THERMAL COMFORT IN TEMPORARY SHELTERS USING THE POP-UP METHOD: CASE OF SAN MARTÍN, PERÚ

CONFORT TÉRMICO EN ALBERGUES TEMPORALES UTILIZANDO EL MÉTODO POP-UP: CASO DE SAN MARTÍN, PERÚ

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Abstract
The designs of temporary shelters are essential for the Sustainable Development Goals (SDGs), promoting accessible, protective, sustainable, and resilient urban developments. This applied research, with a mixed-method approach and a sequential explanatory design (DEXPLIS), surveyed 28 architects and interviewed five professionals from National Civil Defense Institute (INDECI), Regional Emergency Operations Center (COER), Local Emergency Operations Center (COEL), Peruvian General Volunteer Fire Department (CGBVP) and Peruvian National Police (PNP) to optimize the design of foldable shelters inspired by origami. The proposal was implemented through an interactive action-reflection cycle, evaluating actions, observing impacts, and making continuous adjustments. The results revealed a low correlation between the technical, spatial, and technological characteristics of the shelters and their ability to provide thermal comfort. Moreover, officials indicated that in Peru, installation speed and low cost are prioritized over thermal efficiency in temporary shelter design. This suggests that improving designs using the POP-UP method optimizes thermal conditions and enhances the well-being of affected individuals.

Keywords: thermal comfort, emerging structures, habitat, origami, temporary shelters, and housing

Resumen
Los diseños de refugios temporales son esenciales para los Objetivos de Desarrollo Sostenible (ODS), impulsando urbanizaciones accesibles, con protección, sustentables y resistentes. Esta investigación aplicada, con enfoque mixto y diseño explicativo secuencial (DEXPLIS), encuesto a 28 arquitectos y entrevisto a 5 profesionales de Instituto Nacional de Defensa Civil (INDECI), Centro de Operaciones de Emergencia Regional (COER), Centro de Operaciones de Emergencia Local (COEL), Cuerpo General de Bomberos Voluntarios del Perú (CGBVP) y Policía Nacional del Perú (PNP), para optimizar el diseño de refugios plegables inspirados en origami. La propuesta fue implementada mediante un ciclo interactivo de acción-reflexión, evaluando acciones, observando impactos y realizando ajustes continuos. Los resultados revelaron una baja correlación entre las características técnicas, espaciales y tecnológicas de los refugios y su capacidad para proporcionar confort térmico. Además, los funcionarios señalaron que, en Perú, se prioriza la rapidez de instalación y el bajo costo sobre la eficiencia térmica en el diseño de refugios temporales. Esto sugiere que mejorar los diseños mediante el método POP-UP optimiza las condiciones térmicas y el bienestar de las personas afectadas.

Palabras claves: confort térmico, estructuras emergentes, hábitat, origami, refugios temporales y vivienda

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INTRODUCTION

The displacement of people due to natural disasters (61%) and political conflicts (39%) has reached 28 million (De Castro et al., 2021). These populations are housed in Emerging Shelters (ES), where poor thermal and material conditions affect their physical and emotional health (Albadra et al., 2020). In China, disasters such as earthquakes and floods affect more than 100 million households annually, with 5.7 million internally displaced people (Li et al., 2024). Although the State responds effectively to these events, the impact of thermal comfort in ES is overlooked, despite its correlation with health risks and stress (Rajput and Thomas, 2024).

Although tents in humanitarian contexts do not guarantee comfort, Emerging Shelters (ES) have evolved since 2015 with deployable structural designs and adaptable kits. However, the standard family tents (SFT) and geodesic family tents (GFT) distributed by UNHCR still have deficiencies, such as excessive weight, low durability, and insufficient thermal insulation. Improvements are needed in habitability, structural autonomy, fire resistance, and production cost (Ullal et al., 2022).

Peru is highly vulnerable to climate change due to its geography, ecosystems, and climatic diversity, with annual temperatures varying by region. Climate changes, caused by pollution, deforestation, and fossil fuel consumption, lead to natural disasters and the loss of housing for more than 4 billion people, especially affecting rural areas (Tafur et al., 2024; Calle and Elzomor, 2024). To mitigate these impacts, INDECI, under Law No. 29664 and in coordination with the COE, manages shelters and provides hygiene and cleaning kits (Arana, 2023).

Spontaneous family camps are vulnerable to climate changes, damaging their materials and affecting living conditions. Tents, although easy to transport and set up, provide poor internal conditions depending on the climatic zone (Fosas et al., 2020). In San Martín, shelters are managed by the regional COE, but high temperatures (33.3 °C) and heavy rainfall (156.2 mm/month) affect their functionality. Additionally, the materials trap heat and humidity, leading to dissatisfaction with thermal comfort perception (Campos, 2020).

The research seeks to answer six key questions: Does the POP-UP design method for origami-inspired folding shelters optimize thermal comfort conditions in emergency shelters? How do the materials and construction techniques used in the shelters affect their thermal stability and user comfort? What impact does the orientation and ventilation of the shelters have on the thermal comfort of the occupants? To what extent does the temperature regulation inside the shelter meet the needs of the affected population, both during the day and at night? How does the design of the folding shelters contribute to improve air circulation, humidity control and the overall comfort of the users? Finally, what are the perceptions of INDECI, COER, COEL, CGBVP, and PNP officials, as well as users, regarding the thermal performance of shelters designed using the POP-UP method?

The results will enable INDECI and COEs to choose shelters suitable for hot climates (+25 °C), improving the physical and psychological well-being of displaced people. The study will examine the impact of material and morphology on the thermal performance of tents within their structural limitations. The study theoretically contributes to the Pop-Up architectural method, based on Origami, for designing deployable shelters in the Peruvian jungle. Additionally, it aims to validate and consolidate its reliability, establishing a framework for future studies on TC perception in these shelters.

DEVELOPMENT

To understand the phenomena caused by the analyzed categories, various scientific sources were investigated in indexed repositories such as Mylove, ScienceDirect, Elsevier, and Scopus. It has been identified that the thermal performance of Standard Family Shelters (SFS) and other humanitarian shelters varies depending on design and materials, influencing thermal transmittance (U-value) and fabric reflectivity to adapt to extreme climatic conditions (Xu et al., 2020).

The performance of the material and the social context of using tents in cold climates suggest that innovations such as additional insulation should be combined with complementary measures such as bedding and active heating (Hosseini et al., 2021). Experimental tests in different locations have enabled the development of simulation models, demonstrating that modeling the tent fabric with glazing properties improves the accuracy of permeability and transmittance in SFS (Hosseini et al., 2020). Simulations of shelters in the Azraq refugee camp in Jordan have also been developed, highlighting the value of these methods for evidence-based decision-making. Thermal comfort evaluations have shown that the identified ranges underestimate the temperatures at which occupants actually feel comfortable (Ullal et al., 2022), and it has been found that standard measurements are not suitable for humanitarian shelters, as occupants have reported comfort at temperatures outside the SFS range (Casagrande et al., 2021).

Studies on deployable shelters in tropical climates suggest that thermal comfort and indoor air quality can be improved with larger window and opening ratios relative to walls. However, the impact of fuel use inside the shelter affects health, causing respiratory problems, coughing, and eye irritation. The use of ethanol stoves, such as CleanCook, has been proposed to mitigate these effects (Albadra et al., 2020).

Spatial mapping of thermal comfort and air quality (SMTC-AQ) helps determine optimal opening proportions to improve refugee well-being (Matthey et al., 2022). However, recent studies indicate that shelters in camps still do not effectively mitigate extreme climates (Pezzica et al., 2022), leading to dissatisfaction, health problems, and even mortality. In northern Jordan, summer thermal conditions were the residents' second major concern after security and were considered more important than privacy or design flexibility (Matthey et al., 2022). While there is no perfect solution, the need to improve thermal comfort in emergency shelters should not be ignored (Moran et al., 2021).

In Peru, an Origami-based shelter has been developed, whose feasibility was validated by engineering and architecture experts. Its purpose is to provide rapidly assembled emergency housing to ensure victims' safety while their damaged homes are rehabilitated.

The Sphere Project (2018) states that an adequate shelter must provide sufficient living space, thermal comfort, and protection from the weather (Lazar and Chithra, 2020). However, there are no precise requirements for an optimal thermal environment (Obyn et al., 2015). Tents have been identified as effective emergency solutions due to their ease of transportation, distribution, and assembly without requiring specialized skills (Crawford et al., 2005). Shelters can range from simple tarps supported by branches to more robust insulated aluminum or concrete structures (Albadra et al., 2017).

Thermal comfort is achieved when occupants can maintain adequate temperatures with minimal energy expenditure. It has been demonstrated that in warm and dry climates, occupants can feel comfortable at higher temperatures if relative humidity is low (Ismail et al., 2020). Failing to address thermal comfort can lead to occupant dissatisfaction. While studies on shelters exist, most prioritize rapid implementation, planning, and materials without fully considering the impact of extreme climates (Lee et al., 2022).

The proposed solution is based on the Pop-Up architectural method to improve thermal comfort in post-disaster emergency shelters. Inspired by Origami, this flexible design allows spaces to be customized according to occupants' needs (Rian et al., 2008). Its folding system follows scissor and pop-up principles, where a pre-folded card unfolds upon opening, automatically forming the structure with a 90-degree opening angle (Ahmed et al., 2020).

The sliding system, composed of stacked panels, allows for a smooth and stable expansion of space. In folding language, the notations used include L for fold lines, R for opening angle, and N for the total number of openings (Rian et al., 2008).

Origami has inspired applications in various scientific and engineering disciplines (Thrall & Quaglia, 2014). In military operations and humanitarian aid, deployable shelters are essential due to their easy transport and rapid installation (Quaglia et al., 2014).

METHODOLOGY

The study developed the type of applied research considering all the existing knowledge about the Pop-Up method for the design of deployable shelters, based on the in-depth study of Origami. This approach seeks to solve thermal comfort problems in emergency shelters after natural events. The results obtained were evaluated by experts in order to develop possible architectural designs for natural disaster situations in the regions of Peru, addressing the practical objective of this study (OECD, 2018) .

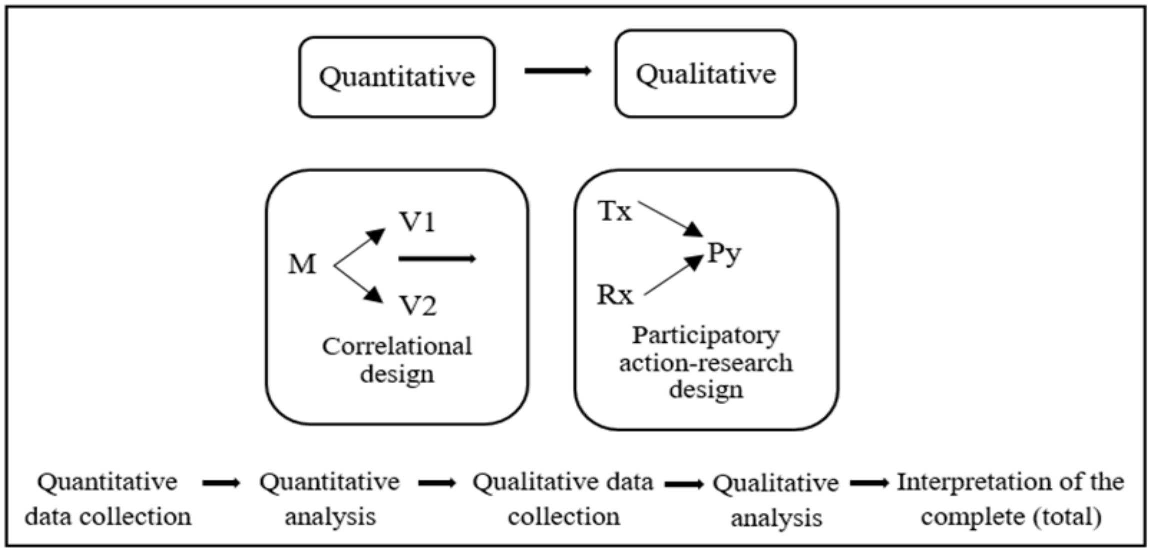
The approach was mixed, with 75% quantitative and 25% qualitative, combining and providing a set of systematic and critical processes for this study; where the quantitative will involve the collection and analysis of the behavior of the variables in order to design the structure of the shelter, and the qualitative will focus on the deep and holistic understanding of the architectural phenomena related to deployable shelters. This was achieved by analyzing the experiences, perceptions, and cultural and social contexts of professionals involved in post-natural disaster processes. This approach has been useful to investigate how deployable shelter designs can benefit people affected by natural disasters.

Likewise, it was guided by a sequential explanatory design (DEXPLIS), it will be characterized by a first stage, where quantitative data was investigated and analyzed in order to design the structure and guidelines of a new foldable shelter design, followed by another where they were collected and evaluated for the shelter design in a qualitative way, causing the initial quantitative result of a pre-coded observation sheet to inform the collection of qualitative data, validating the foldable design through a semi-structured interview, since it focused on solving problems related to the designs of emerging shelters managed by the National Civil Defense Institute (INDECI). This was achieved through a continuous cycle of planning, observation, action and reflection by the experts.

In this process, interviews were integrated (Quantitative: technique: survey, instrument: questionnaire), Qualitative: technique: interview, instruments: semi-structured in-depth interview guide) that allowed participants to express their opinions and experiences, encouraging their active participation and providing feedback. This helped to reflect on what has worked and what needed adjustments. The proposal was implemented in an action-reflection cycle, in which actions are carried out, their impact is observed and the results are reflected on, continuously improving according to the feedback and findings obtained throughout the process (Hernández et al., 2018). Finally, the discoveries from both stages were integrated into the interpretation and preparation of the study report.

The research was outlined as follows:

Figure 1



Note: This design is adapted from the DEXPLIS model by Hernández and Mendoza (2018) and adjusted according to the needs of the researcher in 2024.

Tx Design theories for deployable shelters, based on the study of Origami O: Questionnaire for building the shelter structure Rx: Diagnosis of the reality of emerging shelters and thermal comfort in Post-Natural Events according to semi-structured interviews Pv: Proposal for a validated Pop-Up Architectural model.

For the first QUAN procedure, 28 architects who have designed or have knowledge of the design of shelters, including single-family and family-type deployable shelters, were considered as the population and sample. In addition, Architectural Pop-Up models were included and they must have worked on structural designs considered emergency architecture, with a minimum experience of 7 years to ensure informed opinions based on real life experience and technical operational knowledge in the context of temporary and emergency shelter design. Architects whose specialty is landscape or management, and who have 6 years of experience, were excluded.

On the other hand, for the QUAL procedure, it involved selecting an ideal space to obtain data on the chosen problem, so it was extremely essential to consider the study scenario (Yapo, 2023) Where, the chosen study scenario belonged to the functions in the face of a danger or natural disaster event monitored by the National Institute of Civil Defense - INDECI, where it made decisions in coordination with the Regional Emergency Operations Center -

COER and the Local Emergency Operations Center - COEL and first response entities such as the General Volunteer Fire Corps - CGBVP and the National Police of Peru, described in the Manual for the Management and Coordination of Shelters in Peru and based on Law No. 29664.

Within the present investigation, the participants played a leading role in the improvement of the aspects addressed, their opinions being totally relevant in the constitution of the study categories (Orue, 2021) . Following the aforementioned assertions, 5 professionals who have prestige, experience and vast knowledge in the delivery and design of emerging shelters were assessed for the work; considering two architects with a specialty in shelter design, a public official from INDECI, COER, COEL, CGBVP and PNP, who through their experience were able to improve the design of deployable shelters, based on the Origami study, in addition, 5 people who were affected by a natural phenomenon were interviewed and the Peruvian State provided them with a provisional shelter, which served to measure its thermal performance.

In addition, for the CUAN procedure, the survey and observation were applied as a technique and the questionnaire and observation form as an instrument that allowed proposing an architectural structural design following the Pop-Up model, respecting the guidelines and specifications of the Manual for the Management and Coordination of Shelters in Peru (MGCAP) and based on Law No. 29664.

After having designed the prototype, the QUAL study categories were analyzed, where the interview was chosen as the data collection technique, since through it precise and personalized information was obtained regarding the efficiency and effectiveness of the thermal comfort of the shelter; Management and Coordination of Shelters in Peru. In relation to the instrument that was applied to each participant, the interview guide was proposed, which consisted of 17 questions, 8 questions directed to the architects and 9 questions directed to the affected people, appropriately framed with the objectives and delimited subcategories, where said prototype will be validated.

This study contemplated the procedure, starting with the search, processing and analysis of concepts and definitions based on the categories to be investigated, carried out through the diagnosis of the problem addressed, using indexed scientific journals. Subsequently, with the information collected, the categorization matrix was prepared and validated by experts, where the objectives for each category and subcategory were detailed, among other criteria, these methodological strategies contribute to the verifiability and credibility of the proposal, following the principles of qualitative rigor. Then, the interview guide was designed, which consisted of 17 semi-structured questions, based on the objectives and subcategories of the research;

it was filled out and validated by the required professionals.

In addition, in the development of the study, the principles necessary to apply and maintain scientific rigor were considered in order to ensure the quality of the research. According to Martinez and March (2015), validity in qualitative research requires a paradigmatic approach different from that of quantitative methods. The objective of qualitative instruments was to capture what emerges from the study phenomenon. Therefore, the validity of both interview guides for qualitative variables was assessed through internal validity, designing an instrument based on theoretical concepts and categories, and external validity, minimizing researcher bias and ensuring that the research can be replicated by others.

In addition, a strong emphasis was placed on the rigor of the study through the reliability of the qualitative instruments, ensuring the minimization of researcher biases and inclinations. The method used was also carefully detailed so that others can use it as a guide and achieve similar results. As Mertens (2010) indicates, the strategy to demonstrate reliability includes the detailed explanation of the method used, so that other researchers with the same objective can review the reviews and obtain results comparable to those of the original researcher.

Taking into account the data analysis method, the choice was made to use the Atlas-ti version 9 qualitative data analysis software. This software is versatile and is applied in various areas where it is sought to give validity, credibility and veracity to research that has a qualitative approach. It is especially useful when it is necessary to analyze large volumes of information, allowing the data to be systematically reduced and categorized in order to finally theorize and explain the reality investigated. (Fernandez et al., 2014) . To achieve this, the relationships between the categories, subcategories and indicators were taken into account throughout the execution process. The analysis was carried out through an open and axial classification, to then categorize and interpret the responses of the participants in each interview, as well as those of all the interviews as a whole through content analysis that helped to code the textual data to identify frequencies and co-occurrences of words or phrases.

The study was subject to different ethical aspects, where it was ensured that the shelters provide private spaces for people, especially for intimate and family activities. It provided facilities and resources that guarantee a minimum acceptable quality of life, including access to clean water, sanitation, food, and medical care. It informed each participant about the purpose of the research, the methods used, the duration, and how their information will be handled. It guaranteed that personal and sensitive information is treated with strict confidentiality and stored securely. It was transparent about the objectives, procedures, and possible uses of the results of the research. And it guided the research to generate clear benefits for the participants or the field of study. It avoided any action that could cause harm to the participants or the communities.

RESULT AND DISCUSSIONS

The study was located in Peru, Department and Region of San Martin, city of Tarapoto, located in the jungle region, in the northeastern part of Peru, within the Huallaga river basin, is highly vulnerable to natural disasters due to its geographical and geological location. The highest risk areas include the Amazon regions (affected by gradual increases, floods and river overflows). This analysis focuses on the recent period (2022-2024), marked by a greater frequency of phenomena such as the El Niño Phenomenon, which has generated extreme weather events. Recent emergencies have highlighted the lack of adequate temporary infrastructure.

Where a large part of the population affected by adverse events (natural disasters) belongs to vulnerable sectors, with incomes below the poverty line. These communities face challenges such as limited access to basic services, informal employment and housing built without technical standards. The state response, although immediate, often lacks long-term sustainable solutions.

Expected results:

For its part, the first objective sought to design a 3D prototype based on an emerging module to serve communities affected by disasters. The following ideal results are projected: The Module with the POP-UP method can be assembled and be operational within 24 to 72 hours after a natural disaster. Its resistance to seismic aftershocks, strong winds and other climatic phenomena is optimal. Spaces that will offer thermal comfort, adequate ventilation, natural lighting and separation between common and private use areas. Affordable costs to allow mass manufacturing and distribution in affected areas. And they have a minimum useful life of 6 months to 1 year, while relevant solutions are developed. They have the ability to adjust to diverse climatic and geographical conditions. Adherence to national and international safety and habitability standards, such as those defined in Ministerial Resolution No. 055-2021-VIVIENDA and the National Disaster Risk Management System (SINAGERD) see figures 2 to 5.

In various case studies and documented experiences in Peru and other countries, the observed results show challenges and discrepancies compared to the established objectives: Although some modules were assembled on schedule, the logistics for their transport and distribution delayed their implementation on several occasions. In situations of prolonged disasters or severe weather conditions, several modules showed failures in structural resistance, especially in roofs and joints exposed to wind and rain.

Lack of thermal insulation, resulting in extreme temperatures inside the modules. Insufficient natural lighting and ventilation, affecting the health and comfort of the occupants. Small spaces that made functional use difficult for large families. In certain cases, the cost per unit exceeded the projected value, due to the increase in prices for materials and transport. Some modules show premature deterioration in less than 6 months, especially in materials not treated against humidity.

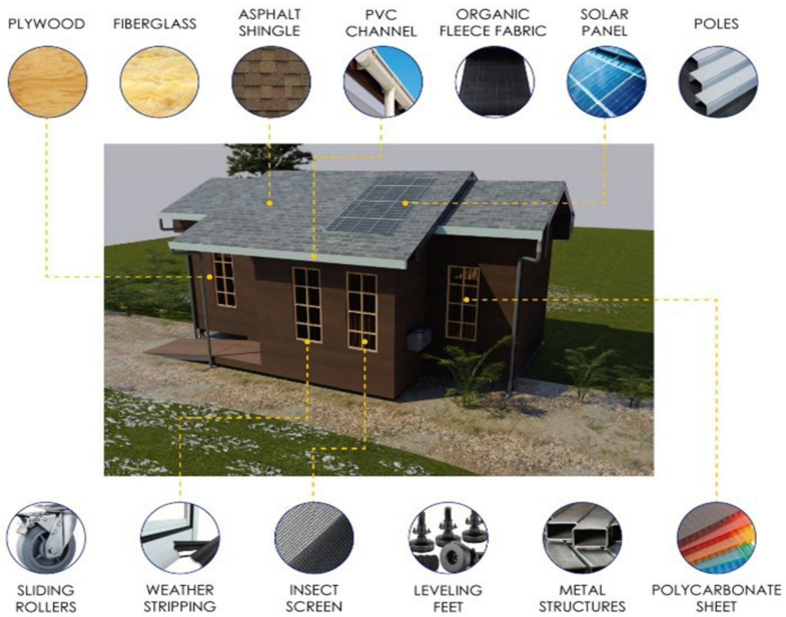
The pop-up module provided by Peru has deficiencies in thermal comfort, ventilation, natural lighting and space distribution, affecting the quality of life of users. The materials used tend to deteriorate quickly in extreme weather conditions, such as heavy rain, extreme heat or cold. The distribution and assembly of the modules is slow due to the centralization of production and the lack of infrastructure in remote areas.

Many designs are not suited to the specificities of the affected regions, which reduces their effectiveness. Although affordability is sought, mass production fails to reduce costs due to the use of imported or specialized materials.

In their identification of the factors influencing the situation, coastal, Andean and Amazonian regions of Peru present specific challenges of temperature, humidity and access. Affected communities often have low incomes, limiting their ability to contribute to temporary solutions. Complying with established standards (such as Ministerial Resolution No. 055-2021-VIVIENDA) can increase costs and complexity. Lack of adequate local materials and dependence on external inputs hinder production. Rural and isolated areas face greater difficulties in receiving aid.

Therefore, according to the Electronic System of State Contracting (SEACE), the budgets for shelters observed in the public contracting registry range from US$320 to US$670, as in the case of the acquisition of family tents for flood zones such as Piura, Cusco or Amazonas in the last 5 years. The POP-UP proposal integrates thermal improvements with low breathability materials, passive cross ventilation, light structure without increasing costs. Compared to current models, with an average thermal efficiency of 46%, this model could achieve better energy efficiency without compromising affordability. Also, the modular collapsible design allows for proper mass production, which could significantly reduce costs by 15-20% compared to other temporary shelters that require manual assembly.

Figure 2

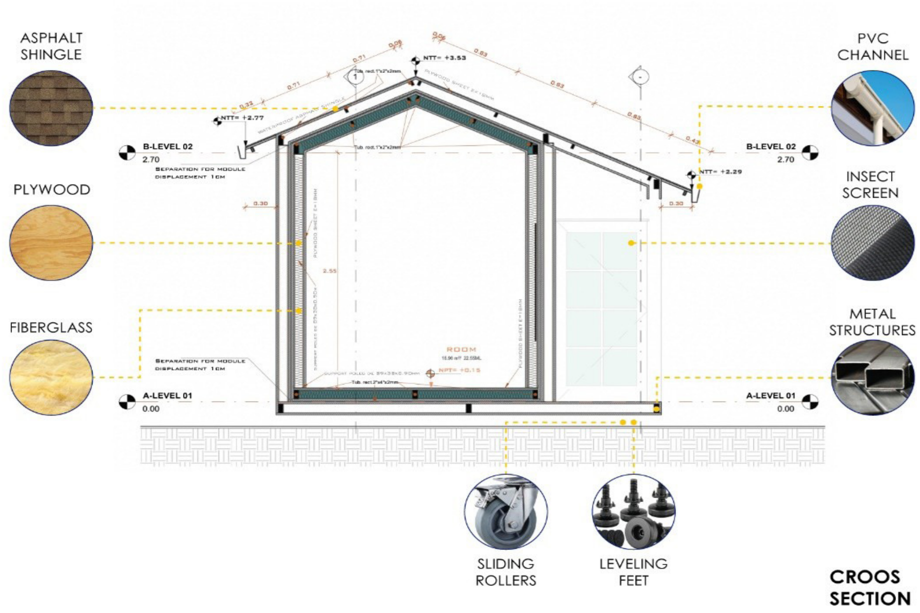


Note: Materialization, exterior view of the architectural Pop-Up Emerging Module. Exterior 3D rendering, 2024

Figure 3

Note: Materialization structural view of the architectural Pop-Up Emerging Module. Exterior 3D rendering, 2024

Figure 4



Note: Cross section with materiality indications of the architectural Pop-Up Emerging Module. Exterior 3D rendering, 2024

Figure 5

Note: Final proposal of the architectural Pop-Up Emerging Module. Exterior 3D rendering, 2024

To answer the remaining five objectives, a sequential explanatory design (DEXPLIS) was used, with the participation of 28 architects who were surveyed and 5 professionals interviewed with extensive experience in the delivery and design of emergency shelters for the interviews. These professionals belonged to entities such as INDECI, COER, COEL, CGBVP and PNP, and thanks to their experience they contributed to improving the design of folding shelters based on the study of origami. In addition, 5 interviewees who had been affected by some natural phenomenon also participated, and their opinions helped to formulate the hypotheses raised.

Wilks normality test was selected as the most appropriate statistic for this study. Since 28 professionals with experience in emergency shelter structures participated, this test was applied to all the variables and dimensions analyzed. The result showed a significance of 0.000, lower than the p-value of 0.05, indicating that the opinions of the participants do not follow a normal distribution. Therefore, it was decided to use the non-parametric Spearman's Rho test. Table 1,

Table 1. Normality tests between variables and their own dimensions

Variable / Dimensions	Shapiro-Wilk		
	Statistical	gl	Next.
Pop-up shelters	,809	28	,000
Technical characteristics	,783	28	,000
Spatial aspect	,590	28	,000
Technological aspects	,809	28	,000
Thermal Comfort	,745	28	,000
Construction systems	,795	28	,000
Materiality of the shelter	,804	28	,000
Thermal performance	,793	28	,000

Note: Collected from the questionnaire to professionals, IBM SPSS version 27, 2024.

For the finding of the second specific objective, it was revealed that although a low positive correlation was evidenced between thermal comfort and the design of emergent shelters in post- natural events in San Martín 2024, its bilateral significance of 0.158, higher than the p level of 0.05, indicating that they are not statistically significant, since the technical characteristics of the design obtained an average score, due to the low accessibility and affordability of INDECI temporary shelters. Although the design of these shelters complies with the principles of temporality and functionality required by Law No. 29664, this regulation does not adapt well to all regions of Peru. Meanwhile, the construction system of these shelters was also rated as regular, due to its insecurity in its designs, it is not possible to determine whether it maximizes sunlight during the day or minimizes exposure to cold wind. They are skeptical about the properties of the materials used, which supposedly offer insulation to maintain comfortable interior temperatures, and are unsure about the flammability of such materials, affecting the perception of safety and durability in the event of natural phenomena.

These results coincide with the study of (Xu et al., 2020) corroborating that the thermal performance and the Standard Family Shelters as well as the result obtained both in cold and hot climatic conditions, showed changing results in the effective practical design, where their thermal performance must be improved, specifically in the reduced thermal transmittance of the fabric (U value) and greater reflectivity of the fabric to cope with cold and hot conditions respectively, on the other hand, in the Peruvian design, Law No. 29664 must be considered. For its part, it held contradictory results since the study (Hosseini et al., 2021) as a solution for accommodating displaced population (DPaddressed cold climate states, where the standard shelters delivered by INDECI, COER, COEL, CGBVP, do not tend to adjust to all the microclimates of Peru. The tents are suitable for cold regions such as Cuzco, Áncash, and Ayacucho, but they require innovations such as additional insulation, along with bedding and active heating.

Table 2. Correlation between emergent shelters and thermal comfort

Spearman's Rho test	Pop-up shelters	Thermal Comfort
Correlation coefficient	1,000	0.274
Next (bilateral)	.	0.158
N	43	43

Note: The correlation is significant at the 0.05 level (two-tailed). Collected from practitioner questionnaire, IBM SPSS version 27, 2024.

Meanwhile, the findings of the third specific objective showed that no dimension of the emerging shelter is related to thermal comfort in Post-Natural Events, San Martín 2024, because the technical characteristics, spatial aspect and technological aspects of the shelter showed a very low and low positive correlation in thermal comfort and their significance levels were (0.591, 0.449 and 0.152) respectively, higher than the p level of 0.05, indicating that they are not statistically significant, because the technological aspects received an average rating of 46%, given that the shelters include elements to resist solar radiation, in accordance with the guidelines of the Ministry of Housing, Construction and Sanitation (MVCS). On the other hand, its spatial design was valued as 71% efficient, since it meets the surface, height and configuration requirements of the internal environments established by the MVCS.

The research by Hosseini et al. (2020) identified deficiencies in emergency shelters and proposed relocating the Azraq camp in Jordan, developing a model adaptable to cold and tropical climates. It was found that modeling tent fabric with glazing properties improves the reproduction of air permeability and transmittance, aiding decision-making in countries like Peru. Studies by Ullal et al. (2022) and Casagrande et al. (2021) similarly concluded that standard thermal comfort measures in humanitarian shelters are inadequate, as refugees feel comfortable at temperatures outside the conventional range.

Table 3. Correlations between dimensions of emergent shelters and thermal comfort

V1 Dimensions	Thermal Comfort		
	Correlation coefficient	Next (bilateral)	N
Technical characteristics	0.106	0.591	
Spatial aspect	0.149	0.449	28
Technological aspects	0.278	0.152	

Note: The correlation is significant at the 0.05 level (two-tailed). Collected from practitioner questionnaire, IBM SPSS version 27, 2024.

Also, the finding of the fourth specific objective presented that no dimension of thermal comfort is related to the emergent shelter in Post-Natural Events, San Martín 2024, since its thermal performance, its materiality and constructive systems of thermal comfort showed a low and null positive correlation with the emergent shelter, its significance levels were (0.280; 0.176 and 0.991) respectively, higher than the p level of 0.05, indicating they are not statistically significant, because the shelters located in areas with temperatures above 23 ° C, such as in the Peruvian jungle, experts believe that they lack materials with a high insulation capacity and resistance to humidity, which makes it difficult to reduce heat transfer between the interior and the exterior, increasing its thermal conductivity and making it difficult to keep the shelter cool. Although most shelters have windows and mesh panels to regulate heat and humidity, indoor air circulation is still insufficient in some regions. In general, the thermal performance of these shelters only provides partial insulation from external cold or heat, and experts recommend their use in similar situations depending on the region.

Although the results of the study were not favorable, the research by (Rajput and Thomas, 2024) reveals how the construction of emergent shelters in tropical climates with moderate outdoor temperatures and lower relative humidity, thermal comfort and indoor air quality can be improved by implementing a higher window-to-wall and opening-to-wall ratio. On the other hand, the Standard shelters provided by the State of Peru do not adjust to the climatic conditions, since according to its geography, more than 12 climates are identified in the country. For their part, (Rajput and Thomas, 2024) highlights the importance of the window-to-wall ratio, since it is a more relevant criterion to improve thermal comfort and a better design of the opening-to-wall ratio is crucial to improve indoor air quality in spaces with natural ventilation, where it is necessary to design shelters according to the standards of the average microclimates that are evident in each region of the country. However, little work has been done to investigate thermal comfort in the field of temporary shelters, as in Peru, where the impact of cooking fuels in the Shimelba camp is also affected when cooking inside the shelter by 69%, using charcoal (42%), firewood (31%) and kerosene (15%), directly affecting health such as coughing, headaches, eye irritation, constant phlegm and difficulty breathing, proposing ethanol stoves known as CleanCook in homes for their contingency (Albadra et al., 2020) meaning that activities including cooking, sleeping and socializing all take place in the same space. Therefore, indoor air quality can be poor, resulting in estimated 20,000 displaced people dying prematurely every year. Very few studies considered the issue and all within one country. This paper describes the first comprehensive study investigating air quality in shelters by looking at Volatile Organic Compounds (VOCs.

Table 4. Correlations between thermal comfort dimensions and emergent shelters

V2 Dimensions	Pop-up shelters		
	Correlation coefficient	Next (bilateral)	N
Construction systems	0.002	0.991	28
Materiality of the shelter	0.263	0.176	
Thermal performance	0.211	0.280	

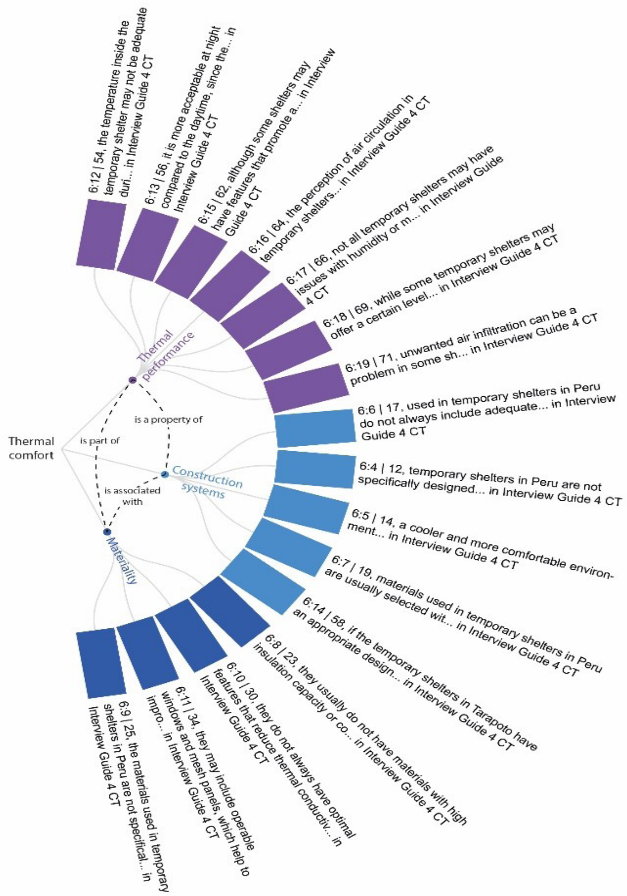
Note: The correlation is significant at the 0.05 level (two-tailed). Collected from practitioner questionnaire, IBM SPSS version 27, 2024.

Finally, the finding of the fifth specific objective revealed, according to the perception of The design of temporary shelters in Peru prioritizes installation speed and low cost over thermal efficiency, affecting occupant comfort (INDECI, COER, COEL, CGBVP, and PNP). These shelters are not optimized to capture sunlight or reduce exposure to cold winds, and their materials lack proper insulation, causing overheating during the day and rapid cooling at night. Incorporating better insulating materials and ventilation could improve thermal comfort.

Victims in San Martín report that excessive heat inside the shelters and inadequate ventilation cause discomfort, while in cities such as Tarapoto, Juanjuí, and Bellavista, ventilation is insufficient for the hot climate. Air circulation and humidity issues vary depending on the shelter design (Ren et al., 2023). No shelter solution is perfect, but this should not be an excuse to ignore thermal comfort in extreme environments (Moran et al., 2021). Additionally, in refugee camps, inadequate thermal conditions affect quality of life and may lead to health problems or even mortality. In Jordan, summer temperatures were reported as the second most significant concern for residents, after safety (Matthey et al., 2022).

In Peru, Calle and Elzomor (2024) propose Origami-based shelters, validated by engineering and architecture experts, to provide rapidly assembled emergency housing. Tang et al. (2022) highlight that Spatial Mapping of Thermal Comfort and Air Quality (SMTC-AQ) determines optimal opening proportions in shelters to improve comfort. However, shelters in camps are still far from effectively mitigating extreme climates (Pezzica et al., 2022).

Figure 6



Note: Opinions of Architects and Disaster Victims in the Face of a Natural Event. Compiled from interviews with architects and victims, ATLAS. Ti version 9, 2024.

CONCLUSIONS

The research sought to analyze improving thermal comfort in RE using the POP-PU method, in San Martín, Peru, where the Module with the POP-UP method can be assembled and operational within 24 to 72 hours after a natural disaster. It has a significant difference between the RE design provided by the Peruvian government, in addition to optimal resistance to seismic aftershocks, strong winds and other climatic phenomena. Spaces offered by the model can improve thermal comfort, adequate ventilation, natural lighting and separation between common and private use areas. Affordable costs to allow mass manufacturing and distribution in affected areas. And it has a minimum useful life of 6 months to 1 year, while relevant solutions are developed. They have the ability to adjust to diverse climatic and geographical conditions. Adherence to national and international safety and habitability standards, such as those defined in RM No. 055-2021-VIVIENDA and (SINAGERD).

The conventional design regarding the RE provided by Peru obtained a low positive correlation between thermal comfort and the design of emerging shelters. Since, by improving the design of the RE provided by the Peruvian State could contribute to optimizing the thermal conditions and the well-being of those affected. It should be noted that no dimension of the RE is related to the CT, because the technical characteristics, spatial aspect and technology of the shelter showed a very low positive correlation and low in thermal comfort. Indicating the urgent need to improve the technical characteristics and the spatial aspect of the RE. Just as no dimension of the CT is related to the RE, since its thermal performance, its materiality and construction systems of thermal comfort showed a low and null positive correlation before the emerging shelter, indicating its urgent need to improve the construction systems and the performance of thermal comfort to also optimize the design.

The design of temporary shelters in Peru prioritizes assembly and low costs over thermal efficiency. Although the shelters have ventilation, it is not adequate in regions where there is low temperature, so it is a priority to improve the design to ensure better thermal comfort strategies for the occupants. The materials used lack advanced insulation properties, which makes it difficult to regulate internal temperature and affects the comfort of occupants. The lack of thermal inertia in these materials also causes overheating during the day and rapid cooling at night, increasing thermal discomfort. Including materials with better insulating properties, as well as operable windows and mesh panels, could significantly improve thermal comfort, providing a more stable and comfortable interior environment. And the opinion of victims in San Martín, the thermal performance of the emergency shelters is insufficient, especially during the day, when the materials overheat, generating discomfort. Lack of thermal insulation and limited ventilation contribute to a hot indoor environment. Although nighttime temperatures are often more pleasant, comfort depends on the design of the shelter, the materials used, and the specific climatic conditions of each location. In cities such as Tarapoto, Juanjuí, and Bellavista, the hot climate means that available ventilation is not sufficient. Air circulation and problems with humidity or mold vary depending on shelter design and location, and many shelters do not offer the necessary insulation to ensure comfort in the face of climatic variations in the region.

From the results obtained, the deficiency in the insulation capacity of current shelters was evidenced, so that materials with high thermal inertia could improve performance in extreme contexts. Therefore, adobe and lightweight concrete, which are materials that stand out for their ability to store heat during the day and release it at night, become a viable option for these climates such as the Peruvian jungle or highlands, where there are findings that are efficient in thermal comfort and accessible in cost.

RECOMMENDATION

It is recommended that INDECI implement new shelter models using high thermal inertia materials, such as adobe or lightweight concrete, to improve thermal stability. These materials showed potential for minimizing thermal fluctuations in environments with high temperatures during the day and cold at night. The use of economical and durable insulating materials, such as fiberglass or laminated bamboo, would enhance thermal comfort and facilitate installation in temporary shelters.

Likewise, the use of qualitative analysis tools allows organizing the categories and volumes of information in a systematic way, favoring a rigorous and transparent process for the identification, validity and credibility of the results, thus, in extreme climates, incorporating materials like compressed earth blocks or lightweight cement would help retain heat on cold nights and reduce overheating during the day. A modular design would allow shelters to adapt to different environments and facilitate transport and assembly in emergencies.

The use of light-colored roofs and walls or reflective materials would minimize heat absorption, while the addition of shaded areas and wind barriers would improve thermal comfort. Additionally, it is recommended to integrate advanced insulation materials and orient shelters to maximize sunlight capture in cold climates and reduce exposure in warm areas.

Finally, the installation of strategically placed windows and mesh panels would promote cross ventilation, helping to regulate internal temperature and improve air circulation.

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