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Informal self-construction and seismic vulnerability: an approach based on citizen perception

Autoconstrucción informal y vulnerabilidad sísmica: una aproximación desde la percepción ciudadana

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Abstract

The purpose of the research was to determine citizens' perceptions of informal self-construction and its relationship to seismic vulnerability in housing. To this end, a basic methodology was used, with a quantitative approach, a non-experimental design, and within the scope of the hypothetical-deductive cross-sectional method. The population consisted of 5,000 people, from which a sample of 357 inhabitants of the hillside sector of Intiorko Hill, in the district of Ciudad Nueva, was selected. The survey technique was used, and a questionnaire was employed as the instrument. The results show that 43.4% of those surveyed consider themselves to have average knowledge of the problems caused by informal self-construction. Consequently, there was also evidence of a fair level of knowledge about the seismic vulnerability of homes. Statistical analysis yielded a value of p = 0.001, with a Spearman's Rho of 0.469, indicating a moderate positive relationship between the variables. It is concluded that, from the public's perspective, informal self-construction is moderately positively related to the seismic vulnerability of homes. Therefore, it is essential to promote knowledge about the quality of construction and the structural characteristics of homes in order to mitigate the risks posed by high-intensity seismic events.

Keywords: citizenship, informal self-construction, seismic vulnerability.

Resumen

La investigación tuvo como finalidad determinar la percepción ciudadana sobre la autoconstrucción informal y su relación con la vulnerabilidad sísmica en las viviendas. Para ello, se empleó una metodología básica, con enfoque cuantitativo, diseño no experimental y bajo los alcances del método hipotético-deductivo con corte transversal. La población estuvo conformada por 5000 personas, de las cuales se seleccionó una muestra de 357 habitantes del sector ladera del cerro Intiorko, en el distrito de Ciudad Nueva. Se utilizó la técnica de la encuesta y como instrumento el cuestionario. Los resultados muestran que el 43,4 % de los encuestados considera tener un conocimiento regular sobre las problemáticas que genera la autoconstrucción informal. De manera consecuente, también se evidenció un nivel regular de conocimiento sobre la vulnerabilidad sísmica de las viviendas. El análisis estadístico arrojó un valor de p = 0,001, con un Rho de Spearman de 0,469, lo que indica una relación positiva moderada entre las variables. Se concluye que, desde la percepción ciudadana, la autoconstrucción informal se relaciona de manera positiva moderada con la vulnerabilidad sísmica en viviendas. Por ello, resulta fundamental promover el conocimiento sobre la calidad de las construcciones y las características estructurales de las viviendas, a fin de mitigar los riesgos ante la ocurrencia de eventos sísmicos de gran intensidad.

Palabras clave: ciudadanía, autoconstrucción informal, vulnerabilidad sísmica.

Introduction

At the international level, earthquakes have demonstrated a high destructive capacity, making seismic vulnerability of housing one of the primary concerns in the construction sector. This aspect is essential for buildings, as it allows for the identification of the need for structural reinforcements. In this regard, Yildizlar et al. (2018) indicate that unreinforced masonry buildings are highly vulnerable to seismic hazards and account for a significant percentage of the losses caused by earthquakes. For instance, in Istanbul, Turkey, a city with a high seismic risk, an assessment of 20,000 masonry buildings revealed that 40% required reinforcement, with the majority being residential structures.

Additionally, there is the issue of constructions that do not adhere to seismic-resistant criteria, which increases the risk for both occupants and the functionality of the urban system. Gazzani (2019) emphasizes that the damage incurred in various school buildings following the Central Italy earthquake in 2016 demonstrated that reinforced concrete structures exhibited significant damage, including the collapse of walls and ceilings. These findings prompted the development of national and regional programs and activities aimed at mitigating seismic risk in public buildings.

In the case of Peru, the situation is not dissimilar to what has been noted. Sulca and Delgadillo (2022) estimate that, in the event of an earthquake with a return period of 475 years, of the 2,078 housing units evaluated in the city of Ayacucho, 61% would suffer moderate to severe damage, with some potentially collapsing. These results are associated with deficiencies in structural configuration and the quality of materials used, creating an alarming scenario. In response, authorities and the public must enhance awareness regarding the seismic vulnerability of housing to mitigate risks arising from seismic events.

In Lima, a city located in a high seismic threat zone, a significant portion of housing has been constructed informally, without technical oversight or compliance with seismic design standards. Sifuentes (2022) warns that Lima is susceptible to an earthquake with a magnitude of 8.8, recalling that the last major earthquake occurred in 1746.

Similarly, in Tacna, a highly seismic city, the same issues are evident. Cartagena (2024) notes that in one district of this city, 40.1% of housing is built with reinforced concrete, masonry, or other similar materials; 36.2% are constructed with lightweight noble material, and 23.7% are prefabricated. However, the majority were built without regulatory criteria, exacerbating their vulnerability to earthquakes.

In this context, the central issue arises: What is the relationship between informal self-construction and seismic vulnerability in housing? The objective of the research was to determine this relationship from the perspective of citizens residing on the slopes of Cerro Intiorko, in the Ciudad Nueva district (Tacna), an area considered highly vulnerable to a significant earthquake (Sin Fronteras, 2024).

Regarding previous studies, Ramírez and Ferreira (2024) assessed the seismic vulnerability of masonry buildings using the Vulnerability Index method. The study, conducted in Atlixco and Morelos (Mexico), considered both quantitative and qualitative parameters to calculate indices and damage curves, concluding that the buildings exhibited a high level of vulnerability and required priority attention.

In Venezuela, Herrera et al. (2016) analyzed framed reinforced concrete residential buildings in Barquisimeto, a city located in the fifth zone of the seismic hazard map. Through static and dynamic analyses and

three-dimensional modeling, they concluded that these infrastructures exhibited moderate damage, noting that torsional stress decreases as building height increases.

In Spain, Serrano and Temes (2015) studied seismic vulnerability in residential buildings in the Valencian Community, an area with seismic intensities exceeding 7 degrees. Using the vulnerability index method and creating maps, they found that the average vulnerability value A was 33%, while categories B and C predominated. These findings enabled the proposal of isoseismic maps to guide prevention and risk management strategies.

Furthermore, Castro et al. (2024) identified the most recurrent seismic risk factors in housing in Rímac (Lima). Through a visual inspection of 403 buildings, they found that 89.3% lacked seismic joints between adjoining constructions, 59.8% exhibited unevenness in the slabs, and 60.3% used low-quality bricks in load-bearing walls.

Similarly, Sáenz and Santana (2023) assessed the seismic vulnerability of the administrative building of the National University of the Center of Peru using fragility curves applied to a structural model in ETABS. The results indicated that, in the North-South direction, there was an 84.62% probability of complete damage and a 14.50% probability of severe damage; while in the East-West direction, the probability of complete damage reached 82.34%, and the probability of severe damage was 16.26%. They concluded that the building exhibited greater vulnerability in the North-South direction.

From a theoretical framework, informal self-construction is defined as the process of building housing without the intervention of specialized professionals, without assessing technical aspects of the construction field (Castillo et al., 2023). Seismic vulnerability, on the other hand, is understood as the degree of susceptibility of a housing unit to suffer damage in the event of a high-intensity earthquake, with potential consequences in terms of loss of human lives and material resources (Garces, 2017; Arteaga, 2016).

Methodology

The research was classified as basic, as its purpose was to expand knowledge related to the studied variables (Nicomedes, 2017). A quantitative approach was adopted (Haro et al., 2024), since numerical scales were employed for data collection, allowing for precise measurement of participants' responses. Additionally, a non-experimental design was utilized (Calle, 2023), as there was no manipulation of the variables or subjects, but rather an inquiry process within the context in which the issue manifests.

Regarding the method, the hypothetical-deductive approach was used (Palmero, 2020), as the research started from previously formulated premises and hypotheses, which were later contrasted with empirical data. The study was conducted at a relational level, aiming to establish the correlation between the variables of informal self-construction and seismic vulnerability. Finally, the design was cross-sectional (Manterola et al., 2023), as data were collected at a single point in time.

The study population was defined as the set of subjects sharing similar characteristics within a specific territory (López, 2004). In this case, it comprised the residents of the slopes of Cerro Intiorko, an area considered to be at high seismic risk, located in the Ciudad Nueva district, province of Tacna, with an approximate population of 5,000 people (Sin Fronteras, 2024).

Using the formula for determining a finite sample, it was established that the research would be conducted with 357 individuals residing in the mentioned area. Inclusion criteria were limited to adults representing a family unit. Exclusion criteria ruled out the participation of minors and duplicate individuals from the same household.

For data collection, the survey technique was employed, using a structured questionnaire as the instrument. This questionnaire underwent a validation process through expert judgment, involving three specialists who provided favorable ratings. Subsequently, an internal consistency test was applied, resulting in a Cronbach's alpha of 0.814 for the informal self-construction variable and 0.834 for the seismic vulnerability variable. According to the interpretation by George and Mallery (2003), both results fall within the “good” range, ensuring the reliability of the instrument.

Operationalization of variables

- **Informal self-construction**

  Dimension: Construction quality → Indicators: technical advice, labor, and use of materials.

  Dimension: Housing characteristics → Indicators: state of conservation, construction process, and technical controls.

- **Seismic vulnerability**

  Dimension: Structural vulnerability → Indicators: height irregularities, plan irregularities, and structural configuration.

  Dimension: Non-structural vulnerability → Indicators: non-structural elements and housing safety.

Results

The research presents both descriptive and inferential results. Initially, the descriptive findings related to citizens' perceptions of informal self-construction and seismic vulnerability in housing are detailed.

Table 1.

Frequency between informal self-construction and seismic vulnerability

			Seismic vulnerability			
			Inefficient	**Regular**	**Efficient**	**Total**
Informal self-construction	Inadequate	Count	16	37	14	67
		%	4,5%	10,4%	3,9%	18,8%
	Regular	Count	18	155	41	214
		%	5,0%	43,4%	11,5%	59,9%
	Adequate	Count	3	17	56	76
		%	0,8%	4,8%	15,7%	21,3%
	Total	Count	37	209	111	357
		%	10,4%	58,5%	31,1%	100,0%

The collected information reveals that 43.4% of respondents consider themselves to have a regular understanding of the issues arising from informal self-construction, which is also reflected in a regular level of knowledge about seismic vulnerability. Additionally, 15.7% indicated having an adequate understanding of informal self-construction and an efficient level of knowledge about seismic vulnerability, while 11.5% reported having a regular understanding of the risks of self-construction but an efficient knowledge level regarding seismic vulnerability.

In general, the results show that 59.9% of respondents possess a regular level of knowledge concerning the consequences of informal self-construction, while 21.3% have an adequate level and 18.8% an inadequate level. Regarding seismic vulnerability, 58.5% report a regular level of knowledge, 31.1% an efficient level, and only 10.4% perceive it as inefficient.

Table 2.

Frequency between construction quality and seismic vulnerability

			Seismic vulnerability			
			Inefficient	**Regular**	**Efficient**	**Total**
Construction quality	Inadequate	Count	9	26	3	38
		%	2,5%	7,3%	0,8%	10,6%
	Regular	Count	22	135	38	195
		%	6,2%	37,8%	10,6%	54,6%
	Adequate	Count	6	48	70	124
		%	1,7%	13,4%	19,6%	34,7%
	Total	Count	37	209	111	357
		%	10,4%	58,5%	31,1%	100,0%

The aforementioned table indicates that 37.8% believe they have a regular understanding of aspects related to parameters for controlling construction quality, reflecting a regular level of knowledge regarding seismic vulnerability. This is followed by 19.6% who report having an adequate level of knowledge about construction quality and an efficient understanding of seismic vulnerability. Finally, 13.4% consider that while they have an adequate level of knowledge about controlling construction quality, they have a regular level of understanding of seismic vulnerability.

Overall, 54.6% indicate having regular notions regarding construction quality, followed by 34.7% who express having adequate knowledge, while only 10.6% consider their knowledge inadequate.

Furthermore, related to the descriptive results concerning citizens' perceptions of housing characteristics and seismic vulnerability, the following results are available:

Table 3.
Frequency between housing characteristics and seismic vulnerability

			Seismic vulnerability			
			Inefficient	Regular	Efficient	Total
Housing characteristics	Inadequate	Count	14	27	10	51
		%	3,9%	7,6%	2,8%	14,3%
	Regular	Count	19	153	53	225
		%	5,3%	42,9%	14,8%	63,0%
	Adequate	Count	4	29	48	81
		%	1,1%	8,1%	13,4%	22,7%
	Total	Count	37	209	111	357
		%	10,4%	58,5%	31,1%	100,0%

On the other hand, regarding the perception of housing characteristics and their relationship with seismic vulnerability, it was found that 42.9% have a regular understanding of both aspects. Additionally, 14.8% stated they have a regular understanding of housing characteristics while declaring an efficient level of knowledge about seismic vulnerability. Finally, 13.4% indicated having an adequate understanding of housing characteristics and an efficient level of understanding of seismic vulnerability. Overall, 63.0% reported a regular understanding of housing characteristics, 22.7% an adequate understanding, and 14.3% an inadequate understanding.

For the inferential results, the Kolmogorov-Smirnov normality test was applied, considering the sample size exceeding 50 participants. A significance level of 0.001 was obtained for both variables, leading to the use of the Spearman's Rho statistic.

The hypothesis testing revealed the following: informal self-construction maintains a positive and moderate relationship with seismic vulnerability ($p = 0.001$; $\rho = 0.469$).

Table 4.
Hypothesis testing

	V2: Seismic vulnerability	
	p-value	Spearman's Rho
V1: Informal self-construction	0,001	0,469
D1: Construction quality	0,001	0,476
D2: Housing characteristics	0,001	0,334

Similarly, construction quality showed a positive and moderate relationship with seismic vulnerability ($p = 0.001$; $\rho = 0.476$). Finally, housing characteristics presented a weak positive relationship with seismic vulnerability ($p = 0.001$; $\rho = 0.334$).

Discussion

The research demonstrated that informal self-construction, from citizens' perceptions, has a moderate positive relationship with seismic vulnerability. Additionally, 43.4% believe they possess a regular understanding of the issues associated with informal self-construction, which translates into a similarly regular level of understanding about the seismic vulnerability of housing.

These findings align with those of Ramírez and Ferreira (2024), who highlight the need for greater attention to homes exhibiting high levels of vulnerability. Similarly, they coincide with the observations of Herrera et al. (2016), who demonstrated that infrastructures tend to experience moderate damage and that torsional stress decreases as building height increases.

Conversely, the results contrast with those found by Paco (2023), as, although citizens report having regular knowledge of these variables, their research revealed that, in practice, the quality of concrete used in constructions does not meet the required minimum standards. This indicates non-compliance with the established standards set forth in the National Building Regulations. Along the same lines, Castro et al. (2024) concluded that despite recognizing the risks associated with seismic vulnerability, visual inspections of homes revealed significant

deficiencies, such as unevenness, lack of seismic joints, and low-quality load-bearing walls, which increase the risk in the event of an earthquake.

A critical analysis suggests the need to address the issue of informal self-construction and seismic vulnerability not only through technical engineering procedures but also from a social perspective. It is essential to raise public awareness regarding the importance of applying the parameters required in building regulations, to promote access to specialized technical advice, and to progressively reduce informality in housing construction. If these shortcomings are not addressed, the occurrence of a seismic event could result in significant material losses and, most importantly, loss of human lives.

Conclusions

It was identified that informal self-construction maintains a positive and moderate relationship with the seismic vulnerability of housing. This finding underscores the urgency of addressing the quality of construction processes and the characteristics of buildings as a preventive strategy against the occurrence of significant seismic events.

Moreover, construction quality emerges as a determining factor. The absence of technical advice, limited oversight during construction execution, and the use of inadequate materials significantly increase structural risk levels. In this sense, ensuring the participation of qualified professionals and promoting stricter regulations regarding the use of appropriate materials are essential measures to reduce seismic vulnerability.

On the other hand, while the physical characteristics of housing present a positive relationship, albeit of low intensity, with seismic vulnerability, they should not be underestimated. Technical oversight and periodic evaluation of the conservation status of buildings represent key actions that, together with strengthening construction quality, significantly contribute to reducing housing exposure to the effects of seismic events.

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