# Study on evaluation method of non-engineered constructions in earthquake prone countries


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**SUMMARY: (10 pt)**
In the earthquake prone countries, especially in developing countries, non-engineered constructions are damaged severely, every time large earthquake occurs. To improve the seismic safety of non-engineered constructions, not only the introduction of structural technology, buy also diverse approaches are needed. Therefore, we propose the simplified method to evaluate the socio-economic circumstances of seismic safety by analyzing some case study projects or public measures, with the purpose of better comprehension to consider the effective approach for improvement of non-engineered constructions. The result of our study may help the brief understanding of the situation in the project site, and may help to find the effective approach to improve the seismic safety of non-engineered constructions in earthquake prone countries.



*Keywords: Non-Engineered, seismic-design, construction practice,*


## 1. BACKGROUND

In earthquake prone countries, especially in developing countries, many houses are constructed with no or little intervention of engineers. These houses tend to have little earthquake- resistant ability and damaged severely every time large earthquake occurs, then the improvement of these houses are world-wide key issue of disaster prevention. These constructions are so-called “Non-Engineered Construction”, and according to the guidelines of IAEE, "The term non-engineered building may only be vaguely defined as buildings which are spontaneously and informally constructed in the traditional manner without intervention by qualified architects and engineers in their design but may follow a set of recommendations derived from observed behaviour of such buildings during past earthquakes and trained engineering judgment." Recently, many efforts have been done in the world to improve the seismic safety of non-engineered constructions by means of intergovernmental, academic, and NGO cooperation etc., which have contributed to some extent, but still there are so many non-engineered constructions that more efforts are needed.

According to the mentioned IAEE guidelines, these buildings can’t have high level of safety because of a number of socio-economic constrains, such as lack of concern or awareness about seismic safety, lack of financial resources, lack of certain materials, lack of skill in design and construction and unorganized nature of the building sector. Table 1 shows the recent Japanese ODA project in disaster prevention filed. As it shows, there are so many factors which we have to confront, and diverse approaches are needed to improve seismic safety. As approaches for public administration, that might be organizational enforcement, development of legal systems, implementation of application system for building confirmation or implementation of public conditional housing-loan system. As approach for technical field, that might be development of seismic technique, analysis of seismic wave with introduction of seismograph, or development of seismic micro-zoning map. And as approaches for community level, that might be training for technicians, dissemination of knowledge for community, disaster education, or publication to the community.

**Table 1** Recent ODA of JAPAN on the field of Earthquake Disaster Prevention

| Year | Country | Project Overview |
|---|---|---|
| 2011- | Indonesia | Building Administration and Enforcement Capacity Development |
| 2011- | Mongolia | Seismic Disaster Risk Management in Ulaanbaatar City |
| 2011- | Haiti | Anti-seismic Measures in Haiti |
| 2011- | Bangladesh | Disaster-Resistant Techniques of Construction and Retrofitting |
| 2011- | Vietnam | Development and Implementation of disaster Education Programs |
| 2010- | Philippines | Enhancement of Earthquake Monitoring |
| 2010- | Peru | Enhancement of Earthquake Disaster Mitigation Technology |
| 2010- | Nicaragua | Earthquake-Resistant Housing Construction Technology |
| 2010- | Armenia | Seismic Risk Assessment and Risk Management Planning |
| 2010- | Turkey | Capacity Improvement Project on Seismic Observation |
| 2009- | China | Earthquake First-aid Capacity Training |
| 2009- | El Salvador | Construction Technology and Dissemination System |
| 2009- | Sri Lanka | Practical Community countermeasure for earthquake |
| 2009- | Indonesia | Reconstruction of Schools |

Generally these projects have carried out with solicitation from opposing party, or with approach from engineer-sides. In these cases, the project have customized or adapted to the actual site-situation, but not necessarily covered all issues or factors for seismic safety that should be solved, and in some cases, there might be "mismatch" between actual situation and input projects (see Fig.1.). In this paper, based on the lessons learned from case-studies, we consider the methodology to figure out adequately these diverse factors and to find out the best approach of input projects in order to improve the seismic safety of non-engineered houses in developing countries.

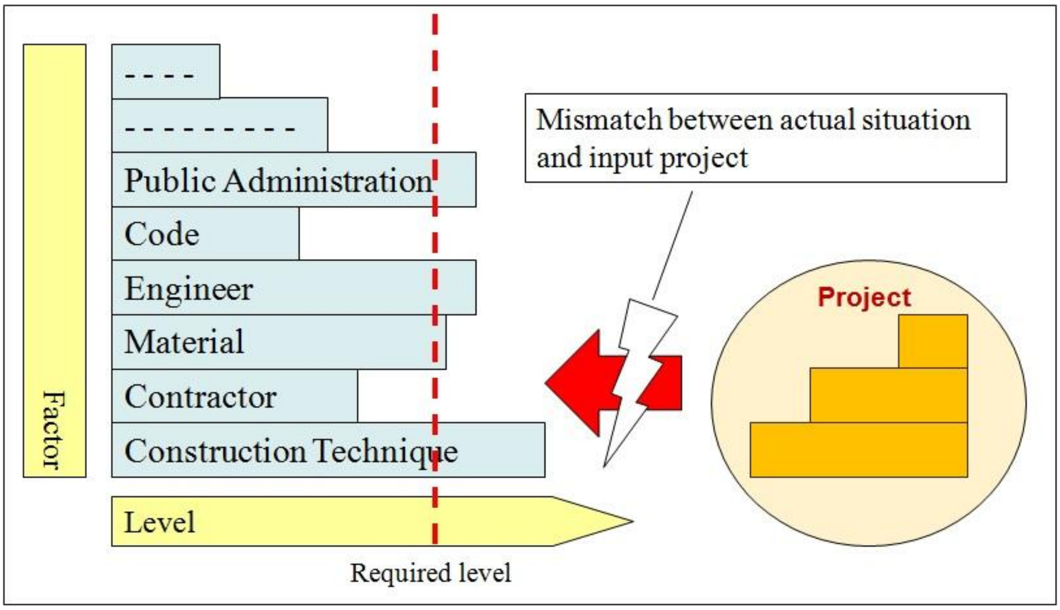


**Figure 1.** Image of diverse factors and "mismatch" of the project

## 2. ACTUAL SITUATION OF NON-ENGINEERED CONSTRUCTION

### 2.1. Process of Housing Construction

In the process of housing construction, there exist three important roles. The first one is "Government" who is in charge of construction administrative system like application of building construction. Second one is "owner", and third one is "construction industry", including architects and engineers. Fig.2.1. shows the relation between the three parties in case of housing construction in Japan, which represent the close relation among the three. In case of Japan, basically each party plays their own role appropriately and then the seismic safety of houses is ensured to the certain level. But if no, the seismic safety might not be secured.

Fig. 2.2. shows the situation in case of non-engineered houses. Usually non-engineered houses are for the poor and then the cost is relatively low. This fact makes it difficult to establish the construction market, and as reported in IAEE guidelines non-engineered construction has “unorganized nature of the building sector”. As a result, there is some difference in the scheme shown in Fig.2.1. and Fig.2.2. For example, the non-existence of construction industry forced the owners to play the role of “project deliver. Also without the active participation of government or researchers, the development of construction technique or construction material, which normally provide by enterprises, has not advanced.

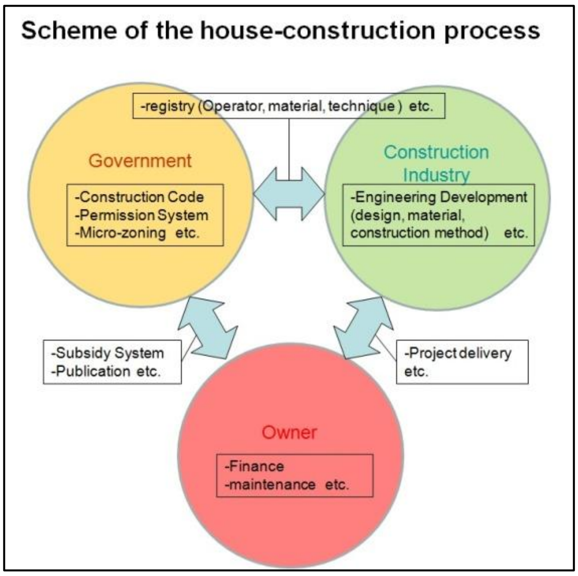


**Figure 2.1.**

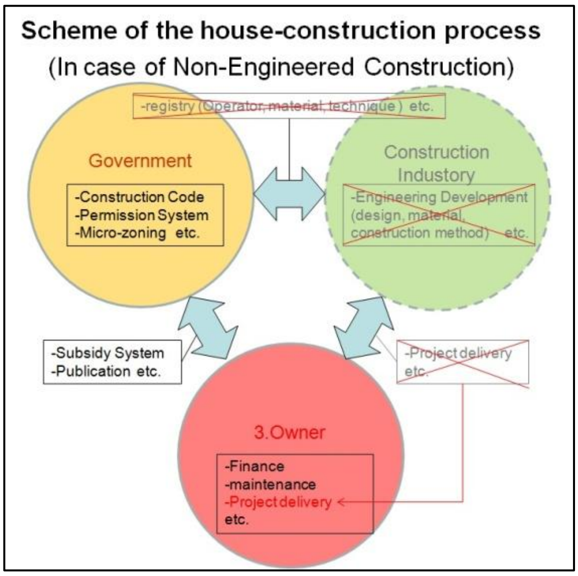


**Figure 2.2.**

**Figure 2.1. &2.2.** Mathematical models for non-linear response history analysis

As mentioned above, the situation of non-engineered houses are different from that of developed countries. And there is the possibility that even if the “anti-seismic technology”, which is most important factor to improve the seismic safety, is implemented, without appropriate grasp of these circumstances, the expected effect might not appear sufficiently. To avoid from this probability we extract the important factor that should be comprehended under the housing construction process and organized systematically, which will help the exhaustive grasp of the circumstances and help the “effective input” of the project for seismic safety of non-engineered houses.

## 3. CASE STUDY – JAPANESE ODA PROJECT IN PERU

In this chapter, we choose the Japanese ODA projects in Peru as case study, which we have opportunity to be involved, and analyze the mentioned “factors”.

### 3.1. “Dissemination on Construction Technology for Low-Cost and Seismic Resistant Houses”

This project started from 2004 as a Japanese technical cooperation thorough JICA – Japan International Cooperation Agency. The purpose of this project is to disseminate the appropriate construction method of non-engineered adobe houses to the community level, by using local materials, conventional method and construction system that already exist. (See fig.3.)

**Figure 3.** Construction of model seismic house of adobe

At first, 8 municipalities with highly motivation are selected, and construct in total 12 model houses. Under the construction process, the training for the workers, not only masons but also community residents who participate the construction is carried out to transfer the appropriate construction method to the community level. Additionally with the coalition of central and local government, this construction method would be disseminated to other areas. Japan sent 8 total numbers of specialists during this project and provided technical advises. For this project, we and sent Japanese specialists have monitored the project and extracted many lessons. Table 2 shows the main lessons or problems through this project.

**Table2.**Lessons from "Dissemination on Construction Technology for Low-Cost and Seismic Resistant Houses"

| | |
|---|---|
| a) | In Peru there exists construction code for adobe. As a result of the construction according to that code by registered architect and engineer, model houses have sufficient seismic safety. Seismic performance has been demonstrated by the earthquake occurred in 2007.8 - Pisco earthquake. |
| b) | With the supervision and training by NGO technician, appropriate construction method has transferred |
| c) | Construction method has changed to ease their work. Then without certain monitoring, the important structural factor might be changed inappropriately without awareness |
| d) | Higher Cost. Construction cost are still high, there are some materials that can't be prepared in the project site. |
| e) | Lack of financial resources. Community residents can't afford for whole cost of construction. |
| f) | Lack of administrative function. Municipality didn't conduct their obligation (preparation of materials, equipment and budget etc.) |
| g) | Lack of incentive and awareness of public officers in central and regional government. |
| h) | Difference between political strategy, especially in case of change of government or chief executive. |
| i) | Understandability. Although the manual for workers are developed, the contents aren't easily understandable. |
| j) | Lack of publicity. The effect of this project is not disseminated neighbouring region in appropriate distribution method. Also the target of publicity is not necessarily comprehended, "who is the decision-maker of house construction?" |
| k) | Lack of follow-up. Continuous monitoring is needed to extract lessons or problems. |

### 3.2. "Provision of Equipment for Production Factory, for the Reconstruction of the South"

This is one of the reconstruction projects financed by Embassy of Japan, providing the equipments for the production of Concrete Brocks (CB) that are used for the construction of seismic concrete block houses. The project was held in 5 districts and also contains the training program held by local government for CB-fabricate technicians.

After the Arequipa-earthquake in 2001, SENCICO, which is semi-governmental organization who supply the training service of construction industry, has promoted the CB-masonry construction houses because the reconstruction of houses without seismic safety nor official intervention were beginning in suffered area. The purpose of this project is the dissemination of fabrication technique of CB with local materials, and promotion of the reconstruction of anti-seismic CB-masonry houses with product CB. (See fig.4.)


**Figure 4.** Equipment (left) and fabricated concrete blocks (right)

Table 3 shows the main lessons or problems through this project, which extracted from the embassy's monitoring report done by specialists, and interview from them.

**Table3.**Lessons from "Provision of equipment for production factory, for the reconstruction of the South"

| | |
|---|---|
| a) | Equipments are used appropriately and training courses are carried out almost as it planned. |
| b) | Produced CB has adequate quality and slightly distributed in the marked. |
| c) | Little awareness for CB. CBs aren't used for house reconstruction.(used mainly for CB fence) |
| d) | Lack of administrative function. Dissemination of CB anti-seismic houses project is not carried out. |
| e) | Low incentive. The productivity of factory is low because it's public enterprise. |
| f) | Appropriate project area. Because the project carried out in district level, effects of the project including seismic awareness for community are efficiently disseminated. |
| g) | Rising of the level of "informal sector". With distribution of authorized CB into the marked, the awareness of informal vendor is changed to supply better production and lower costs. |

## 4. CASE STUDY – JAPANESE MEASURES FOR SEISMIC SAFETY

In this chapter, we selected some of Japanese measures for seismic safety as case study, and analyze as done in chapter 3. As mentioned in chapter 2, the circumstances around non-engineered houses and that of Japan are different, so we try to extract the key point by comparing the differences.

### 4.1. Promotion for Earthquake-Resistance of Existing Houses

In Japan, one of the earthquake prone countries, the promotion for earthquake-resistance of existing houses is important political issue. According to MLIT- Ministry of Land, Infrastructure, Transport and Tourism of Japan, earthquake-proof rate of dwellings is 62% in 1993, so government is promoting to improve this situation with the target of 95% in 2020. Table 4 shows the measures held by MLIT from 1995, and Fig.5 shows the transition of earthquake-proof rate. With these measures, the rate have improver a certain level, but with the purpose for more effective promotion, MLIT conducted policy evaluation in 2012, analyzing the obstructive factor for this measure.

**Table 4** Main measure of MLIT for earthquake- resistance of existing houses

| Year | Measures |
|---|---|
| 1995 | -Establishment of Act for Promotion of Renovation for Earthquake-Resistant Structures |
| 1998 | -Introduction of subsidy system for seismic diagnosis |
| 2000 | -Introduction of Housing Performance Indication *System (rating system on anti-seismic level)* |
| 2002 | -Introduction of subsidy system for seismic retrofitting<br>-Reduction in income tax for seismic houses |
| 2004 | -Introduction of preferential housing loan system for seismic houses |
| From then on, gradual improvements were made such as increase of subsidy etc. | |

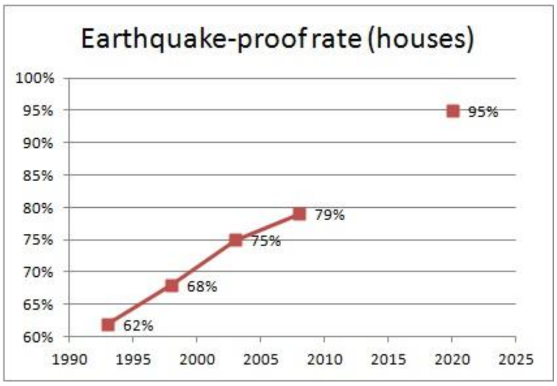


**Figure 5.** Transition of earthquake-proof rate

### 4.2. Promotion for Participation of Earthquake Insurance

In parallel with promotion for earthquake-resistance of existing houses, Japanese government also promote the participation for earthquake insurance, which help the reconstruction of damaged houses from large earthquakes. Recently, after the Great East Japan Earthquake occurred in 2011.3, the amount of 15 billion USD is distributed as insurance payments, as of 2nd of April, 2012.Japanese earthquake insurance system was established in 1966 by law, and government is in charge of fund administration unlike in the case of other insurances. Then Ministry of Finance (MOF) has making efforts to increase the participation rate though improvement of the insurance system and continuous publicity, but the rate is still low while gradually increasing these days.

### 4.3. Lessons from Each Measure

*4.3.1. Relation between earthquake risk awareness and effect of political measures*

Table 5. shows the measures held by MOF for these 15 years and Fig.6. shows the transition of participating rate of earthquake insurance. The red mark in fig.6 shows the MOF's measures in Table 5. and bar graph shows the death toll from earthquakes. As is shown, the number of death, which was the result of large earthquakes like the Great Hanshin-Awaji Earthquake in 1995.1 or Niigata-Chuetsu Earthquake in 2004.10, affected strongly to the increase of participation rate, while government's approach has not necessarily affected to the rate increase. We can also presume this from questionnaire survey held by MLIT, which shows "the anti-seismic retrofitting is progressed where large earthquakes have occurred," or "the earthquake-proof rate has risen according to the earthquake risk level" etc. Also we can presume from Fig.7. which shows the relation between the earthquake risk level and participating rate of earthquake insurance in each 47 prefecture.

This fact suggests that the awareness of earthquake risk affects very strongly to the earthquake safety in Japan. But also, according to the questionnaire survey held by OKAZAKI in 6 developing countries, those who have experience of earthquake damage tend to pay more money for disaster prevention of their own houses. .

**Table 5** Main measure of MLIT for earthquake- resistance of existing houses

| | |
|---|---|
| 1996 | Increase of coverage , change of the payment |
| 1997 | Increase of coverage |
| 1999 | Increase of coverage |
| 2001 | Change of the payment, Introduction of discount rate according to the anti-seismic level |
| 2002 | Increase of coverage |
| 2005 | Increase of coverage, Introduction of discount rate for long time contract |
| 2007 | Review of earthquake zoning risk, Reduction in income tax |
| 2009 | Increase of coverage |

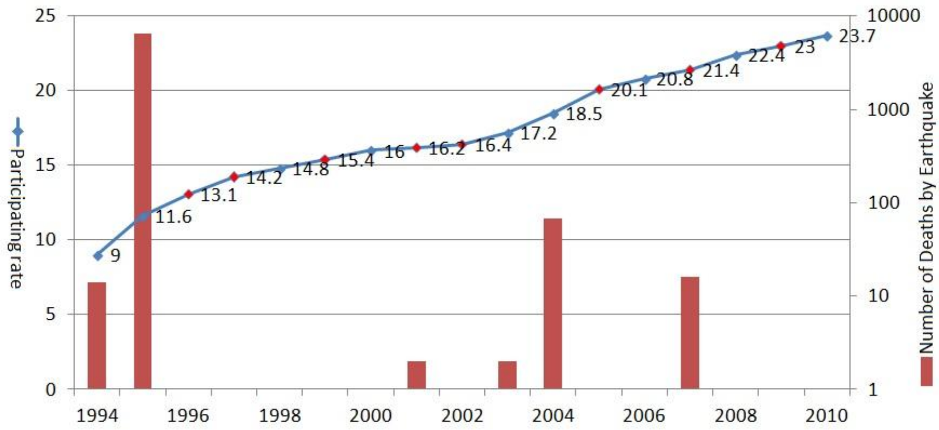


**Figure 6.** Transition of participating rate of earthquake insurance and number of death by earthquakes

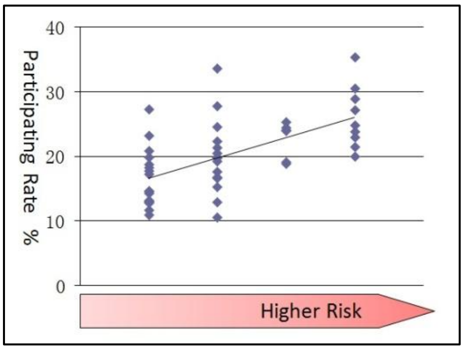


**Figure 7.** Relation between the earthquake risk level and insurance participating rate in each 47 prefecture

*4.3.2 Cost*

Fig.8.1. show the relation between the insurance participating rate and average income in each prefecture. It is obvious that the rate increase as their income. But according to MOF's questionnaire survey, there are other reason of non-participation such as "there is no catalyst (20%)", "The house will not receive damages (11%)"and "Difficult to understand the contents (10%)", apart from "cost"(39%). Also MLIT's survey shows the same idea (See fig.8.2.). This result suggests that only financial resource will not be the perfect solution. It's not sure if this theory also adjusts to other countries, but during the site research in Peru, we found some obstructive factors other than "cost", although many engineers or public officials mentioned "cost" as first word.

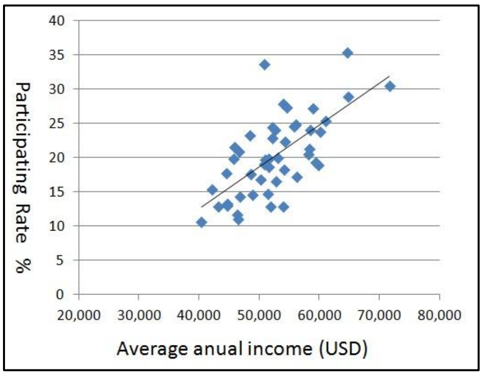


**Figure 8.1.**

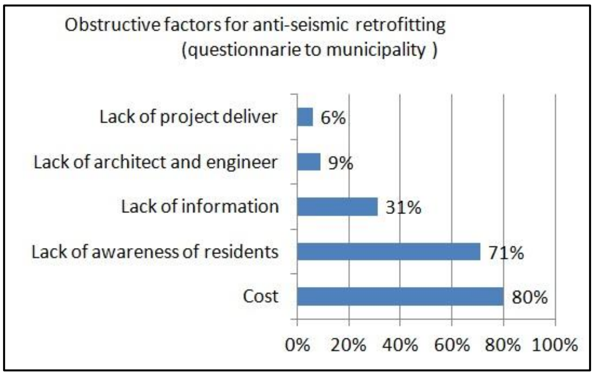


**Figure 8.2.**

**Figure 8.** Relation between insurance participation rate and average annual income (left) and result of MLIT's questionnaire survey to the municipality (right)

*4.3.3 Reliability of relevant parties and techniques*

MLIT's report mentioned that one of the obstructive factors is "reliability" to building contractor and building technique. According to the MLIT's survey, more than 45% of the information factors which affect the decision for conduct of seismic diagnosis has relation with "reliability".(see fig.9.) During the interview survey held in adobe project in Peru, community residents demand to send the masons or trained technicians when they build new houses. This fact indicates that the lack of reliability to workers or techniques might be the obstructive factor with which community residents can't make a decision to construct in anti-seismic method, even if there is strong incentive.

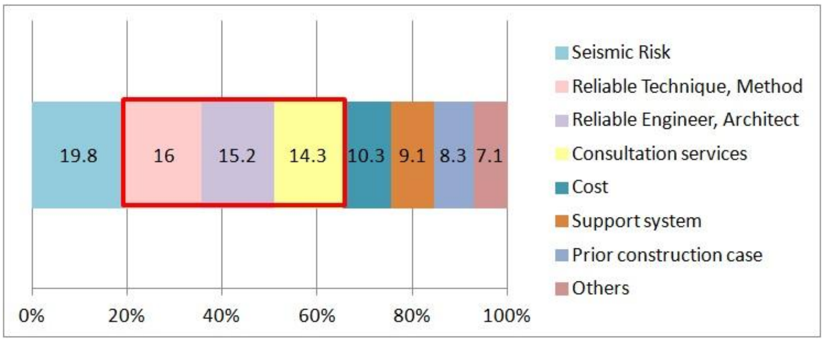


**Figure 9.** Information factors which affect the decision for conduct of seismic diagnosis

## 5. EVALUATING METHOD THROUGHOUT THE HOUSE CONSTRUCTION PROCESS

In this chapter, we marshalled the factors from the case study in chapter 3 and 4, as an evaluating method to comprehend effectively the circumstances of non-engineered houses.

Fig. 10 shows the general process of house construction. As it shows, there is a cycle from decision making to maintenance, and in case of dissemination of the project this cycle slide to other houses or other sites. Then, Table 6. shows the obstructive factor in each steps extracted from case study and this table or check-sheet will support to comprehend the circumstances correctly and make us notice "what we should pour in" to improve the situation. Because this proposal, or check-sheet, is only build from the case study in this paper and our experiences, further verification is needed to utilize universally. But for now, the efforts for seismic safety for non-engineered houses tend to complete internally, and even if there is report document of the project, it is not easy to extract the key point to utilize for other project. Therefore, idea of this proposal, in other words sharing the result of the each effort for the improvement for non-engineered hoses is useful to carry the project efficiently. As a future work, it is necessary to do more case studies to extract other (or hidden) obstructive factors to develop this sheet.

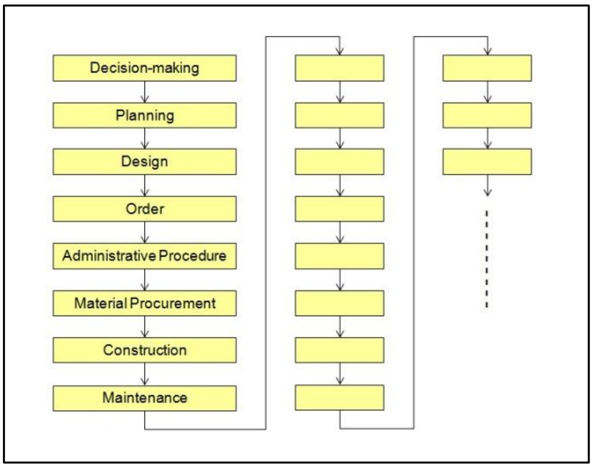

**Figure 10.** Construction and dissemination cycle of house

**Table 6** Factors that should be evaluated throughout the process of non-engineered house construction

| Steps | Obstructive factor | Evaluation Index | How to get? |
|---|---|---|---|
| Decision -making | Governmental strategy | House safety strategy and policy | Exist or no? |
| | | Awareness of public officials | Interview |
| | | governance capacity | Investigation |
| | | Budget for housing safety | From publications |
| | | Publicity measure | Investigation |
| | | Change of government and chief executives | Investigation |
| | Awareness of seismic risk | Awareness of community residents | Interview |
| | | Past seismic history | Investigation |
| | Decision making | Decision maker in the family | Interview |
| Planning | Decision of the site | Seismic risk of the site | Micro-zoning map |
| | Financial resources | Loan system (public and private) | Exist or no? |
| | | Owner's income | Interview |
| | | Budget limit | Interview |
| Design | Selection of adequate architect and engineer | Qualified system | Exist or no? |
| | | Difficulty in finding | Investigation |
| | | Level of architect /engineer | Investigation |
| | Adequate design | Level of Construction code | Investigation |
| | | Code/Guideline for non-engineered houses | Exist or no? |
| Order | Selection of project deliver, including masons or community participants | Conductor registry system | Exist or no? |
| | | Difficulty in finding | Investigation |
| | | Level of conductor | Investigation |
| | | Reliability to conductor | Interview |
| Administrative procedures | Construction permission system | Construction permission system | Exist or no? |
| | | Level of public official | Investigation |
| Material procurement | Procurement of adequate materials | Material recognition system | Exist or no? |
| | | Industrialization of materials | Investigation |
| | | Existence of producer | Investigation |
| | | Quality of materials | Investigation |
| | | Market situation, sales price | Investigation |
| | | Residents' awareness of materials and market | Interview |
| Construction | Appropriate supervision | Existence of appropriate party like NGO | Exist or no? |
| | | Manual/guideline for construction | Investigation |
| | | Level of manual/guideline | Investigation |
| | | Understandability of manual/guideline | Investigation |
| Maintenance | Appropriate maintenance | Awareness of the importance of maintenance | Interview |
| | | Manual/guideline for maintenance | Investigation |
| | | Level of manual/guideline | Investigation |
| | | Understandability of manual/guideline | Investigation |
| | Possibility of diffusion | Existence of appropriate party like NGO | Exist or no? |
| | | Transfer medium in the site | Investigation |

## 6. CONCLUSION

To improve the situation of non-engineered houses, diverse socio-economic- based approaches are needed as well as introduction of structural engineering techniques. In order to maximize the effectiveness of the project, appropriate and systematic understanding of actual circumstances is indispensable. In this paper, we proposed the idea and evaluation method to support this.

There are still many problems to be solved to make a progress in the field of non-engineering houses, but it is very important to accumulate the knowledge and lessons of the many efforts in the world. We expect more researchers or related parties to share this valuable information by utilizing our idea of proposal to make this situation better.

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