Prioritizing Criteria of Earthquake Safe Housing in Earthquake Prone Areas A Case of Housing in Padang City

by Prima Fithri

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Prioritizing Criteria of Earthquake Safe Housing in Earthquake Prone Areas: A Case of Housing in Padang City

Prima Fithri[#1], Rika Ampuh Hadiguna[#2], Puti Gina K I Putri[#3]

[#]*Department of Industrial Engineering, Faculty of Engineering, University of Andalas, Kampus Limau Manis,Pauh, Padang 25163, West Sumatera, Indonesia*
E-mail: [1]primafithri@eng.unand.ac.id; [2]hadiguna@eng.unand.ac.id; [3]putiginakartika@gmail.com

***Abstract*— The aims of this research are to determine earthquake-safe housing development criterion in Padang City and find the relationships level of these criterions with customer requirements. The data of consumer perceptions on which is safe houses in prone areas to earthquake and tsunami was collected by questionnaires. The questionnaires used in this research were divided into two phases. In the first phase, the questionnaires were distributed to 30 consumers for the purpose of validation. In the second phase, the questionnaires were disseminated to 109 residents (consumers who buy housing on "Tsunami Yellow Zone" and developers who develop housing on the same area) and the results were processed using QFD (Quality Function Deployment) and AHP (Analytical Hierarchy Process). AHP showed the priority level of each indicator within the criteria. The results of this research, It can be seen that criteria for earthquake-safe housing development in the city of Padang can be sorted as follows: Implement technical factors in building earthquake-safe homes, Taking into account the legal and environmental aspects, Providing service facilities around the housing, Housing facilities and infrastructure, Marketing factor friendly, Low Cost and Pay attention to the aesthetics surrounding factors of housing. This research focused on housing developers and consumers in a disaster-prone area such as Padang City. The value of this research is to know the consumer requirements and its relationships with developer's technical characteristics. In the end, these developers will consider the criteria that required by the consumer and make the developed safer housing for consumers at the disaster-prone area.**

***Keywords*— housing; customer requirement; disaster areas; quality function deployment; analytical hierarchy process.**

I. INTRODUCTION

Geographically, Indonesia is an archipelago that lies at the confluence of four tectonic plates, the Asian Plate, Australian Plate, Indian Ocean plate and the Pacific Ocean Plate. In the southern and eastern parts of Indonesia located volcanic arc that extends from the island of Sumatra, Java, Nusa Tenggara, and Sulawesi in the form of old volcanic mountains and lowlands are mostly dominated by swamps. These conditions have a potential for disasters such as volcanic eruptions, earthquakes, tsunamis, floods, and landslides. Building condition is an essential issue all over the world to enhance safety [1].

In the past ten years recorded six times large earthquakes that occurred in Indonesia. West Sumatra Province is one of the regions at risk by a magnitude 8.9 earthquake on the Richter scale and could trigger a tsunami. The earthquake that hit West Sumatra province in September of 2009 centered 57 kilometers north-west of the city of Pariaman with 7.9-Richter scale and caused damage to the infrastructure in residential areas, especially in the city of Padang.

Padang residents yearn for building a house back in the safe zone since many houses were damaged. Buying a house from the developer is an option because payments can be tailored to the buyer's pocket [2], [3]. Therefore, housing developers must know the criteria in fulfilling customers' needs [4]–[6]. Furthermore, the criteria of the house have an important role in the housing project since it relates to the house buyer's satisfaction and also private developers profit and market share [7]–[11].

Based on data obtained from Real Estate Indonesia (REI) of the city of Padang, the number of a home purchased from the developer increased since the earthquake in 2009. The developer usually provides some types of home based on land and building extents [12], [13]. When making a purchase, some consumers who want the custom homes specification different with the types provided, so that the consumer will be charged an additional fee for making customizations. So, determining what the exact criteria for the residential development of disaster-prone areas in the city of Padang are and how the level of the relations of each criterion with the needs of consumers.

II. Material and Method

In this research, a survey was used to collect the data. The questionnaires used in the survey were divided into two phases. In the first phase, the questionnaires were distributed to 30 consumers for validation. In the second phase, the questionnaires were disseminated to 109 residents, and the results were processed using QFD (Quality Function Deployment) and AHP (Analytical Hierarchy Process). In industry, QFD is a technique of product development to translate customer requirements for product development activities and services [14]–[17].

Respondents in this research were people who wish to buy houses in the prone area and need some criteria to make themselves safe from earthquakes for example.

The next step was to develop the instrument for collecting the data. The instrument was a questionnaire divided into two parts. Part one was used to identifying the requirements from customers, and part two was used to make prioritize criteria for the requirement.

After collecting the data, the next step was to analyze the data using statistical methods to build the House of Quality (HOQ). In order to assure the reliability and validity of the instrument, a pilot study was conducted. In the pilot study, questionnaires were distributed to 30 respondents. The results of the pilot study showed that all questions used in the questionnaires to measure the variables are reliable and valid. In the pilot study, the reliability and validity criteria were made according to Zikmund *et al*. [14]. The variables are said to be reliable if the value of Alpha Cronbach > 0.6 and it is valid because the output that is shown from *software* SPSS 16.0 is above $r_{table,}$ 0,188. After using HOQ, to identify the prioritizing of customer criteria, AHP (Analytical Hierarchy Process) method was used in this research [18]–[20]. AHP was used to identify the prioritizing of houses' criteria in prone areas.

III. Results and Discussion

The collected data is the perception of the consumer in choosing a housing development criteria and characteristics of data, weighting technique performed by the developer. Consumer perception data was collected by distributing questionnaires to consumers who have bought houses in the yellow zone to a residential developer. Meanwhile, questionnaire criteria weighting techniques earthquake-safe housing development completed by the experts from the developer. Conducted to test the validity of each attribute in the criteria. Testing is done on the validity of each criterion and then the results of validation test there are two indicators which are not valid, i.e., indicators availability of commercial and industrial facilities and infrastructure criteria settlement conditions, and indicators of the well-ordered environment in the home site characteristics criteria. Therefore, both of these indicators are not included in further calculations as r-count obtained is smaller than r-table. Beside doing validity test, a reliability test was conducted to determine the extent to which the indicator is measuring trustworthy and reliable. Moreover, the results are reliable.

A. QFD Calculation Phase I

QFD calculation of phase 1 is done to get the customer's perception of value priorities that can be satisfied with the technical characteristics of the future.

B. Calculation of Consumer Interests

The calculation of the level of interest of consumers conducted by the indicator on each of the criteria. Recapitulation consumers to value the importance of each criterion can be seen in Appendix A.

C. Technical Characteristics

The characteristics of each technique and attributes gained from previous research and have been validated by experts and discussed the entire housing developers who responded. Technical characteristics are presented in Table 1.

Table 1
Technical Characteristics

No	Technical Characteristics
1	The legal and environmental aspects friendly
2	Housing facilities and infrastructure
3	Implement technical factors in building earthquake-safe homes.
4	Taking into account the marketing factor
5	Taking into account the aesthetic factors of residential areas
6	Providing service facilities around the housing
7	Taking into account the low cost

D. Consumer Needs with Technical Characteristics Relation Matrix

After determining the technical characteristics, the next step is to determine the relationship between customer needs with technical characteristics.

E. Priority Value of Technical Characteristics

Characteristics priority value is obtained by multiplying the technique level of consumer interests about the value of each symbol contained in the relationship matrix. Recapitulation of calculating the value of priority technical characteristics are presented in Table 2. From table 2, technical implementation factor in building earthquake-safe housing is the highest priority for the developer in building housing. Moreover, the lowest priority is esthetics factor. Aesthetic factor does not become too important for the developer to build earthquake-safe housing. Developers must concern in technical factor in building earthquake-safe housing and legal and environmental aspect for building housing.

F. Correlation Technique

Correlation technique contains a relationship between each of the technical characteristics of the item. This correlation is the result of discussions with Dian Vista, ST as a site manager at PT Hati Prima Griya Elok. Correlation technique between technical characteristics can be seen in Figure 1.

G. Calculation of the Analytical Hierarchy Process (AHP)

In the calculation of the analytical hierarchy process, data collected using a weighting questionnaire. The weighting of

each expert has validated previous questionnaires, and there are additional attributes to some criteria.

H. The weighting of Criteria and Indicators

The weighting which has been done on the technical characteristics of each attribute is predetermined. Experts will give a score to the pairwise comparisons between the technical characteristics and each attribute in the technical characteristics based on the level of importance. It can be seen from figure 2 to figure 6.

TABLE II.
RECAPITULATION OF CALCULATING THE VALUE OF PRIORITY TECHNICAL CHARACTERISTICS

No.	Technical Characteristic	Costumer Need	Matrix Value	Priority Value			Priority Percentage
				Value	Total	Average	
1	Taking into account the legal and environmental aspects	Location home safe from earthquake	9	4.28	38.52	37.71	28.39
		Location home safe from tsunami	9	4.35	39.15		
		The air around the housing free from pollution	9	4.19	37.71		
		Residential neighborhood located in flood free area	9	4.13	37.17		
		the condition of housing is quite	9	4	36		
2	Housing facilities and infrastructure	Sources of clean water and electricity in good condition	3	3.88	11.64	18.31	13.78
		Rainwater drainage and sewage in good condition	3	3.8	11.4		
		Availability of landfills	3	3.67	11.01		
		There are sports facilities and parking areas	3	4.49	13.47		
		Overall housing facilities according to the needs	9	3.86	34.74		
		Overall housing facilities capable of meeting the needs of all residents	3	3.94	11.82		
		Availability of facilities building evacuation	9	4.49	40.41		
		The location is close to the fire department	3	3.99	11.97		
3	Implement technical factor on developing earthquake safe house	Location home safe from earthquake	9	4.28	38.52	39.96	30.08
		Location home safe from tsunami	9	4.35	39.15		
		Availability facilities building evacuation	9	4.49	40.41		
		Location home safe from earthquake	9	4.64	41.76		
4	Marketing factor	Residential location with easy reach	3	3.65	10.95	8.77	6.6
		Residential location passed by public transport	3	3.59	10.77		
		Access to housing well	3	3.61	10.83		
		Transportation from or to the location of housing available	3	3.49	10.47		
		Residential location close to the central town	3	3.14	9.42		
		Residential location close to the work or activities	3	3.42	10.26		
		The roads on residential in good condition	1	3.96	3.96		
		The special lanes for pedestrian are available	1	3.52	3.52		
5	Pay attention to the aesthetics	Land area is by requirements	1	3.58	3.58	3.61	2.72
		Building area is by requirements	1	3.62	3.62		
		The spacing of the building and yard is sufficient (30% and 70%)	1	3.64	3.64		
6	Providing service activities around the housing	There are kinder garden education facilities	3	3.55	10.65	20.69	15.58
		Availability of elementary school	3	3.48	10.44		
		Availability of junior high school	3	3.42	10.26		
		There are high school educations	3	3.54	10.62		
		Availability of clinics	9	4.25	38.25		
		Availability worship facilities	9	4.88	43.92		
7	Low cost	The cost of house maintenance is cheap	1	3.78	3.78	3.78	2.85
TOTAL						132.83	100

I. Calculation Priority Technical Characteristics

After the experts provide weight to each of the criteria and indicators of the criteria, it will be calculated using the local weight analytical hierarchy process method. The calculation is done for all the criteria and indicators in it and produces a priority interest.

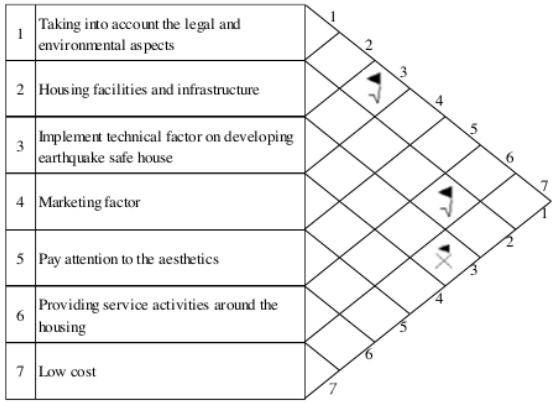

Fig. 1 Correlation Technique

From figure 1, legal and environmental aspects are absolute requirements in building a house. These aspects consist of layout city and location of the house. This criterion has a weak positive relationship with the criteria of a technical factor in building earthquake-safe housing. It is because of in legal and environmental aspect; housing should be built in the safe earthquake area and safe from a tsunami. Housing facilities in infrastructure have a weak relationship with criteria in providing service facilities around the housing. These technical characteristics will increase customer satisfaction if they are equipped. The other characteristic technics is implemented technical factor in building earthquake-safe housing. This factor has a weak negative relationship with low-cost criteria. It means that if a technical factor in building earthquake-safe housing will be implemented, cost if housing will increase.

After knowing the relationship of individual technic each indicator, the next step of this research is knowing the priority in each criterion. Figure 2 to figure 6 explain about indicator priority in each criterion.

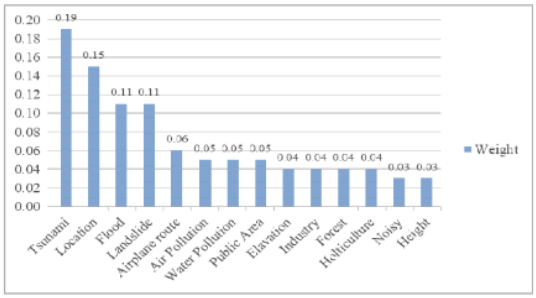

Fig. 2 The weighted Indicator of Legal and Environmental Criteria

From figure 2, developers must concern about tsunami safe area as the priority. In legal and environmental criteria, developers also must concern in location and area which is free from flood, landslide, airplane route and the last is the height of the area.

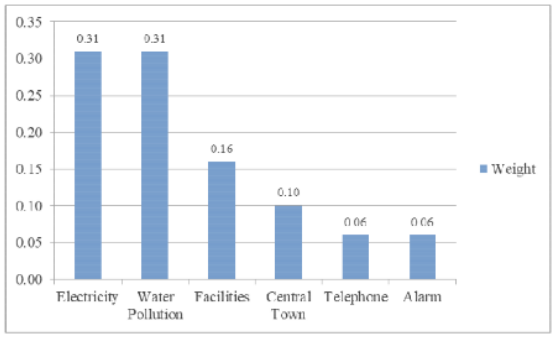

Fig. 3 The Weighted Indicator of Facilities Criteria

Electricity is essential factor for the developer in building earthquake-safe housing. It can be seen in figure 3, electricity, water and facilities is the highest weighted indicator of facilities area. House without electricity and water will be no meaning. Costumer will not be satisfied and not comfortable to stay in their house.

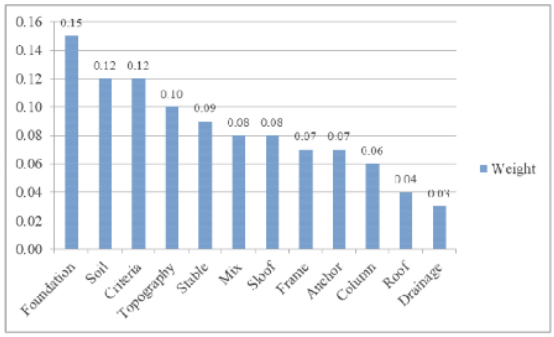

Fig. 4 The Weighted Indicators of Technical Factor Criteria

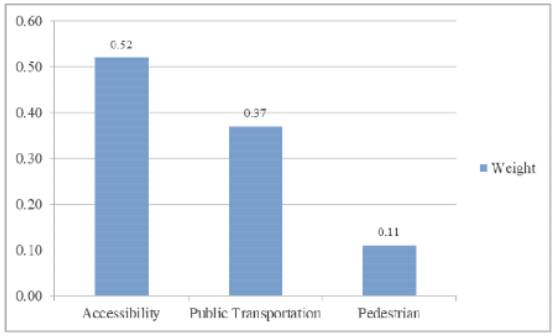

Fig. 5 The Weighted Indicators of Marketing Factor

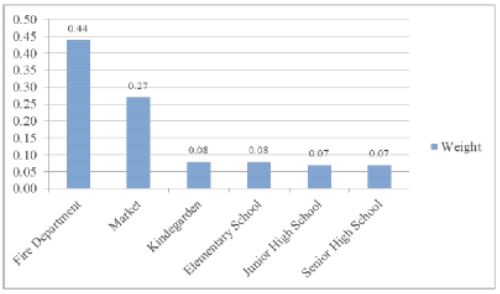

Fig. 6 The Weighted Indicators of Service Facilities Criteria

In technical factor criteria, the foundation of the house is the crucial thing that developer must concern on it. The customer always wants sturdy housing, and it depends on the foundation of the house. If the foundation is good, so the housing will be sturdy. It can be seen in figure 4. In the marketing factor, developers must concern accessibility. Customers will buy housing that has good accessibility for reaching the house. Good accessibility is also supported by public transport. From figure 5, we see public transport is the second priority for marketing factor. The last criteria are service facilities, from figure 6, developers must pay attention to the fire department, market, and schools. The fire department and market are important factors for a customer in buying a house. It is because of their safety and comfort in living somewhere.

IV. Conclusions

This research sorted the criteria for earthquake-safe housing development in the city of Padang. Firstly, implement technical factors in building earthquake-safe homes. Secondly, taking into account the legal and environmental aspects. Thirdly, providing service facilities around the housing. Fourthly, housing facilities and infrastructure. Fifthly, marketing-friendly factor. Sixthly, Low Cost and Pay attention to the aesthetics surrounding factors of the housing.

Housing development criteria that can meet the needs of consumers with the level of relationship that is strongly linked. Criteria by the laws of the environment with the needs of consumers and location of earthquake-safe housing, the safe residential location of the tsunami, the air around the housing free from pollution, residential neighborhood are in a flood-free area is fairly quiet and residential location. House criteria were built with attention to technical factors with the needs of consumers safe residential location of the earthquake, tsunami safe residential location, available facilities and the evacuation of the building housing the location is in the earthquake zone. Criteria for adequate residential care facilities around the needs of consumer's available clinics, available facilities for worship. Housing facilities and infrastructure criteria with the overall housing facilities meet the needs of building occupants, and evacuation facilities are available.

The results of this study can be used as a reference for residential development in areas which prone to earthquakes and tsunamis. Criteria and indicators can also be used to support pre-disaster activities to increase community preparedness. The characteristics of the technique and its relationship with the consumer desire can be used to mitigate the structural scale disaster. The developer should be able to ensure the suitability of housing between the desires of consumers, the technical characteristics of earthquake-safe houses, with homes that will be accepted by consumers with an evaluation during the construction process.

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References

[1] J. Wahlqvist and P. van Hees, "Influence of the built environment on design fires," Case Stud. Fire Saf., vol. 5, pp. 20–33, 2016.
[2] C. Shimizu, K. G. Nishimura, and T. Watanabe, "House prices at different stages of the buying/selling process," Reg. Sci. Urban Econ., vol. 59, pp. 37–53, 2016.
[3] C. O. Brassington, "Briefing an eLearning developer," Train. Dev., vol. 39, no. 3, pp. 28–29, 2012.
[4] E. Nonko, "Tiny house zoning regulations: What you need to know," Curbed. 2016.
[5] A. Panya and L. Ramingwong, "A framework for building trust in B2C E-commerce based on consumer's viewpoint in Thailand," in Proceedings of the 20th Asia-Pacific Conference on Communication, APCC 2014, 2015, pp. 271–276.
[6] S. B. Kalatage and G. Nagarajan, "Impact on customer buying behavior towards residential properties in Bangalore," Int. J. Appl. Eng. Res., vol. 10, no. 6, pp. 14149–14174, 2015.
[7] Y. H. Chiang and B. S. Tang, "'Submarines do not leak, why do buildings?' Building quality, technological impediment and organization of the building industry in Hong Kong," Habitat Int., vol. 27, no. 1, pp. 1–17, 2003.
[8] M. G. Holm, "Service quality and product quality in housing refurbishment," Int. J. Qual. Reliab. Manag., vol. 17, no. 4/5, pp. 527–540, 2000.
[9] J. Sommerville and J. McCosh, "Defects in new homes: an analysis of data on 1,696 new UK houses," Struct. Surv., vol. 24, no. 1, pp. 6–21, 2006.
[10] S. Ong, "Building defects, warranties and project financing from pre-completion marketing," J. Prop. Financ., vol. 8, no. 1, pp. 35–51, 1997.
[11] I. Wiesel et al., Developing sustainable, affordable housing: A project-level analysis, no. 183. 2012.
[12] S. Pasternak, "Thinking about urban services needs in fast-growing cities: Housing in São Paulo," in Global Urbanization, 2011, pp. 294–309.
[13] M. Johnston, M. Guaralda, and S. Sawang, "Sustainable innovation for Queensland's housing design: A case study," Australas. J. Constr. Econ. Build., vol. 14, no. 4, pp. 11–31, 2014.
[14] W. G. Zikmund, B. J. Babin, J. C. Carr, and M. Griffin, Business Research Methods. 2013.
[15] Z. Baran and M. S. Yıldız, "Quality Function Deployment and Application on a Fast Food Restaurant," Int. J. Bus. Soc. Sci., vol. 6, no. 9, pp. 122–131, 2015.
[16] M. M. Aghdam, I. Mahdavi, B. Shirazi, and J. Vahidi, "House of quality improvement by new design requirements generation," in IEOM 2015 - 5th International Conference on Industrial Engineering and Operations Management, Proceeding, 2015.
[17] S. R. Gangurde and S. S. Patil, "Benchmark product features using Kano - QFD approach: a case study," Benchmarking An Int. J., pp. 00–00, 2018.
[18] L. G. Socaciu and P. V. Unguresan, "Using The Analytic Hierarchy Process To Prioritize And Select Phase Change Materials For Comfort," Math. Model. Civ. Eng., vol. 10, no. 1, pp. 1–8, 2014.
[19] G. H. de Sousa-Mendes, E. Gomes-Salgado, and B. E. Moro-Ferrari, "Prioritization of TQM practices in Brazilian medical device SMEs using Analytical Hierarchy Process (AHP)," DYNA, vol. 83, no. 197, pp. 195–203, 2016.
[20] N. Hasan and A. A. Rahman, "Ranking the Factors that Impact Customers Online Participation in Value Co-creation in Service Sector Using Analytic Hierarchy Process," Int. J. Inf. Syst. Serv. Sect., vol. 9, no. 1, pp. 37–53, 2017.

Appendix A. Value of Customer Requirement Recapitulation

Criteria	No.	Indicator	indicators Assessment					Number of Respondents	Importance	Total Score Average
			STS	TS	BS	S	SS			
Suitability Location	1	Residential location within easy reach	0	0	30	33	6	69	3,65	3,692
	2	Residential location passed by public transport	0	0	28	41	0	69	3,59	
	3	Access to housing well	0	0	27	42	0	69	3,61	
	4	Transportation from or to the location of housing available	0	0	35	34	0	69	3,49	
	5	Residential location close to the the central town	0	7	45	17	0	69	3,14	
	6	Residential location close to the work / activity	0	0	44	21	4	69	3,42	
	7	Location home safe from earthquake	0	0	9	32	28	69	4,28	
	8	Location home safe from tsunami	0	0	10	25	34	69	4,35	
Infrastructures conditions Settlements	9	Sources of clean water and electricity in good condition	0	0	20	37	12	69	3,88	3,8841
	10	Rain water drainage and sewage in good condition	0	0	23	37	9	69	3,80	
	11	Available landfills	0	0	35	22	12	69	3,67	
	12	There kindergarten education facilities	0	0	36	28	5	69	3,55	
	13	Available Elementary School	0	0	38	29	2	69	3,48	
	14	Available junior high school	0	0	42	25	2	69	3,42	
	15	There are high school education facilities	0	0	36	29	4	69	3,54	
	16	Available clinics	0	0	13	26	30	69	4,25	
	18	Available worship facilities	0	0	1	6	62	69	4,88	
	19	There are sports facilities and parks	0	0	38	18	13	69	3,64	
	20	Overall housing facilities according to the needs	0	0	22	35	12	69	3,86	
	21	Overall housing facilities capable of meeting the needs of all residents	0	0	16	41	12	69	3,94	
	22	Available facilities building evacuation	0	0	6	23	40	69	4,49	
	23	The location is close to the fire department	0	0	21	28	20	69	3,99	
Environmental conditions Settlements	24	The air around the housing free from pollution	0	0	14	28	27	69	4,19	4,1
	25	Sewer works fine	0	0	18	21	30	69	4,17	
	26	Available sources of clean water	0	0	11	31	27	69	4,23	
	27	Residential neighborhood located in a flood-free area	0	0	18	19	32	69	4,13	
	28	The location of housing is in the earthquake safe zone	0	0	7	11	51	69	4,64	
	29	The condition of housing is safe enough	0	0	2	29	38	69	4,20	
	30	The condition of housing is quite enough	0	0	21	27	21	69	4,00	
	31	The roads on residential in good condition	0	0	21	30	18	69	3,96	
	32	The special lanes for pedestarians is available	0	1	43	13	12	69	3,52	
	33	The residential neighborhood is not noisy	0	0	21	30	18	69	3,96	
Home Site Characteristics	34	Land area is accordance with requrements	0	0	26	43	0	69	3,62	3,6435
	35	Building area is accordance with requirements	0	0	29	40	0	69	3,58	
	36	Number of room according to the needs	0	0	28	41	0	69	3,59	
	37	The cost of house maintanance is small	0	0	22	40	7	69	3,78	
	38	Spacing of building and yard is sufficient (30% and 70%)	0	0	25	44	0	69	3,64	

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