



IDENTIFICATION OF INFRASTRUCTURE INDICATORS IN URBAN HOUSING DEVELOPMENT IN INDONESIA

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Abstract

Urban housing development is an important aspect of sustainable spatial planning, where adequate infrastructure is a major factor in creating decent, comfortable, and safe housing. Infrastructure includes basic facilities, accessibility, security, and environmental sustainability. Semarang City, as one of the metropolitan cities in Indonesia, faces various challenges in managing housing infrastructure. Rapid population growth, limited land, and the threat of disasters such as floods are the main factors that affect infrastructure planning. Therefore, a clear parameter is needed to assess infrastructure capability in urban housing development. This research aims to identify infrastructure indicators in housing development. The results of this study have reached consensus on 23 indicators in only two rounds of Delphi, with 15 experts indicating a percentage of agreement over 75%, meaning the experts are in the agreed-upon category. The $IQR \leq 1$ value indicates a high degree of agreement. While $SD < 1$, indicating that the experts' answers are homogeneous. In addition, the CV value obtained < 0.2 or 20% indicates that stability is achieved, and there is no further Delphi round. There are four indicators of input from experts, including housing signage, a one-gate system, a jogging track, and a gathering point. However, one indicator that needs to be eliminated is the internet network, as it is not provided by housing but is instead held by each homeowner. The results of this study are expected to serve as a reference or influence existing regulations for policymakers and developers, ensuring that every housing development meets standards that support quality of life, efficiency, and sustainability.

Keywords: Indicator, Infrastructure, Housing

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INTRODUCTION

Urban housing development is one of the main challenges in spatial planning in Indonesia. Along with increasing urbanization, the need for adequate housing is increasingly urgent, so supporting infrastructure is a crucial factor in creating a comfortable and sustainable environment (Telaumbanua et al., 2024). Good infrastructure, such as transportation networks, drainage, clean water supply, sanitation, energy, and public facilities, plays an important role in supporting people's lives in urban areas. Therefore, identifying infrastructure indicators in housing development is necessary to ensure the quality of housing is up to standard (Rahadian & Oetomo, 2024).

Semarang City, as one of the metropolitan cities in Indonesia, faces various challenges in managing housing infrastructure. Rapid population growth, land constraints, and the threat of disasters such as flooding are the main factors affecting infrastructure planning. By identifying key indicators relevant to urban needs, planning for housing development in Semarang City can be more effective and sustainable. In addition, research by (Pigawati et al., 2023) highlights how land use and infrastructure growth must be aligned to reduce the negative impacts of urbanization.

Research by (Enwin & Ikiriko, 2023) highlights that inadequate infrastructure in urban areas is a significant barrier to providing affordable housing, underscoring the need for an integrative approach to develop the necessary infrastructure. It highlights the need for more attention to planning infrastructure that is both adaptive and proactive in addressing challenges.

This study aims to identify infrastructure indicators that support urban housing development to serve as a reference for developers and policymakers. It is also to ensure that every housing development meets standards that support quality of life, efficiency, and sustainability.

LITERATURE REVIEW

Housing Infrastructure

Housing infrastructure is a complex and vital system in supporting the quality of life of residents. Housing is an important aspect of modern life, not only because of its cost, but also because of its relationship with various urban challenges (Aqlima Ramli et al., 2024). The relationship between housing and infrastructure, according to (Onyejiaka et al., 2020) that the house where a person lives shows their status, a measure of achievement, community acceptance, an expression of their personality, and is a barometer that shows the way and attitude a person is perceived in society

Research (Omar et al., 2018) emphasizes that housing infrastructure is not just a physical building. However, it includes utility networks, accessibility, and support systems that are interrelated to create a decent and sustainable residential environment. (Mangalekar & Gumaste, 2021) also explained that the

main aspects of housing infrastructure include clean water supply, sanitation, and waste management. The availability of clean water that is sustainable and safe for consumption is a top priority. According to research (Byagaba & Mukiibi, 2021), efficient sanitation systems prevent environmental pollution and disease. Effective solid and liquid waste management keeps the environment clean and healthy. Additionally, it is argued that access to reliable and affordable electrical energy supports daily activities and can improve the quality of life of residents (Ahmad et al., 2024).

According to (Intan et al., 2020), in addition to basic utilities, housing infrastructure also includes road accessibility and transportation. A well-planned road network ensures residents' mobility and access to public facilities such as schools, hospitals, and workplaces. An efficient public transportation system reduces congestion and air pollution. Last but not least, according to (Molnar et al., 2018) adequate telecommunication connectivity supports communication and access to information. Another important aspect is environmental security and safety.

In the research of (Celhay & Gil, 2020) the authors emphasized that integrated security, including adequate street lighting and neighborhood security systems, creates a sense of security for residents. Research of (Huang et al., 2019) emphasizes that infrastructure planning should also consider aspects of disaster resilience, ensuring infrastructure is resistant to various threats such as earthquakes, floods, and fires. Overall, adequate infrastructure in a housing estate is essential to support residents' quality of life.

Housing Infrastructure Indicators

Based on the review results in several journals, the following are housing infrastructure indicators in Table 1

Table 1: Review of Infrastructure Indicator Articles

Infrastructure Indicators	Reference
Nature / Environment	
Green open space	(Giuliani et al., 2021)
Natural Water Reservoir	(Huang et al., 2019)
Social	
Educational Facilities	(Telaumbanua et al., 2024)
24 Hour Clinic	(Zhou et al., 2020)
Mosque	(Jaffar & Abdullah, 2020)
Other worship	(Ormsby, 2021)
Shopping	(Omar et al., 2018)
Public service facilities	(Hamzah et al., 2024), (Rafee Majid et al., 2020)
Sports field	(Giuliani et al., 2021), (Hamzah et al., 2024)
Parking space availability	(Wai Lam et al., 2023)
Waste management	(Cheng et al., 2022), (Intan et al., 2020)
Security system	(Celhay & Gil, 2020), (Musa et al., 2019)

Infrastructure Indicators	Reference
Facilities and infrastructure	
Road Conditions	(Ali et al., 2023),
Lighting/PLN/Electricity	(Ahmad et al., 2024), (Graves et al., 2021)
Availability of Clean Water	(Tumwebaze et al., 2023)
Telecommunication Availability	(Graves et al., 2021), (Molnar et al., 2018)
Internet Network	(Graves et al., 2021), (Molnar et al., 2018)
Drainage network	(Pei et al., 2024), (Pigawati et al., 2023)
Wastewater network	(Cheng et al., 2022)
Availability of local transportation	(Intan et al., 2020), (Zhang et al., 2024)

Source: Review Artikel, 2024

Based on several articles from several journals, 20 indicators were obtained, of which two indicators are natural factors, 10 indicators for social factors, and eight indicators for facilities and infrastructure factors (Graves et al., 2021)

Stakeholder Analysis

Determining expert respondents is important because experience and knowledge determine the reliability and validity of the results. Therefore, expert respondents must meet four key requirements: they must have relevant knowledge and experience, be willing to participate in providing opinions or input, have sufficient time to participate, and possess effective communication skills (Giannarou & Zervas, 2014).

Table 2: *Experts (Stakeholders) involved*

Stakeholder	Role
Department of Housing and Residential Areas	Responsible for formulating policies, coordinating between sectors, implementing policies, monitoring and evaluating, and providing technical guidance related to housing and settlements
Department of Spatial Planning	Responsible for formulating policies, preparing strategic plans, coordinating programs, establishing cooperation, implementing programs and activities, as well as conducting monitoring, evaluation, and reporting related to spatial planning, building planning, development, construction services, and land.
National Housing Corporation	Organizing housing and settlements, developing housing for low to middle-income communities, and managing and planning land use.
PLN (State Electricity Company)	Provision of electricity for the community and industry in settlements
Water Company	Providing raw water for drinking and meeting community needs through a clean water distribution system.
Telkom (Telecommunication)	Providers of information and communication services and telecommunications networks in settlements
Lecturer/Researcher	Contribute to the development of new theories and methods, examine current issues, and seek innovative solutions to

Stakeholder	Role
	improve the quality and sustainability of settlement infrastructure.
Developer	Planning, designing, and building a housing project and its infrastructure, along with permits
Social Institutions Housing Society	Monitor and provide critical input in housing infrastructure planning with a focus on environmental impact analysis, sustainability, and green technologies.

Source: survey results, 2024

Based on the results of the three stages of stakeholder analysis above, several preliminary plans can be developed to involve these stakeholder groups in the stages of the program/project. The stakeholder categories include subjects, who have high influence and low importance; key players, who possess both high influence and high importance; context setters, who have low influence but high importance; and the crowd, representing stakeholders with both low influence and low importance.

RESEARCH METHODOLOGY

This qualitative research used the Delphi method to identify housing infrastructure indicators because the topic is multidisciplinary and involves diverse views from various stakeholders. The Delphi method was chosen because it allows for anonymous input collection, thus reducing bias and encouraging a more objective consensus.

Although the Delphi method is designed to gather anonymous input (Musa et al., 2019), it highlights that the topic of housing infrastructure involves diverse views from different stakeholders. According to (Musa et al., 2019), this may pose a risk that the opinions of some influential experts may influence those of other experts, resulting in the final results not fully reflecting independent views.

This approach involves a group of experts to reach an agreement on a problem. Experts are selected based on experience, field of knowledge, and specialized expertise (Rafee Majid et al., 2020). Territorially, the Delphi process can continue to repeat until a determined consensus has been reached. The appropriate number of respondents to engage in a Delphi study, according to research (Daniel et al., 2019), is 10-15 respondents. Ten to fifteen respondents can be sufficient if the background expertise is homogeneous. The Delphi method, as described by (de Brito et al., 2017), requires three rounds to achieve its objectives. In each round, participants are given 2 weeks to respond (Musa et al., 2019).

This process uses anonymous feedback to reduce variation in answers (de Brito et al., 2017). According to (Al-Qawasmi, 2021) the Delphi questionnaire is said to be in consensus if the standard deviation value is < 1 and

the IQR value is ≤ 1 . In addition, the difference coefficient of variation (CV) is determined for each indicator, which aims to provide a normalized measure of dispersion. CV is a dimensionless value (coefficient) and is calculated as the standard deviation divided by the mean. The difference is obtained by subtracting the CV from round 2 and the CV obtained in round 1, CV difference smaller than 0.2 or 20% indicates it.

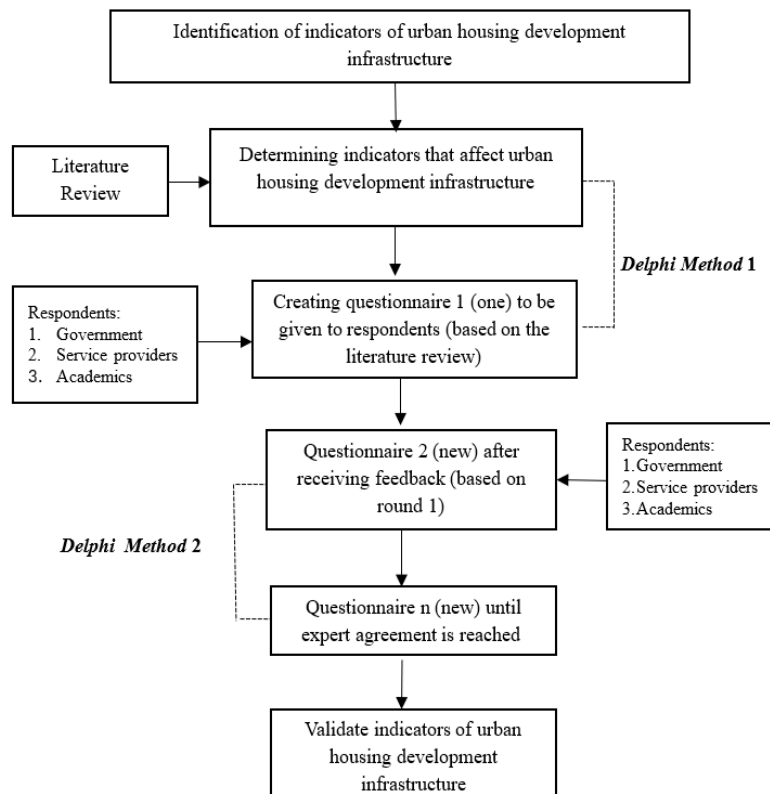


Figure 1: Research Flow Diagram
Source: Author

Figure 1 shows the flowchart of the research using the Delphi method that goes through various stages to reach the final result. First, housing infrastructure indicators were identified based on the literature review. Next, the first round of questionnaires began with closed-ended questions relating to housing infrastructure.

There were six government experts, three from academia, four from property developers, and two from the Social Institutions Housing Society, totaling 15 experts. The second round asked for responses to the indicators and

concepts of urban housing infrastructure. It provided feedback on how to formulate indicators and improve concepts. In the next round, the questions were closed-ended, where consensus was reached on the results, indicators, and concepts. However, the Delphi rounds are not always three but usually two as long as consensus is reached.

RESULT AND DISCUSSION

Based on the Stakeholder Importance and Influence Matrix in Figure 2, it is found that stakeholders are included in the Key Player category, namely, stakeholders who have high influence and importance, so that they can be fully involved in all stages of identifying infrastructure indicators in housing development, thereby giving them confidence that the program's success is due to their support.

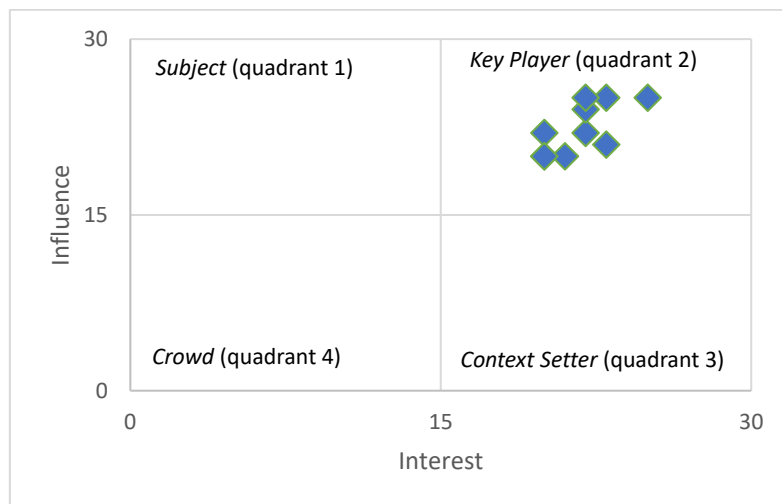


Figure 2: Stakeholder interest and influence matrix

Source: Author

Table 3 shows that, based on the review of articles and given to experts, the following results were obtained:

Table 3: Percentage Answers 4-5, Mean, Standard Deviation, Interquartile Range, and Coefficient of Variance Delphi Rounds 1 and 2

Indikator	Delphi 1				Delphi 2			
	% (4-5)	SD	IQR	CV	% (4-5)	SD	IQR	CV
Nature / Environment								
Green open space	100.00	0.52	1.00	0.11	100.00	0.52	1.00	0.11
Natural Water Reservoir	100.00	0.46	0.50	0.10	100.00	0.46	0.50	0.10
Social								

Indikator	Delphi 1				Delphi 2			
	% (4-5)	SD	IQR	CV	% (4-5)	SD	IQR	CV
Educational Facilities (Kindergarten & Elementary School)	100.00	0.46	0.50	0.10	100.00	0.46	0.50	0.10
24 Hour Clinic	100.00	0.46	0.50	0.10	100.00	0.46	0.50	0.10
Mosque	100.00	0.49	1.00	0.10	100.00	0.49	1.00	0.10
Other worship	100.00	0.52	1.00	0.11	100.00	0.52	1.00	0.11
Shopping	93.33	0.52	1.00	0.17	93.33	0.52	1.00	0.17
Public service facilities	93.00	0.59	1.00	0.14	93.00	0.59	1.00	0.14
Sports field	100.00	0.51	1.00	0.12	100.00	0.51	1.00	0.12
Parking space availability	93.33	0.52	1.00	0.11	93.33	0.52	1.00	0.11
Waste disposal	100.00	0.77	1.00	0.18	100.00	0.77	1.00	0.18
Security system	100.00	0.51	1.00	0.12	100.00	0.51	1.00	0.12
Jogging Track	-	-	-	-	80.00	0.52	1.00	0.17
One gate system	-	-	-	-	80.00	0.52	1.00	0.17
Housing identity board	-	-	-	-	100.00	0.51	1.00	0.12
Assembly point	-	-	-	-	80.00	0.52	1.00	0.17
Facilities and infrastructure								
Road Conditions	100.00	0.50	1.00	0.10	100.00	0.50	1.00	0.10
Lighting/PLN/Electricity	100.00	0.46	0.50	0.10	100.00	0.46	0.50	0.10
Availability of Clean Water	100.00	0.51	1.00	0.11	100.00	0.51	1.00	0.11
Telecommunication Availability	100.00	0.46	0.50	0.10	100.00	0.46	0.50	0.10
Internet Network	73.33	0.64	0.50	0.18	-	-	-	-
Drainage network	100.00	0.51	1.00	0.11	100.00	0.51	1.00	0.11
Wastewater network	100.00	0.51	1.00	0.11	100.00	0.51	1.00	0.11
Availability of transportation	100.00	0.46	0.50	0.11	100.00	0.46	0.50	0.11

Source: Data Processing, 2024

In Delphi round 1, the results of the article review amounted to 20 indicators and were given to experts. Indicators that have an accepted percentage > 75% are 19 indicators, and indicators that have a percentage < 75% are one indicator. Likewise, the IQR (interquartile range) value ≤ 1 indicates a high degree of agreement among experts, who agree that the 19 indicators provided can be used for housing development, except for one indicator. A value of SD (standard deviation) < 1 indicates that the expert's answer is homogeneous. It means that experts agree on 19 indicators, but there is disagreement on one. One indicator that is not agreed upon has a percentage value < 75%, an IQR value ≤ 1 , and an SD < 1 is the internet network indicator because each house installs its own internet network, rather than being provided by the developer. Similar results were also reported where broadband availability is often treated as a household responsibility rather than community infrastructure (Graves et al., 2021).

In round 1, several input indicators from experts were also considered, leading to the addition of 4 indicators: housing signage, a gate system, a jogging

track, and a gathering point. According to experts from the private sector, housing signage is a housing identity. This indicator has a vital role in building the image and pride of its residents (Intan et al., 2020). Experts from academia also pointed out that the one-gate system in this housing provides extra security for all residents. Only vehicles that are registered and have special access are allowed to enter through one main gate that is strictly guarded. Another expert from the private sector also provided input that the jogging track in this housing offers a comfortable and safe path for exercise, suitable for jogging, walking, and cycling (Intan et al., 2020) dan (Hamzah et al., 2024).

Meanwhile, the gathering point, as identified by government experts, can serve as a gathering place for residents in the event of a natural disaster or fire, provided the location is easily accessible, such as a field or park (Omar et al., 2018). The importance of such additional livability indicators in peri-urban housing has also been emphasized in recent studies (Rafee Majid et al., 2020). Based on expert input, the indicators for Delphi round 1, which originally totaled 20, were revised to 23. One indicator was not agreed upon, and four indicators were input from experts.

In round 2, experts again rated the 23 indicators generated in round 1. After the assessment, the results of this round have reached consensus. Where all indicators have a percentage of agreement greater than 75%, so that respondents are in the agreed category. The IQR (interquartile range) value ≤ 1 indicates a high degree of agreement. While SD (standard deviation) < 1 , indicating that the answers of the experts are homogeneous.

Meanwhile, the value of ΔCV (difference in coefficient of variation) has a value < 0.2 or 20%, indicating stability. Thus, no further Delphi rounds are needed for this indicator, as the level of certainty and agreement that has been reached among the experts is sufficient. The data generated from the second round can be considered as a valid representation of the experts' perceptions of the 23 indicators, with the two main indicators of natural elements being the presence of green open spaces and natural water reservoirs. This finding is consistent with other Delphi-based studies on urban quality of life indicators, which also confirmed consensus stability through IQR, SD, and ΔCV statistics (Al-Qawasmi, 2021).

Previous research, which may have involved more Delphi rounds and a larger number of respondents, aimed to achieve a higher level of consensus and reduce uncertainty in the results. However, this study, with only two rounds and 15 respondents, showed efficiency in achieving significant consensus for 23 indicators. Despite the smaller number of respondents and shorter rounds, achieving a ΔCV value below 20% in the second round indicates that the sample used is representative enough to generate a strong consensus. This efficiency aligns with findings that Delphi consensus can be achieved more quickly when expert homogeneity is high (Barrios et al., 2021).

CONCLUSION

The study achieved a strong consensus on 23 indicators in only two rounds of the Delphi study with 15 respondents, as indicated by the coefficient of variation (ΔCV) being below 20%. In the first round, there were 20 indicators, of which two were for natural factors, 10 were for social factors, and eight were for facilities and infrastructure factors. In round 2, there were 23 indicators, of which two indicators were for natural factors, 14 indicators were for social factors, and seven indicators were for facilities and infrastructure. There are four indicators of input from experts, including housing signage, a one-gate system, a jogging track, and a gathering point. However, one indicator that needs to be eliminated is the internet network, as housing does not provide it, but is held by each homeowner. The results of this research are expected to serve as a reference or influence existing regulations for policymakers and developers, ensuring that every housing development meets standards that support quality of life, efficiency, and sustainability.

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