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The Sub-Criteria for Evacuation-Based Pedestrian Route Design Parameters

Veiga Mustika Agenta[1], Fitra Rifwan[1 *], Yosritzal[2], Purnawan[2], Yossyafra[2]

[1] Civil Engineering Department, Engineering Faculty, Universitas Negeri Padang
Jl. Prof. Dr. Hamka, Kampus UNP Air Tawar Padang, Indonesia-25131

[2] Civil Engineering Department, Engineering Faculty, Universitas Andalas
Limau Manis, Kec. Pauh, Kota Padang, Sumatera Barat, Indonesia-25175

**Corresponding author: fitrarifwan5163@ft.unp.ac.id* Doi: https://doi.org/10.24036/invotek.v23i3.1128

Abstract

Indonesia, surrounded by three major tectonic plates—the Indo-Australian plate, the Pacific plate, and the Eurasian plate—faces a relatively high disaster risk. The city of Padang in West Sumatra, located on the western side of Sumatra Island and in proximity to tectonic plates, is particularly susceptible to earthquakes and tsunamis. To mitigate disaster risk, Padang requires evacuation-focused road infrastructure, including pedestrian paths. This study aims to assess the validity of sub-criteria parameters for creating pedestrian evacuation routes in Padang. It employs quantitative descriptive research methods, utilizing Aiken's V and Cronbach Alpha. The study involved distributing validation forms to five experts, comprising two Civil Engineering lecturers and three members of Padang City's BPBD (Regional Disaster Management Agency) specializing in Planning and Preparedness. The participants' responses, recorded through the forms, served as data for analyzing and identifying sub-criteria for evacuation-oriented pedestrian route design parameters. The study's findings reveal that one sub-criteria—Safety Fence from the Amenities parameter with a value of V = 0.7—is invalid.

Keywords: Tsunami, Evacuation Route, Disaster Mitigation, Pedestrian Route, Aiken's V.

1. Introduction

Padang, one of the city in Indonesia have a fairly high level of disaster risk (earthquakes and tsunamis), located in West Sumatra because of its geographical positioning along the Sumatra Island coastline, directly adjacent to the Indian Ocean [1]. As a consequence of its geographical positioning, it has two potential sources of large-scale earthquakes and tsunamis, namely the presence of the Semangko fault line on land and the confluence of Australian plate and Eurasian plate at the bottom of the ocean. History records that there was an earthquake measuring > 9 SR around the Mentawai Islands in 1798 and 1833. The earthquake followed by a tsunami that submerged approximately one-third of the city of Padang. The Meteorology, Climatology, and Geophysics Agency (BMKG) reported a total of 10,792 seismic events in Indonesia (one case in Padang) during 2022, with 809 earthquakes being perceptible and 22 causing significant damage. The tragedy also had the potential to trigger tsunami [2]. Figure 1 below explains the distribution of areas prone to earthquakes and experiencing the resulting vibrations. The location of the epicenter in the sea can affect in the threat of a tsunami disaster in areas along the coastline adjacent to that location. Figure 2 below shows areas that are vulnerable to tsunami disasters as a continuation of the impacts described in Figure 1 previously.

Geologists estimate that large earthquakes with the potential for tsunamis, such as those that occurred in 1797 and 1833 in the city of Padang, will repeat themselves in a cycle of 200 – 300 years [3]. The Head of the Meteorology, Climatology, and Geophysics Agency (BMKG) stated that the seismic energy generated along the western coast of Sumatra is concentrated in the Mentawai-Siberut Megathrust earthquake source segment, which aligns with the West Sumatra coastline. This segment is capable of generating earthquakes with a potential maximum magnitude of 8.9 and according to the

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BMKG's tsunami modeling, the resultant tsunami wave could exceed 10 meters in height and reach the coast in less than 30 minutes [4]. The energy released from the Mentawai-Pagai segment megathrust earthquake in 2010 was only a third of the earthquake energy in that segment. If the energy generated by an earthquake in the future is greater, the tsunami will be three times larger [5]. The majority of residents of Padang city live in coastal areas. In 2022, the population of Padang city was projected to be 919,145, reflecting a growth rate of 0.62% compared to the preceding year, while the coastal population in 2019 was recorded at approximately 650,000 [6], [7]. Given the city's vulnerability to seismic and tsunami events, there is a heightened concern among the populace of Padang city, emphasizing the critical need for both government and community preparedness and response mechanisms to mitigate the impact of such disasters.

Figure 1. Seismicity Map of Indonesia Year 2022 (Source: BMKG, 2023 [2])

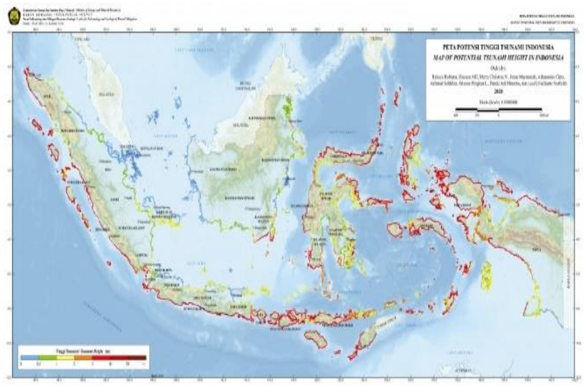

Figure 2. High Potential of Tsunami Map of Indonesia (Source: PVMBG, 2020 [8])

The Padang city government has undertaken initiatives to address and mitigate potential losses resulting from a tsunami disaster. A key measure among these initiatives is the establishment of tsunami evacuation routes. Tsunami evacuation routes are an important aspect for visualizing the strategies formulated for a region in the event of a disaster. The main principle in evacuation is to ensure the safety of the community when evacuating from a hazardous area to secure locations [9]. However, based on records of earthquakes that occurred in previous years, the city of Padang still has problems in terms of tsunami evacuation. The development and enhancement of evacuation routes in the city of Padang have been notably slow, this is proven by the very small number of routes and many of the roads used as evacuation routes are still too narrow and damaged so that they will hamper people's mobility when used during evacuation [10]. Rifwan and Rizqullah (2021) in their research also stated that the evacuation route in the red zone of sector 6 of Padang city is ineffective for use [11].

The evacuation process in the city of Padang shows that people rely more on vehicles than walking as a mode of evacuation. Motorized vehicles are an inefficient mode considering that traffic conditions are difficult to predict during evacuation. Apart from that, people prefer the final evacuation place as a safe place for disasters because there are still many people who do not know for sure which buildings can be used as shelters [12]. This makes the evacuation process subject to many obstacles such as traffic jams, distance traveled, and so on [13]. The traffic jams resulted in an ineffective evacuation process, as individuals were unable to reach safe locations in a timely manner. Additionally, motorized vehicle users also use sidewalks that should be intended for pedestrians. This creates more problems because pedestrians are also unable to move. Another obstacle is the habit of parking vehicles and the presence of street vendors (PKL) on the sidewalks [14].

The previous evacuation process showed that the city of Padang is in need of proper road infrastructure that that satisfies essential requisites, one of which is an evacuation-based pedestrian route. Designing pedestrian routes is a form of management to assist the evacuation process. The integrity of the infrastructure and terrain plays a pivotal role in determining the likelihood of building collapse during an earthquake, particularly if the quality is poor, and currently there is still a lot of infrastructure that is utilised where some of materials do not meet the quality standards, as a consequence the useful life of the infrastructure is not according to plan [14], [15]. The previous research stated that the density of the soil on the Salido-Bukit Langkisau evacuation route was in poor condition. Based on this, the design of road infrastructure is very important to consider in expediting the evacuation process. In an effort to minimize the impact of the tsunami disaster, it is imperative to establish design parameters for evacuation-based pedestrian route, facilitating self-evacuation for individuals [15].

There are four key design parameters for evacuation-based pedestrian paths, namely Walking Path Mode Conflict, Availability of Walking Paths, Amenities, and Obstruction [16]. Each of these parameters encompasses several sub-criteria, which must be aligned with the objective of evacuation-based pedestrian routes. The previous research only resulted in parameters for normal conditions, not for emergency situations such as evacuation. The vulnerability of several areas in Indonesia and the lack of facilities for evacuation, especially for pedestrians, against the tsunami disaster are the main background for this research. Therefore, this research was carried out with the aim of determining the level of validity of sub-criteria parameters for designing pedestrian evacuation routes in Padang City through the application of Aiken's V and Cronbach Alpha methods. Validity tests are carried out by experts in the field. The findings from this research are expected to provide valuable insight and guidance for the formulation of evacuation-based pedestrian routes.

2. Research Methodology

To achieve the goal of finding sub-criteria for each parameter of the design of evacuation facilities for pedestrians, a validation and reliability test method were needed for the criteria themselves based on literature and field observations. The data supported the method. Data collection was undertaken by distributing validation forms, each of which contained columns representing the sub-criteria for each parameter for designing pedestrian evacuation routes. These forms were completed by five experts, two Civil Engineering lecturers at Padang State University specialized in planning and three people from the Padang City Regional Disaster Management Agency (BPBD) in the field of Prevention and Preparedness. The respondents provided their inputs by assigning scores within a range of 1 to 5. The expert assessments were subsequently processed using Aiken's V method, using the following equation [17]:

$$V = \frac{\sum S}{[n(C-1)]} \tag{1}$$

Information:

S	$= r - l_o$
R	= number given by the researcher
L_o	= lowest assessment number
C	= highest assessment number
n	= number of raters

In Equation 1, V value is matched by adjusting the Table "Table Values of Right Tile Probabilities (P) for Selected Values of The Validity Coefficient (V)".

Reliability testing was carried out using the Cronbach's Alpha (∝) method. Cronbach's Alpha analysis was carried out using the Statistical Package for the Social Sciences (SPSS) software. Data is deemed reliable if the Cronbach Alpha value is > 0.6. Reliability refers to the understanding that an instrument is reliable enough to be used as a data collection tool, using the equation [18]:

$$r11 = \left[\frac{k}{k-1}\right]\left[1 - \frac{\sum 6b^2}{6t^2}\right] \tag{2}$$

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Information:

$r11$	=	Instrument Reliability
K	=	Number of Question Items
$\sum б b^2$	=	Number of Item Variants
$б t^2$	=	Total Variance

The research method prepared to achieve the objectives can be seen in the flow diagram in Figure 3 below.

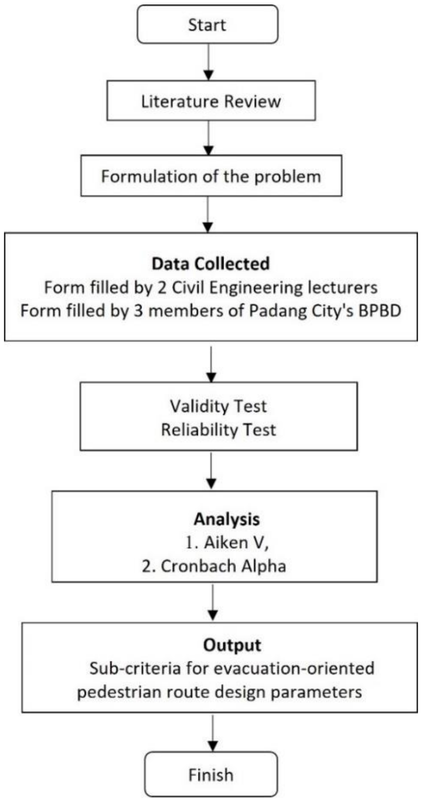

Figure 3. Research Flowchart

3. Result and Discussion

3.1 Validity Test

Validity testing is essential to evaluate the suitability of the indicators used with the expertise of professionals in the relevant field. The indicators in this case are sub-criteria of four evacuation-based pedestrian path design parameters, namely Walking Path Mode Conflict, Availability of Walking Paths, Amenities, and Obstruction [19].

3.1.1 Validity Test of the Walking Path Mode Conflict Sub-Criteria

Walking Path Mode Conflict parameter refers to conflict that occurs between pedestrians and other modes, such as motorized vehicles. It is crucial that the paths are accessible from all roads and are not excessively narrow. This parameter is comprised of three sub-criteria: Paths Specifically for Pedestrians, Management Evacuations, and Priority for Individuals with Disabilities. The validity test results conducted by five experts for these sub-criteria are presented in Table 1 below.

Table 1. Validation Test Result of the Walking Path Mode Conflict Sub-Criteria

Indicator	Aiken's Calculations (V)	Category
Paths specifically for pedetrians	0.90	Valid
Management evacuations	0.80	Valid
Priority for Individuals with Disabilities	0.80	Valid

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Based on the calculations presented in Table 1, it can be observed that each of the sub-criteria under the Walking Path Mode Conflict parameter falls within the "Valid" category

3.1.2 Validity Test of the Availability of Walking Paths Sub-Criteria

Availability of Walking Paths parameter refers to the need, availability and condition of walking paths. Path requirements can be seen from their effective width. Routes must be provided in areas with a high population and connected to shelters. Meanwhile, the physical condition of the pedestrian path can be seen from the care and maintenance of the pedestrian path. The sub-criteria of this parameter consist of six, namely Lane Width, Track Surface, Pavement Material, Lane Height, Drainage, and Connectivity to Shelters. The following results of the validity test by five experts can be seen in Table 2 below.

Table 2. Validation Test Result of the Availability of Walking Paths Sub-Criteria

Indicator	Aiken's Calculations (V)	Category
Lane width	0.80	Valid
Track surface	0.80	Valid
Pavement material	0.80	Valid
Lane height	0.80	Valid
Drainage	0.85	Valid
Connectivity to shelter	0.85	Valid

Based on the calculations presented in Table 2, it can be observed that each of the sub-criteria under the Availability of Walking Paths parameter falls within the "Valid" category.

3.1.3 Validity Test of the Amenities Sub-Criteria

Amenities parameter refers to the availability of pedestrian facilities that provide comfort and convenient to the users. These facilities should fulfill the dual functions of pedestrian pathways as walking spaces and disaster evacuation routes. This parameter is composed of nine sub-criteria, namely Evacuation Maps, Evacuation Signs, Street Lights, Safety Fences, Shade Trees, Seat, Rubbish Bin, Bolard, and Disability Support. The results of the validity test conducted by five experts for these sub-criteria are presented in Table 3 below.

Table 3. Validation Test Result of the Availability of Amenities Sub-Criteria

Indicator	Aiken's Calculations (V)	Category
Evacuation maps	0.90	Valid
Evacuation signs	0.85	Valid
Street lights	1.00	Valid
Safety fences	0.70	Invalid
Shade trees	0.80	Valid
Seat	0.80	Valid
Rubbish bin	0.85	Valid
Bolard	0.80	Valid
Disability support	0.85	Valid

Based on the calculations presented in Table 3, it can be observed that eight of the nine sub-criteria fall within the "Valid" category, while one sub-criteria is deemed "Invalid".

3.1.4 Validity Test of the Obstruction Sub-Criteria

Obstruction parameter refers to the presence of impediments, either permanent or temporary, that could affect the effective width of pedestrian paths, thereby disturbing user comfort. It is essential for pedestrian evacuation routes to be free of obstacles, such as parking lots and street vendors along the route. This parameter is composed of three sub-criteria: Width of Obstacles, Height of Obstacles, and

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Number of Obstacles. The results of the validity test conducted by five experts for these sub-criteria are presented in Table 4 below.

Table 4. Validation Test Result of the Availability Obstructions Sub-Criteria

Indikator	Aiken's Calculations (V)	Category
Width of Obstacles	0.80	Valid
Height of Obstacles	0.80	Valid
Number of obstacle	0.80	Valid

Based on the calculations presented in Table 4, it can be observed that each of the sub-criteria under the Obstruction parameter falls within the "Valid" category.

According to Aiken, data is considered valid if the V value satisfies the criteria specified in the table "Table Values of Right Tail Probabilities (P) for Selected Values of The Validity Coefficient (V)" [17]. In this study, the number of raters was 5 individuals, and the number of categories was 5 categories, which implies that the V value should be ≥ 0.80 with a confidence level of 4%. Based on the data presented above, it can be concluded that there is one instance of invalid data in the Amenities variable, specifically the sub-criteria Safety Fence, which has a V value of 0.7.

3.2 Reliability Test

Reliability testing was conducted utilizing the Cronbach's Alpha method, facilitated by the Statistical Package for the Social Sciences (SPSS) software. The summary of the reliability test results is presented in Table 5 below.

Table 5. Reliability Test Result

Variabel	N of Items	Nilai Cronbach's Alpha	Category
Walking Path Moda Conflict	3	0.618	Satisfactory
Availability of Walking Path	6	0.938	Satisfactory
Amenities	8	0.908	Satisfactory
Obstruction	3	0.974	Satisfactory

Based on the reliability test conducted using the Cronbach's Alpha method utilizing the Statistical Package for the Social Sciences (SPSS) software, it can be concluded that the Cronbach's Alpha value exceeds 0.6. Therefore, the data for each variable is deemed reliable and falls within the satisfactory category [20].

After the two tests, a discussion of the sub-criteria for the parameters could be obtained [16], [21]. Each of the sub-criteria was determined following the tests. The sub-criteria support the parameters in the previous research. It can be shown in Table 6.

Table 6. Parameters and the Sub-Criteria for Evaucation Path of Pedestrian

Parameters	Sub-criteria	Percentage
Walking Path Moda Conflict	a. Paths specifically for pedetrians b. Management evacuations c. Priority for individuals with disabilities	25
Availability of Walking Path	a. Lane width b. Track surface c. Pavement material d. Lane height e. Drainage f. Connectivity to shelter	25
Amenities	a. Evacuation maps b. Evacuation signs c. Street lights d. Safety fences	25

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	e. Shade trees f. Seat g. Rubbish bin h. Bolard i. Disability support	
Obstruction	a. Width of obstacles b. Height of obstacles c. Number of obstacle	25

Table 6 previously described valid parameters and indicators from literature reviews and expert validation and reliability tests. The percentage scores displayed in Table 6 are a development of the percentage proportion from Leather et al [21]. Then, the scores (value) are matched to see the current condition of the existing pedestrian path if it is later used as an evacuation facility (Table 7) [22].

Table 7. Walkability value and description for evacuation

Walkability Value	Description
90-100	Walker's Paradise it can walk very freely during evacuation
70-89	Very Walkable It can walk freely during the evacuation
50-69	Somewhat Walkable It can walk quite freely during the evacuation
< 50	Not Walkable It is difficult to evacuate on foot

4. Conclusion

There are four parameters for designing pedestrian evacuation routes, those are Walking Path Mode Conflict, Availability of Walking Paths, Amenities, and Obstruction. Each parameter consists of several sub-criteria. Based on the calculations of validity and reliability for each sub-criterion, it can be concluded that one sub-criterion is invalid as a parameter for the design of evacuation-based pedestrian routes, namely the Safety Fences sub-criterion in the Amenities parameter, which has a V value of 0.7. This research has provided implications in the form of developing walkability indicators for urban areas that are prone to disasters, especially tsunamis. These indicators and parameters can be a guide in planning a city that is pedestrian-friendly and ready to face disaster challenges in the form of services for refugees to get to a safe place.

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