due to the impact sound transmission on wood-frame of traditional building. The receiver represented by the room obtains a little noise oscillation than its source after being attenuated by its distance and building wall. Resulted from the peak road noise in the daytime, the higher frequencies (more than the most sensitive band, 1000 Hz) of the noise source give the highest impact to the noise transmission received by the building (Figure 5). The 125 Hz frequency as the lowest band has less effect to the room disturbance while the highest consequence on the noise is experienced by the source area itself.

Again, analyzed through Indonesian and WHO noise standard, the most of sound frequency of the room meet to Indonesian standard while a problem is still found for the WHO has. That condition is valid for lowland while the highland building’s room obtains dominantly for all the requirements. The comfort in noise adaptation of the highland building is resulted in about 25% where the higher frequencies from the noise source have a little effect perceived by the receiver. Likewise, the 4 kHz as highest frequency in this context has no significant result in both condition of the road and room noise propagation.
The analysis for peak noise sample is conducted in an hour field measurement (L.Aeq.1h) of lowland and highland road noise. It considers the phenomena in the peak density of the urban traffic activities at daytime (Figure 6). In general, both tropical representative locations have same noise propagation pattern in transferred sound from source to the receiver. Although the highland building receives a lower annoyance, the unpredictable grade resulted in several frequency bands affects the other disturbance because it produces fluctuated noise scale.

Figure 5. Effect of frequency on the receiver by source noise.

Figure 6. Sample test in noisiest time of lowland.
In general, the mid-frequency, 1 kHz, is indicated as the most penetrating frequency for human living. In this noise frequency, the lowland building obtains 10 dBA reductions similar to 14 dBA in the highland. The building aperture has opened schedule in the lowland more often than in the highland because as the strategy for occupants’ adjustment, the ventilation is selected as the critical solution in hot environment. In fact, as indicated by the spectrogram of the signal produced by Matlab coding, the SPL of high frequency is higher than the lower. However, the high frequency of sound propagation is produced in shorter period and occurred in inconsistent time. This result will be valuable for predicting future noise control. With a higher wavelength of lower sound frequency, providing a larger absorber or a resonator noise control will also be very important and urgent for a denser urban environment.

3.4. Future noise control
To extend the previous research integrated with attention to energy efficiency [15], this study also intends to achieve a natural control for the future hybrid method as a compromise strategy for a better living environment. As illustrated in Figure 8, the future noise control is projected by two methods such as directing closed door and providing site barrier for opened door schedule. The empowered traditional house for future design for the most critical, lowland at daytime, in fact, is achieved by a closed-door operation. With 18 dBA transmission loss as the average coefficient of the wood wall, less than 35 dBA of receiver environment is obtained. The similar circumstance is in effect of the night-time SPL which is not more than 30 dBA. The analysis on acoustical properties is very urgent considered for the higher noise source in the future.

Based on the occupancy schedule, the possibility of the opened door for circulation activities or for providing natural ventilation of energy efficiency is reasonable. Integrated thermal and noise control is one of the cause factors of the adaptation for future urban design in the tropical area. Therefore, empowering traditional building should respect to social and economic dimension by designing site barrier. The overhang is created to accelerate air movement and to increase wind speed for physiological cooling. It is expected that the air flow for this purpose will not be interfered by airborne noise transfer, and the dealing heat with noise control is effective with this method. It is proven by the similar receiver performance in responding the noise source by opening the door as the ventilation aperture.

Figure 7. Empowered traditional house for future design.

In the future, the potential traditional house is also developed by accumulating the propagation distance by raising the existing floor and roof. Not only increasing wind speed for controlling tropical climate but also by the extended distance, a reduction of sound pressure level especially for the lower
frequency annoyance could potential be attenuated. The noise abatement by constructing a further
distance will be a little opportunity to follow the rapidity of urban growth. Therefore, the sustained
idea of delivering the terrace as a transitional area could be a smart decision for the upcoming proposal
of the future urban designer. The thermal environment will also be the similar challenge in urban
density to the noise attenuation. The native design of traditional terrace has joined the social and
physical attention absolutely (see also Figure 3).

4. Conclusion
This study finds there are about 25% of the highland tropical buildings reaching their comfort
condition. Most of them area resulted by situation in shorter distance, the other indicators are the direct
effect of noise fluctuation annoyance, and lack of building barrier. In low frequencies, the traffic area
as main noise source has a high contribution in noise propagation perceived by the building. Because
of the less wavelength and occurred in the shorter and unstable period, the highest frequency has the
lowest effect on the noise propagation even having higher SPL. Furthermore, the room as receiver
experiences a little fluctuations compared to its source because of the distance role and building
envelope barrier, especially for the front side of the building.

The availability of transition area, terrace, could be considered as a multipurpose design idea. In an
urban environment, this cultural richness provides social and physical dimension advantages. Not only
for gathering activities, the terrace is also empowered as solar radiation, air temperature through wind
acceleration, and outdoor glare transition. Furthermore, in this context, the building envelope as a
barrier is reinforced by terrace through creating the extended distance. Designing site barrier will be
the manifestation of the concept for empowering traditional design dealing with the respect to social
and economic dimension. The overhang barrier integrates wind acceleration for physiological cooling
through upgrading wind speed to restore thermal comfort. The efficient system as an economical
intention of natural high air flow is deliberated not interfered by airborne noise transfer.

For future works, this study will cover low-frequency absorber developed from the traditional material.
Prospective natural treatment of traditional house design in the future is predicted of having capacity
in environmental adaptation and resilient design. By significant empowerment of frequency coefficient
of material, the probable noise control from any kind and high source annoyance will be translated
definitely.

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