Post Occupancy Evaluation after Earthquake and Tsunami in Meuraxa Sub-District: Case Study in Banda Aceh

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Abstract. An earthquake with 9.0 SR faced Aceh, followed by a tsunami in the coastal areas of Aceh, causing severe damage, especially in the city of Banda Aceh. The worst affected area was the Sub-district Meuraxa because it was directly adjacent to the sea. In-depth and ongoing evaluations were needed to solve these problems. In this case, POE was used as a study. POE is a process of evaluating the performance of buildings, occupants and their environment. POE consists of three aspects, namely functional, technical, and behavior aspects. There are three levels in this study, namely indicative, investigative, and diagnostic levels. The level used was investigative because it was a continuation of previous study with two comparative objects. So, the formulation of the problem in this study was to look at the performance of the elements of POE and the response of occupants of the house. The method used in this study was Mix Method Research which was a combination of qualitative and quantitative methods with descriptive statistical techniques which were then analyzed using theory and related references so as to produce a kind of comparative study. The study results were as follows: technical aspects which included structural systems, lighting, and interior finishing as a whole having better performance than comparable objects. Functional aspects included organizational structure, communication, workflow, spatial organization, and circulation and support of human having better performance than comparable objects. While the behavioral aspects which included productivity and territoriality, privacy and interaction, perception, image and meaning, and cognition and orientation tended to be the same as the objects of comparison, it could be said that the behavioral aspects in this study began to move in a more positive direction.

1. Introduction
Aceh is one of the regions or provinces in Indonesia, located at the western end of the Unitary State of the Republic of Indonesia. Aceh Province is located on the fault / Eurasian and Indo-Australian plate. It means that, under this area, there is active tectonic activity. So, it is not surprising that the Acehnese people themselves are accustomed to seismic activity. On December 26, 2004, precisely Sunday at 08.00 WIB a 9.0 SR earthquake with the epicenter in the southwest of the city of Banda Aceh faced the area of Seumelue District, Aceh Province. However, due to the natural habits and environment in Aceh, the community after the earthquake immediately carried out activities as usual. This was due to the weak knowledge of the public about the effects of the aftermath of a large earthquake, the tsunami wave. Meuraxa Sub-district is one of the sub-districts located in the Banda Aceh City Government area which is directly adjacent to the sea. It had a total area of 725.8 Ha with the built area was 347 Ha. It had 16 villages namely [1].

This study is simultaneous and structured one, namely the development of previous studies (study by Beginning Lecturers of Higher Education in 2015-2016) [2]. So, the study is now broader in scope, namely all Meuraxa Sub-districts with a higher level of investigation and fundamental differences with previous studies. It was necessary to have a field study in residences and settlements that had a better category or assessment even though only a few sub-aspects of POE. The conducted comparative study was Budha Suci Residence in Lueng Bata Sub-district, Banda Aceh and Tiongkok Jacky Chen Residence in Masjid Raya Sub-district, Aceh Besar.
According to the Indonesian National Disaster Management Agency, the city of Banda Aceh was an area that had a disaster risk index of 167. The score is a high category [3]. If it was related to Durkin’s opinion, it was very important to evaluate buildings in reducing the danger and effects of earthquakes [4]. So, the role of building evaluation was actually recommended especially in areas prone to natural disasters, such as, Aceh.

The evaluation used was Post Occupancy Evaluation (POE). POE was a process of evaluating the performance of buildings, occupants and their environment. The evaluation was carried out in a systematic and thorough manner for buildings that had been used for a certain period of time (minimum of five years). The results would be used as one of the bases for environmental development and the construction of future spaces or buildings [5]. There were three elements in the POE study, namely Functional Element, Technical Element, and Behavioral Element, and there were three levels, namely indicative, investigation, and diagnosis [6]. This study was in level II investigation because of the development of previous study and the scope of this study covering all aspects of POE. This hope is the forerunner of a sustainable and structured EPH study of residences and settlements in the city of Banda Aceh towards a disaster-responsive city.

EPH’s comprehensive study covered three aspects, namely: Technical, Functional and Behavioral aspects and these were divided into 21 sub-aspects, namely: functional aspects (human factors, storage, communications and workflows, flexibility and change, specialization within building types), technical aspects (fire safety, structure, sanitation, ventilation, electrical, exterior walls, roofs, interior finishing, acoustics, lighting, and environmental control), behavioral aspects (proxemics and territoriality, privacy and interaction, environmental perception, immunity and meaning, and environmental cognition and orientation) [7]. The formulation of the problem in this study was what were the performances of the technical aspects, functions and behaviors and responses of occupants.

2. Methodology
This study used a mix method, a combination of qualitative and quantitative methods. Qualitative data in the form of data that were not numbers or values could be in the form of information, theory, or standardization and spatial requirements [8]. In this case, data were collected in several ways, such as, literature study, observation, documentation, and interviews with respondents as many as 210 people with details of the 150 main objects of residences in the Sub-district of Meuraxa, and each 30 for Jacky Chan and the Buddha Suci residences. The respondents were also given questionnaires that, in this case, were users or homeowners. Samples were taken randomly because of the elements of physical similarity, location, and use of houses. While quantitative data were data that consisted of values or numbers that were the results of a measurement such as laboratory tests and recapitulation of the results of the questionnaire. Descriptive statistical analysis techniques were used to describe data which were then processed using SPSS data processing techniques [9]. In addition, this analysis used the Likert scale technique support, gутman scale, and semantic scale. In this study, there were three objects of study. The main study object was residences in Meuraxa Sub-district. While the object of comparison was two residences, namely Tiongkok Jacky Chan Residence (refer to Figure 1) and Tiongkok Buda Suci Residence (refer to Figure 2). Comparative study was carried out because it was a procedure from POE research at a higher level.

![Figure 1. Physical Condition of Jacky Chan Residences](image1)

![Figure 2. Physical Condition of Budha Suci Residences](image2)
3. Results and Discussion
3.1 Technical aspects and occupant’s response
3.1.1 Structure. Below are horizontal column concrete test results (9 points) on residence in Meuraxa Sub-district with 120 units and Jacky Chan Residence with 30 units. While the Budha Suci Residences was not taken because it used a lightweight steel frame on the structure of the building. Table 1 shows the recapitulation of hammer test result of residences.

| No. | Houses in Meuraxa Sub-district | Jacky Chan Residence | Budha Suci Residence |
|-----|--------------------------------|----------------------|----------------------|
| 1.  | 180 – 260.55 kg/cm²           | 78.77 – 236.65 kg/cm²| -                    |

Based on the above results and the quality of concrete quality for residences of K-225 is 225 kg/cm² [10]. So, the houses in Meuraxa Sub-district had better quality concrete.

3.1.2 Lighting. The three study objects had two types of lighting, namely natural and artificial lighting. Natural lighting was obtained from sunlight entering the room while artificial lighting (night) fully used electrical energy (lights). Table 2 shows the recapitulation of lighting power result of residences.

| No. | Jacky Chan Residences | Holy Budha Residences | Meuraxa Residences |
|-----|-----------------------|-----------------------|-------------------|
| 1.  | Day 11000-115000 lux  | Day 7500-8500 lux     | Day 10000-115000  |
| 2.  | Night 40 lux          | Night 90 lux          | Night 61-175 lux  |

Based on the results of measurements in the field, the daytime tended to be bright and hot (tropical climate). While for the night (indoor), the results varied. Based on SNI standardization [11] which had quite good performance, there were houses in Meuraxa Sub-district. The strong minimum and maximum conditions of light in the area were still categorized quite well. Figure 4.0 shows the recapitulation of lighting system sub aspect questionnaire result.
Figure 4. Recapitulation of Lighting System Sub-Aspect Questionnaire Result

It is relevant to recapitulation questionnaire of the building occupant’s opinion results mentioned above. The questionnaire has three questions as follows: first, how is the condition organization current lighting; second, how is quality lighting reviewed from visual aspect; and third, how is quality lighting reviewed from esthetical aspect. Answers to the three questions consist of very good, good, medium and less categories. Based on the chart above, the condition of Meuraxa is better.

3.1.3 Air Circulation. Air circulation systems in the three study objects were of two types, namely natural and artificial types. Natural type was obtained from the air or quite a lot of wind in the area. Openings in the subsidized houses provided fresh air in the rooms. However, the weather in the area was sometimes extreme due to coastal areas. Table 3 shows the recapitulation of air flow and temperature result of houses.

Table 3. Recapitulation of Air Flow and Temperature Result

|                  | Jacky Chan House | Holy Budha House | Meuraxa House |
|------------------|------------------|-----------------|---------------|
| 0.1 – 0.8 m/s    | 0.1 – 0.5 m/s    | 0.1 – 1.3 m/s   |               |
| (indoor)         | (indoor)         | (indoor)        |               |
| 3.6 – 19 m/s     | 0.2 – 2.5 m/s    | 0.1 – 13 m/s    |               |
| (outdoor)        | (outdoor)        | (outdoor)       |               |
| 24 – 36,5 ºC     | 22 – 34,5 ºC     | 23 – 36 ºC temp.|               |

According to Toisi NH and Jhon KW [12] and the results of measurements in the field indicating that the Budha Suci residences had a fairly good performance in terms of wind speed and air temperature. It was if it was associated with Samodra TBFX's opinion [13] stating that air flow for physiological comfort ranged from 0.8 to 1.5 m/s and the results tended to be relevant. The results of questionnaire are relevant to the current condition. The questionnaire has two questions as follows: first, how is the current condition of air circulation system; second, how is quality air conditioning reviewed from comfort aspect. The answers to the questions consist of very good, good, medium, and less categories. The chart shows similar results, such as, Budha Suci Residence is better in terms of air circulation system. Figure 5 shows the recapitulation of air circulation system sub aspect questionnaire result.
3.1.4 Sound Pressure and Acoustic. Below are the results of measuring the sound tone level on the three study objects. Recapitulation of sound pressure are tabulated in Table 4.

|          | Jacky Chan | Budha Suci | Meuraxa |
|----------|------------|------------|---------|
| L        | 0%         | 0%         | 34%     |
| M        | 63%        | 40%        | 30%     |
| G        | 37%        | 60%        | 34%     |
| VG       | 0%         | 0%         | 2%      |

The above test results were related to Samodra TBFX’s opinion [14]. A good recommendation for environmental noise levels was 30 - 49.9 Decibels (dB). So, Jacky Chan’s residence in this case was better. Figure 6 shows the recapitulation of sound system sub aspect questionnaire result.

3.1.5 Utility/ME. The ME systems and utilities at homes tended to be simple and did not consider other aspects because the electrical power used was very minimal, namely 450 watts or 4-6 A. Based on field observations, the Clean Water Pipelines (PDAM) performed well in Budha Suci Residence and had sanitation and drainage which were quite good because it had sewers that functioned well and then were channeled to the main sewers of the city disposal, while for solid waste, there were workers who routinely took it to the location every day. So, in this case, the Budha Suci Residence had a good
performance. In residences of Meuraxa sub-district and Jacky Chan residence, there were no clean water systems from the government (PDAM) that only relied on artificial wells. The drainage systems and solid waste were same as the Budha Suci residence.

3.1.6 Fire Safety. The three study objects did not have fire systems so that, in this case, the performance could not be assessed.

3.1.7 Finishing Interior (floor, wall, plafond). Based on observations in the field, the condition of interior elements tended to be simple, but still feasible to use in terms of safety and comfort. Physical conditions were identified that, from the entire residential houses, in this case, the post-tsunami subsidized houses, subsidized houses of UPLINK Germany could be categorized as the best ones because these had a sturdy structure and there were two types of houses and quite good interior finishing. Whereas, the second position was the ADB-subsidized houses which were almost the same as the UPLINK houses. The residential houses were mostly found in Meuraxa Sub-district, so, in this case, Residences in Meuraxa Sub-district had better value. Figure 7 shows the recapitulation of finishing interior sub aspect questionnaire results.

![Figure 7. Recapitulation of Finishing Interior Sub-Aspect Questionnaire Result](image)

The result of questionnaire recapitulation above show that the residences existing in sub-district of Meuraxa are better. Questions of the questionnaire are associated with physical conditions of floor, wall/pole and plafond. The answers to the questions consist of the following categories: very good, good, medium and less categories. If associated with recapitulation of the occupants’ opinions above, the results are more or less relevant to the study assumptions.

3.2 Functional Aspects and Occupants Response

3.2.1. Organizational Structure. The Organizational Structure of Village or Gampong in Aceh was contained in Law No. 6 of 2014 [15]. So, in terms of the organizational structure, the Village that was the object of study and the object of comparison was standard and followed the existing system and everything performed well.

3.2.2. Communication, Work flow, Storage and Circulation. The communication system in the three study objects generally used the current technological facilities. It had a simple spatial-organizational system and had good workflow and circulation. However, the existing residences in Meuraxa Sub-district were better performing because, in terms of communication, these still protected the local culture, had adequate environmental circulation paths using asphalt matrices with a width of 3 - 4 m of road body. This was very good considering that the condition was the disaster-prone area of Meuraxa. However, residences in Meuraxa Sub-district had a negative value based on the user's opinion regarding the physical condition of the building. Meuraxa area was a red zone of disaster, in addition to having adequate facilities and infrastructure, it was expected that socialization from the government in the
event of disaster was more optimized if there was a regular evacuation simulation. Figure 8 shows the recapitulation of physical conditions room questionnaire results.

![Figure 8. Recapitulation of Physical Conditions Room Questionnaire Result](image)

The questions of questionnaire concern the physical conditions of each room in the houses, such as, bathroom, kitchen, family room, guest room, bedroom, terrace, and yard. Answers to the questions consist of very good, good, medium and less categories. Based on the results of questionnaire above, the better physical condition of room is Jacky Chan residence. However, it tended to lead to negative level. It can be concluded that the subsidized houses were given free (subsidy) by various social and governmental organizations that were automatically understood by all limitations and disadvantages.

3.2.3. Human Factors. In terms of human factors, there were sub divisions, namely, furniture, work support equipment, arrangement and capacity of space, warehouse, and flexibility as well as change in space. Figure 9 shows the recapitulation of human factors questionnaire result.

![Figure 9. Recapitulation of Human Factors Questionnaire Result](image)

In this case, the asked questions in the questionnaire consist of physical condition of current equipment and their functions, available furniture, width of room, layout of equipment and flexibility of room. Answers to the questions consist of very good, good, medium and less categories. Based on the recapitulation of the questionnaire results, the results lead to better residences available to the Sub-district of Meuraxa. The graphic shows results of sufficiently dominant position. Storage area in this case study was not found. Goods stored in place is everywhere and every time.

3.3 Behavioural Aspects
3.3.1 Proxemics and Territoriality. Proximity is closely related to personal space. In the three study objects, productivity tended to occur at intimate, personal, and social levels [17]. Outer territoriality was indicated by the use of road signs, plant fences, and gates, while territoriality was shown using written communication that was easily visible and accessible. Based on the results of observations and interviews, Residences in Meuraxa Sub-district and Comparative Object Residences, user behavior in terms of proxy and territoriality tended to move to the normal direction.

3.3.2 Privacy and Interaction. In the three study objects, there was very little privacy. It aimed at making it easier to socialize (interact) with neighbors. This situation was due to cultural factors and customs. So, in this case, it was contrary to the POE study.

3.3.3 Perception. In this case, questionnaire technique used Likert scale. Available answers are only yes or no. Perception prefers to lead to the current room conditions. Questions consist of whether the room is narrow, dense, dazzled, noising, hot, scent, and dusty. The Figure 10 shows the recapitulation of perceptions sub aspect questionnaire result.

Based on the results of questionnaire recapitulation, there is different in each result. The results show that Jacky Chan residence is better, but, if seen from total samples overall, residences existing in the Sub-district of Meuraxa are more dominant. In the three study objects, spatial perception level comprehensively leads to poor (narrow, dense and hot).

3.3.4 Image and Meaning. The following are results of questionnaire recapitulation of users or occupants’ opinions. Technique used was semantic scale, where respondents could choose scores ranging from 1 to 5. The questions consist of simple – complex, bad – beautiful, common – unique, plain – decorative, boredom – attractive, narrow – wide, closed --- open, melancholy – cheerful, rejecting – curious, chaotic – orderly, unsafe – loosing, depressing – pleasing, and dirty – clean. Figure 11 shows of recapitulation of image and meaning sub-aspect questionnaire results.
Based on the results above, the Budha Suci residence is dominant in terms of value scale (see blue brown colors). However, if seen from total samples and minimal scale scores, then the residences available to the Sub-district of Meuraxa are better. The study objects and comparison tend to move to negative score for simple, common, plain, boring, narrow, unsafe, and dense points. Whereas, other points move to better points.

3.3.5. Cognition and Orientation. User orientation and cognition in the three study objects were under normal and good conditions. Each of residences had its own characteristics so that it was easy to remember and was supported by good facilities and infrastructures. This can be seen in the photo of the physical condition of the building and the environment.

4. CONCLUSION

The main study objects in this study were residences in Meuraxa Sub-district and the objects of comparative study were Jacky Chan Residence and Budha Suci Residence. Residences in Meuraxa Sub-district in this study did not mean that its performance was better than the residences of comparable study objects and vice versa. The nature of POE study was standard and consistent with the direction of the theory so that it could be implemented properly and systematically. Comparative studies of POE only existed at the investigative and diagnostic levels. It aimed at providing input and suggestions to solve the shortcomings of the main study objects. Therefore, the objects of comparative study were needed, which had minimum quality and quantity equal to or more than the main objects. The result was a recommendation for further studies that had a wider and more detailed scope. In essence, POE of this study was the final results at the final level (level of diagnosis) which contained recommendations whether the building and the environment was feasible or not (disaster review). If it was uninhabitable, the intervention of the government and experts related to the field of science had to be deployed to solve the problem. Living side by side with natural disasters was a big consequence that had to be lived. No human knew when a disaster would come. Therefore, we as humans who think are required to innovate and develop strategies so that when natural disasters occur in the area, we could reduce the negative impact. If buildings and dwellings are not safe, at least we as occupants must survive to be able to overcome the disaster in the future.
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