



## Organized self-help housing in Pachacútec, Peru: Training women's groups in earthquake resistant housing construction

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World Journal of Engineering and Technology Research, 2022, 02(01), 018–030

Publication history: Received on 12 August 2022; revised on 18 September 2022; accepted on 20 September 2022

Article DOI: <https://doi.org/10.53346/wjetr.2022.2.1.0037>

### Abstract

Ciudad Pachacútec is a suburban development scheme north of Lima, where deficiencies were great from the start. The main problem was the population's safety in the sandy and arid urban landscapes, which are prone to earthquakes. The main objective of the NGO Estrategia - together with the municipality of Ventanilla - was to provide the self-builders with technical and organizational knowledge to improve housing quality. The NGO has developed effective programs to support women's groups in building earthquake-resistant houses. The result was that building materials were produced locally by households that were also trained in construction technology. Some families working together in groups, were able to start businesses. The developed model for earthquake resistant housing in New Pachacútec is effective and can be used in other areas alongside Peru's Pacific coast, that are prone to earthquakes.

**Keywords:** Earthquake-resistant housing; (Assisted) Self-help housing; Organized self-construction; Sites-and-Services; Pachacútec; Lima urban development

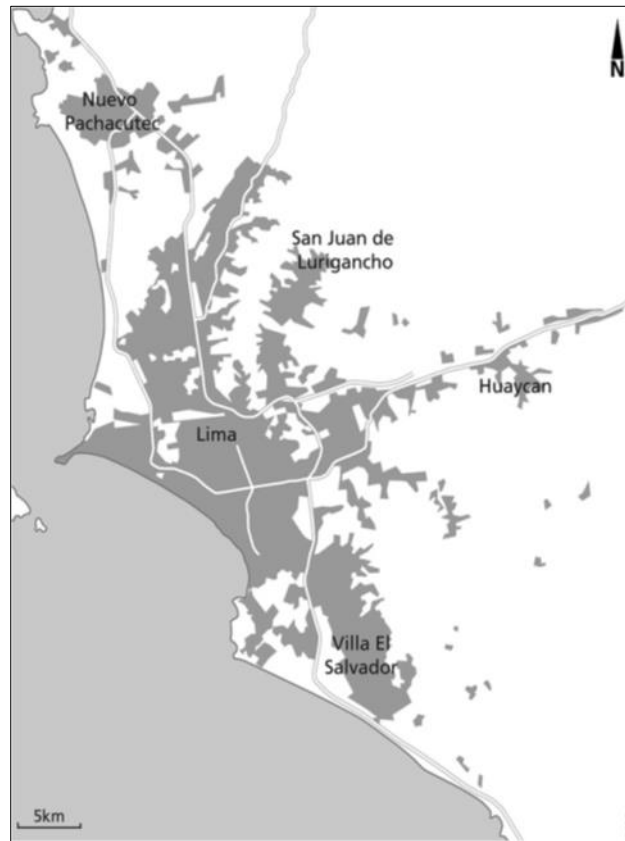
### 1. Introduction

Ciudad Pachacútec is part of the development axis to the north of Lima, which runs along the Pacific coast and is known as the 'Northern Cone' of the Lima metropolis. It is also part of the municipality of Ventanilla and the province of Callao. By the 1960s, Ventanilla had been designated as a satellite city of Lima and Callao, about 20 km north of the capital. The vision with this satellite city was twofold: firstly, to reduce the demographic pressure on the central city and, secondly, to create a new economic urban core with houses and jobs for the growing population. Initially, Ventanilla was known as a dormitory city where inhabitants had jobs in the central city. Later, the municipality of Ventanilla developed two zones of economic growth where residents could also find employment. Starting in 1988, the first inhabitants settled in the remote desert area north of Ventanilla, a district designated for the development of the 'Pachacútec City Special Project' on publicly owned land. The first phase of this project went slowly. At one point, about half of the plots had been officially sold to families and the other half were illegally occupied. This has led to civil unrest and disharmony between different groups. This is just one of the dilemmas that play a role in distributing cheap plots to low-income households.

The primary goal of this article is to clarify how the sub-urbanization of Pachacútec took place in this remote area, where housing quality is at stake. The difficult living conditions of the residents in this dry and sandy landscape is addressed. The article also describes the application of earthquake-resistant building technologies and explores possibilities to apply the developed practice on a larger scale. The conclusions are relevant to a large percentage of the Peruvian population living in the coastal zone. This zone, where houses are often self-built, is prone to earthquakes. In Pachacútec, the occurrence of self-built housing combined with the risks posed by earthquakes have made the residents extremely

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vulnerable. Figure 1 shows the spatial structure of Lima with in the north New Pachacútec, which is part of greater Pachacútec.



Source: Fernandez-Maldonado and Bredenoord

**Figure 1** Lima with Pachacútec in the north

## 2. Research, objectives, questions, structure

The suburban development in the north of metropolitan Lima has received little attention in Peru, certainly compared to the earlier development of Villa el Salvador (VES) in the south of Lima. The two areas are the same distance from the center of Lima: around 25 kilometers. Moreover, earthquakes pose a similar threat, as both locations are directly along the coast where undersea seismic activities can have negative consequences. The early Sites-and-Services project of VES is (internationally) seen as being consolidated, but Pachacútec is only halfway through the consolidation phase. The authors believe that the recommendations in this article with regard to improving housing quality in Pachacútec can also be applied elsewhere along the coast of Lima and in surrounding areas.

The NGO Estrategia has gained experience in Pachacútec, among other areas, with regard to involving residents in improving the housing quality in this large new suburban residential area of Lima. The authors have jointly, but each from a different perspective, looked at the need for earthquake-proof construction in Pachacútec. The first author has approached the problems of low housing quality and urban inequality within the residential area, and the difficulties posed by the sandy landscape, the problematic soil conditions, and the isolated location. The second author has approached the housing quality issue by analyzing the practical work carried out by the NGO Estrategia to create earthquake-resistant housing realized by groups of residents. Participants, most of whom were women, were trained in the production of building blocks and the construction of housing. The authors have drawn the conclusions outlined in this article based on the existing literature concerning the urban development of the area, the dangers of earthquakes, the soil types, and the self-construction of housing that occurs everywhere in the country. Internal documents of Estrategia were used too. Based on their research, the authors believe that organized and assisted self-construction – as described in this article – offers opportunities to improve housing quality. In this article, they aim to answer the following research questions:

- How can the residents' groups be involved in Pachacútec to contribute to the improvement of their own homes and living environments?
- What preconditions are needed to facilitate residents' groups in home improvements, specifically those involving the production of sustainable building materials and the self-construction of homes?
- What recommendations can be made with regard to the fulfillment of these preconditions in Peru?

The further structure of the article is as follows. Section 3 describes the background of the suburban growth of Pachacútec City, locally known as 'Ciudad Pachacútec', where self-construction of houses has been central for many years. Section 4 describes the growth of New Pachacútec starting around 2000, with its initial deficiencies, such as the lack of infrastructure, services and safety, while there is always the threat of an earthquake. Section 5 discusses the need for earthquake resistant building techniques. With the help of the NGO Estrategia, self-building families in Pachacútec can obtain technical assistance to build their own homes properly, and to make them earthquake resistant. In Section 6, the working method of Estrategia is explained. In Section 7, discusses two important issues, among them how to support self-builders. This leads to suggestions for further research. In section 8 the Conclusions are presented, with a recommendation for governmental support of residents' groups that are improving their self-built homes.

### 3. Pachacútec as a whole

New Pachacútec is an extension of Ciudad Pachacútec and was developed jointly from the year 2000 by the provincial governments of Lima and Callao, initially to solve problems with a large group of migrant families in Villa el Salvador (VES). There, families from some areas south of Lima attempted in 1999 to occupy land designated for agricultural use in VES. The national government decided in 2000 to move more than 7,000 families from VES to Ciudad Pachacútec, a distance of approximately 50 kilometers. This led to the second phase of Pachacútec's growth in 2001 and 2002 with a vast expansion in a northwesterly direction as the 'New Pachacútec Pilot Project' (PPNP). This project was managed in the early stages by a government project office, in order to be able to effectively help migrants from VES with land for housing. The government also launched the National Family and Community Health Training Program (PROFAM) which allowed for funding and implementation. The development involved several government organizations, including COFOPRI, the institution that issued land titles to families, and the Lima and Callao Development Corporation (CORDELICA). Initially, the project office, which was part of the Ministry of Housing, drew up the spatial plans and allocation for the PPNP. In 2004, the municipality of Ventanilla became involved in the management of Ciudad Pachacútec, including the PPNP.

The landscape of Ciudad Pachacútec is strongly influenced by its sandy hills. The area is divided into three sectors, see the map below: (1) the first formalized human settlements (in Spanish: Asentamientos Humanos Formalizados, shortly AHF) (eastern part), (2) Ciudad Pachacútec Special Project (central part), and (3) Nuevo Pachacútec Pilot Project (western part). These three sectors consist of 37, 60 and 36 settlements respectively with a total of approximately 45,689 plots. In addition, there is the extension of El Mirador. It is estimated that the population in Pachacútec is between 180,000 and 200,000 inhabitants. According to the Congress of the Republic, there were in 2015 around 174.000 inhabitants in the area of Pachacútec, while the foreseen number for 2030 is 244.000 inhabitants [1]. The number of inhabitants of Pachacútec varies somewhat in different sources. Alvino has made a compilation of Table 1. [2].

**Table 1** Combined number of inhabitants. Source: Sandoval

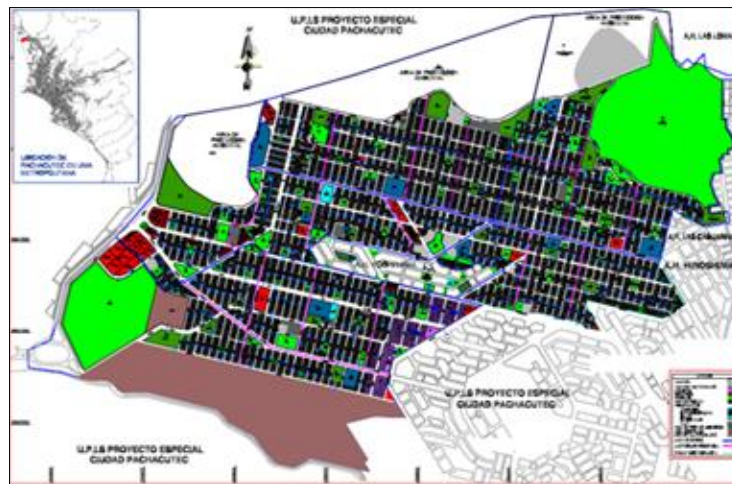
	Areas of Pachacútec	2017 (INEI) inhabitants	2022 Estimations of inhabitants
1	Sector 3 First formalized 'AHF'	26,000	31,500
2	PECP Special project	32,000	39,000
3	PPNP Pilot project	75,000	91,000
	Total	133,000	161,000

In Figure 2 an overview is given of the Municipality of Ventanilla, with Ciudad Pachacútec in the north-western part. Figure 3 shows the urban development scheme of New Pachacútec. The initial urban design was realized by the then governmental office of the pilot project of New Pachacútec (PPNP). Besides geographical information from the Municipality [3], the authors also consulted geo-information from the Regional Government of Callao [4].



Source: Municipalidad Distrital de Ventanilla

**Figure 2** Ventanilla with Ciudad Pachacútec



Source: Gobierno Regional de Callao

**Figure 3** New Pachacútec.

New Pachacútec, like Villa el Salvador (south of Lima) and Huaycán (east of Lima), was designed according to the principles of the 'Sites and Services' projects, which initially had minimal infrastructure and basic services for families who were given a plot. Firstly, 10,000 plots were realized for housing. In the initial phase many homes were built with wood and thatched mats. Building materials were offered locally by retailers. Some initial housing solutions of New Pachacútec are shown in Figure 4. Around 2002/2004 basic services in New Pachacútec were very limited; for example, drinking water was supplied by tanker trucks. Later, drinking water systems were installed with storage tanks on the hills, with networks of pipes and collective water taps in the streets. At the start, there were no sewage facilities available and residents had to dig latrines on their own plot. Access roads were not asphalted and residential streets were not paved. The electricity supply had just been started. Nowadays, shortcomings are still common. For example, many houses are of low quality and there is limited public security in the city. New Pachacútec has been divided into five sectors (A, B, C, D and E), each with an elected council. Each sector consists of neighborhood units with around 300 houses, each with its own board. Commercial activities and some services are concentrated in various commercial areas, as is shown in Figure 5.



Source: Bredenoord

**Figure 4** Initial housing solutions (2004)



Source (2022) Sánchez Hurtado

**Figure 5** Commercial area

Pachacútec was further expanded in 2006/2007 into an adjacent area known as 'El Mirador'. Around 1500 lots were sold to families. The plots came with core houses – modest start-up houses – which were then enlarged and improved by the residents. This land-for-housing project was developed in accordance with the government's then new housing finance policy, which made subsidies and loans possible.

The public fund Mi Vivienda made it possible for low-income groups to obtain soft loans or a mortgage. These options were also available to families in El Mirador [5]. The price of a core house in El Mirador was US\$ 4000 at that time (2009-2011). To be eligible for financing, a deposit of 10 percent from the families' own resources was required. If they met all requirements, the selected households could also receive a loan for building materials from the building materials bank 'BANMAT'. This public organization was established in 1989. First loans were granted in building materials. Since 2002 they provided access to housing finance to the poorest families. It is estimated that that until 2006, BANMAT had 540,000 borrowers. It had then the programs 'Casa Bonita' for home improvement and 'Mi Casita' for home construction on an own plot [6]. The BANMAT closed granting new loans just after 2010, and is in liquidation.

The allocation of plots with a core house to households was carried out by private banks. Most families have extended their core house themselves. Therefore, self-construction remains the most important activity in this area. Some neighborhoods are organized as residential cooperatives. The El Mirador project is divided into five neighborhoods, which were realized in 2006/2007.

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#### **4. New Pachacútec's growth**

The development of New Pachacútec has boomed since its launch in 2000. In the early stages, the sand dunes of Pachacútec were still clearly visible. Now, New Pachacútec is occupied almost entirely with houses, many of them with a workshop. Individual home improvements are being implemented throughout the whole New Pachacútec area.

The main roads in the area are largely paved and the connections to the older parts of Pachacútec and Ventanilla are good. Southbound road connections leading to Lima are crucial in case large groups of residents have to be evacuated.

Public vegetation along roads is completely deficient. It is difficult to grow trees and shrubs in this dry area, due to the scarcity of water. Space has been reserved for neighborhood parks in areas where resident committees have control.

The regional government of Callao considers it convenient to create a separate municipality for Pachacútec and will decouple it administratively from the municipality of Ventanilla [1]. Greater Pachacútec could be managed more efficiently as a separate municipality, while the participation of the inhabitants would increase.

There is a great theoretical potential for growth of Ciudad Pachacútec because vertical development – a family can realize up to three floors – has not yet begun. This growth potential depends on economic development, local employment and the incomes of the self-building families. In this area you can find hills with slight to steep slopes on which houses are built; this requires good urban development and research on soil and subsurface stability. The landscape show houses in the sandy and slightly sloped landscape, see Figure 6. In most houses wooden facades were changed in walls with masonry. On steeper slopes, retaining walls must be built, which was done in El Mirador among others.



Source: Sánchez Hurtado

**Figure 6** Housing in the sand (2022)

In February 2016, the newspaper El Comercio reported new land occupations in desert areas in the vicinity of Pachacútec. The land was illegally divided into parcels by hundreds of men, women and children who wanted to occupy the area, according to the earlier method in Peru of obtaining free plots. They tried to claim land, while staying there in tents. They were sent away, but have returned. There was very little police oversight to enforce a ban. The situation shows that demand for cheap plots in this remote area remains high and that informal urbanization in Peru continues.

The Pachacútec area has considerable security risks. Theft is common in everyday life. Each family tries to secure their own home to the fullest extent. Other common forms of crime include drug trafficking, violent crime, youth gangs, and the illegal purchase and sale of plots. As a result, the sense of security of the inhabitants is low. Although police patrol major routes twice a day, residents have little confidence in the police. This has led to residents arming themselves and setting up watchdog groups. Safety within residential neighborhoods depends on residents' initiatives to secure neighborhoods. Insecurity is particularly a problem on the edges of New Pachacútec [7]. Accessibility by public transport is also declining there, especially at night. Some of these insecure situations are the result of the current growth phase. If the area becomes more developed in the future, security measures may show positive effects. Another aspect of the insecurity is that New Pachacútec is located in an area with high seismic risk. Thus, there must be an emphasis on earthquake-resistant construction and an emergency plan to evacuate the residents if needed. In some cases traditional masonry is still usual, as a replacement for the thatched mats of the in the initial stage. In Figure 7 it is shown that traditional masonry is not always earthquake-resistant. The bricks are fired ones and not locally produced. The mortar used did not contain sufficient cement, which makes a collapse possible in case of an earthquake.

The municipality of Ventanilla is positive about the development of the whole city of Pachacútec over the last 15 years (according to a notice on the municipality's website). Fifty thousand families now have a better quality of life thanks to the construction of important public works and services. In 2015, as many as 200,000 people were already living in Pachacútec, which was made possible by the construction of roads, public lighting, retaining walls, drinking water facilities, sewerage, schools, health posts, civil security posts, sports and recreational parks, and internal connections. However, not all services were realized completely.



Source : Bredenoord

**Figure 7** Traditional masonry (2008)

Initially, economic development of Pachacútec began with small scale trade, mainly through shops and workshops. Now several commercial centers are present. The actual Productive Development program of Ventanilla shows the following services: productive fair, pig farming, artisanal fishing, and productive workshops [8]. In 2015, Pachacútec saw significant economic development, in part thanks to the coordination of cluster and neighborhood leaders with local government. Several civil society and humanitarian organizations have provided assistance to the neediest residents in this vast area of Ventanilla. The NGOs World Vision, Coprodeli, Plan Internacional, Unicef, Propoli, Alternativa, Estrategia and others, together with institutions and public services and the municipality of Ventanilla, have worked on the development of Pachacútec. In 2017, the drinking water and sewerage systems of the whole of Pachacútec special project were put into operation as was reported by the Ministry of Housing, Building and Sanitation. These works should lead to the full functioning of crucial basic services throughout the urban area. To improve the drinking water and sewerage system, a water treatment plant was planned for Pachacútec third phase, which also required considerable investments [9]. Therefore, the government continues to make significant investments in order to further consolidate the former sites-and-services projects. After the completion of all necessary public works and public facilities, Pachacútec can continue to grow through individual densification.

Many houses are still in the early stages, but there are also finished houses to be found. Only a few homes have a second floor. The building materials used for the walls and separation walls were mainly braided reed panels and wood in the early stages from 2000 onwards. Timber materials were reused at a later stage. Building materials such as bricks, concrete blocks, and reinforced concrete structures are also used, especially if a family has saved enough money. In building structures, a skeleton is constructed with columns on concrete floors. Between the columns, bricks or building blocks are laid. Facades are often plastered and painted. In the initial construction, corrugated iron ('zinc') is almost always used as a roof. The quality of the architecture is variable, but generally low. It is clearly visible that poverty still is present everywhere. The residential area is very extensive with the many settlements in which residential functions are in full development.

## 5. Construction of earthquake-proof housing in Pachacútec

In Ciudad Pachacútec and Nuevo Pachacútec, the dangers of earthquakes that create uncertainties for residents must be taken into account. On the maps of risks of earthquakes and tsunamis in the municipality of Ventanilla, prepared by CENEPRED (see below), the western part of Ciudad Pachacútec has the indication 'high risk', while the eastern part is indicated as 'medium risk'. However, all of Pachacútec is vulnerable in the event of a high-magnitude earthquake [10]. There is no risk of tsunamis in Ciudad Pachacútec; the urban area is too high above the level of the Pacific. A nearby area along the coast is vulnerable to tsunamis. The El Mirador area has steep slopes, sometimes of more than 20 per cent [5] which is shown in Figure 8. The figure shows also the core houses built around 2011. These were prefabricated houses of concrete. Retaining walls had to be built here, as well as in some other areas of Pachacútec, including the settlements (A.H.) Los Girasoles [11].

Due to the presence of the sandy area, in the event of an earthquake, seismic waves can be strengthened and houses with adobe (called also loam bricks or mudbricks) and 'quincha' structures (a structure made of wooden panels with braided reed and covered with mud) will likely collapse. The subsoil is classified as sand to mud sand, which can be up to a few meters deep. The compactness of this material, being superficially loose, increases with depth according to CENEPRED, the National Center for Disaster Risk Estimation, Prevention and Reduction [12]. Consequently, soil research is needed to determine how homes can best be built in a specific neighborhood. Attention must be paid to good foundations and reinforced concrete structures, see Figure 9. Building safe houses requires that self-building families

must be provided with information and technical assistance. Herewith, governmental organizations such as CENEPRED and regional and local authorities must all play their crucial roles.



Source: Klaver

**Figure 8** View on El Mirador with core houses (2010)



Source: Sánchez Hurtado

**Figure 9** A basic house under construction

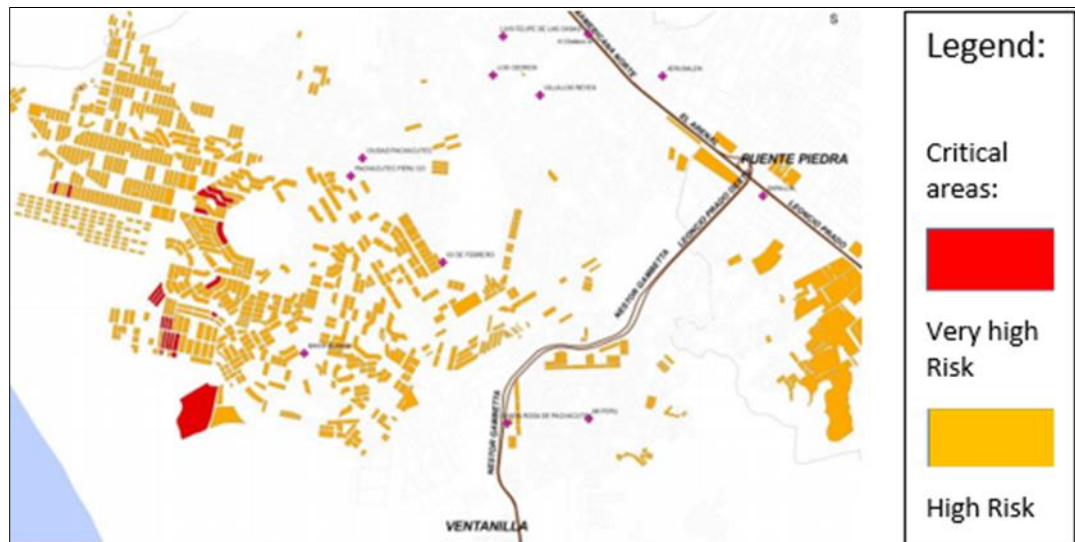
Building safe houses requires technical expertise, but the application of durable building materials such as concrete materials and the contribution of professional construction workers is costly – seen from the interests of the low-income households. Because homes are usually built informally, i.e., without planning permission and without sufficient construction supervision, many homes are probably not earthquake resistant.

In recent decades there have been no devastating earthquakes along the coast of Lima. As a result, the population may not be sufficiently alert to the danger of earthquakes. To keep the population alert, the local government needs to develop a new strategy on how to bring construction knowledge to the inhabitants, to make a good policy for housing safety, and finally to communicate adequately with the local communities. Of course, the local government is busy with these things and normally makes a security plan. Residents must be informed and trained. Evacuation routes and strategies must be implemented. The protection of the local population is undoubtedly a challenge. The map of critical areas shows the indication 'high risk', while some parts have the indication 'very high risk'. See figure 10. This is the case in large parts of Ciudad Pachacútec including the whole of New Pachacútec.

The NGO Estrategia already has a lot of experience in providing information and technical assistance to women's groups in Pachacútec who work together to produce durable building materials to build their own houses and simultaneously develop economic activities (production and sale). Estrategia, in collaboration with 'Arc Peace Peru', has helped improve the human settlement 'A.H. Los Olivos de la Paz', in Pachacútec Sector E, and the settlement 'A.H. Costa Azul'. The first pilot housing program in these settlements concerned the construction of 10 houses with 40 m<sup>2</sup> of living space each, as well as a community dining space. The training process for both women and men, took place during the construction process of one year. Around 160 individuals were trained. Two groups of 40 people were trained intensively over 15 days. Later, groups of 60 people were trained. The housing units were built to demonstrate to the population that they would be able to build 'dignified houses' that could be expanded later with an extra story. A second housing project was started with 15 houses in Costa Azul. These were built with concrete blocks produced by residents who were trained in advance. A school for children aged 3, 4 and 5 was also built. The latter was done by women in two construction groups.



Around 240 people gained the knowledge necessary to produce concrete blocks, concrete domes for the roofs and concrete beams. Other groups organized the transport of building materials to the construction sites. Several heads of households became producers of building materials and now have small businesses. Incidentally, individual households benefitted from the purchase of building materials, which were delivered at their plots. Nowadays, more than 800 people are making their own concrete bricks and another 800 are improving their homes individually. As a result of these projects, many residents have become, for example, carpenters, painters or electricians and were able to find a job in construction.



Source: CENEPRED

**Figure 10** Map of critical areas: Ventanilla and Puente Piedra

In Pachacútec, Estrategia strived for integral area improvement, in collaboration with SENCICO, the National Housing Research Institution of Peru, the municipality of Ventanilla and other local partners. Proposals were made by the NGOs to further stimulate the production of sustainable materials for low-cost housing construction to benefit vulnerable groups. Unfortunately, this was not followed up on a national scale. But, in Pachacútec, the people who were already trained continued to produce the building materials for the construction of earthquake resistant housing. Unfortunately, the government's Techo Propio (Own Roof) financing program could not be further disseminated [13] [14]. As a consequence, the earthquake-proof housing projects led by women's groups stopped in Pachacútec. At that time (2003/2004) the United Nations Special Rapporteur on social housing Architect Miloon Kothari had recommended the Government to review the aid programs to orient them towards the poorest segment of the population, and to expand its assistance for upgrading self-built housing. Furthermore, he stated that the Government should consider other alternative approaches that have resulted in job-creation, greater cost-saving and increased participation by the beneficiaries, particularly poor women, such as those projects realized in Pachacútec [15].

For a long time, the structural quality of many homes in Pachacútec remained low, as elsewhere in the country. That's disappointing because years ago there were already opportunities to scale up the earthquake-proof construction [16]. In 2018, Estrategia was able to make further use of subsidies from Techo Propio and Sitio Propio (Own Land) to develop technologies for earthquake-resistant housing. These are current governmental finance programs to make housing accessible to low-income households.

### 5.1. Changes in housing legislation in Peru.

Until 2021 the Constitution of Peru does not yet point to housing as a human right. Fortunately, the social housing law that already was approved by Congress in 2021, points out access to decent housing mainly to vulnerable sectors and clearly mentions the important position of women.

The NGO's 'Mujeres Unidas para un Pueblo Mejor' and 'Estrategia' have in 2022 made public their National Housing Program proposals to make sure that future housing policy allows low-income households to participate in self-construction housing programs with technical assistance.

Several articles in the social housing law - Law 31313 – ‘Ley de Desarrollo Urbano Sostenible’ – should be modified in order to ensure access to decent housing to the poorest parts of population [17]. When this law takes effect, the construction of earthquake-resistant housing can be restarted for the poor, and hopefully brought to scale.

## 6. Estrategia’s working method

The aid organization Estrategia helps low-income people living in underdeveloped neighborhoods in Lima and its surroundings with home renovations and the construction of community facilities such as schools. Another core focus is on income-generating activities for families. The empowerment of women's groups is vital in reaching important development goals. This is underlined by (inter)national aid organizations, among them Habitat International Coalition (HIC) [18], and the NGO DESCO (DESCO: Center for Studies and Promotion of Development, is a leading NGO that has been working in Peru on the improvement of housing conditions for 55 years) with HIC in Peru [19]. Offering professional support to groups through the participation of professionals in training and knowledge transference is necessary, e.g., by social promoters, architects, sociologists, lawyers and engineers. Many local 'development poles' have already sprung up with participants who can carry out housing projects. The NGO primarily serves the women's groups, and it focuses on gender equality. Nevertheless, it always seeks to invite men from households to participate in training and economic activities.

The housing policy of Estrategia always provides decent housing with basic services which are earthquake resistant in the sandy areas with unstable soil and unevenness in level, which is the case in Pachacútec. There, houses are normally built with concrete blocks and other structures with pozzolanic cement, which makes them also resistant to the salinity of the terrains and the proximity of the ocean.



Source: Sánchez Hurtado

**Figure 11** Concrete structures for houses to be earthquake resistant

Migrant populations to Lima come normally from rural coastal areas, mountains and the jungle where community work for the construction of housing and public works have an family origin. As such the houses and small works In Pachacútec were also made with mutual help.

Estrategia collaborates among others with "Mujeres Unidas para un Pueblo Mejor", a Peruvian social movement, and with the NGO MISEREOR from Germany. Furthermore, it cooperates with the relevant government agencies. Housing programs that were carried out in the districts of Surco and Chorrillos in southern Lima were income-generating projects. There were, for example, horticulture programs, and food production programs in which families learned to produce yogurt, jam, fruit nectar, cheese, etc.

At the beginning of 2000, Estrategia began working to reduce the risks of natural disasters, first in Surco and Chorrillos and somewhat later in Pachacútec. This was done in collaboration with the National Housing Research Institute (ININVI; National Institute for Housing Research and Standardization, which is related to SENCICO; National Training Service for the Construction Industry) as well as with the local governments. It continued to support the population in the province of Chincha south of Lima after the earthquake of August 15, 2007. The women and men of the area were trained in the production of concrete blocks and beams, according to the production and income generating system as was described for Pachacútec.

Houses realized in Pachacútec are often plastered. Facades of houses are always colored. Most houses have only one floor, but a second floor is possible in the future. The houses are prepared for that. All houses can be expanded individually over time, horizontally and/or vertically. Concrete structures for houses are shown in four steps, from foundations, foundations and columns, to construction of walls and roofs (see Figure 11); all to build the houses earthquake resistant. Roofs are often covered with metal sheets.

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## 7. Discussion

The 'Estrategia model', as described in this article, was already developed between 2000 and 2004. It was aimed at supporting self-builders, who could achieve a certain success through mutual cooperation. This model is based on, among other things, the principles of 'Assisted Self-help Housing' (A-SHH), which were described by Bredenoord and Van Lindert in 2010 [20] and 2014 [21]. The focus of Estrategia's assistance in Pachacútec was on the need to make homes earthquake-proof, given the risks posed by of earthquakes in this area. In the mentioned period, financial assistance from the central government in the form of a subsidy could also be used. Currently, the term 'Organized Self-Help Housing' (O-SHH) – as described by Arroyo (2013) - is also used, besides the term A-SHH. [22] The Estrategia model is very similar to O-SHH, especially with regard to mutual assistance within resident groups and the professional technical assistance. The big issue is how to apply the development model on a larger scale in suburban areas around Lima and elsewhere in Peru. Follow-up research could focus on this. This research could investigate the way in which public housing financing could be set up to support organized self-construction on a larger scale.

Another discussion matter concerns the use of the building materials in earthquake-resistant homes in Pachacútec. Due to the requirements for earthquake-resistant homes, cement and concrete are widely used, such as in foundations, columns and beams for frameworks, and also in hollow concrete blocks for walls. The use of concrete ensures that the houses are earthquake-resistant, and therefore are 'durable'. However, concrete is no longer seen worldwide as 'sustainable', as a result of carbon dioxide emissions in the production of cement, and because it is not circular. Moreover, high costs are a constraint for many households. The application of compressed stabilized earthen building blocks (CSEB) could be a solution, but that is not possible in Pachacútec due to the lack of clay. In other Peruvian regions, where construction with adobe is common, CSEB can be applied, as is shown by recent academic studies [23] [24]. Besides these, the 'Centro Tierra group' of the PUCP (leading University in Lima) studied compacted fiber blocks, wooden structures, and a hybrid form. These techniques have good behavior against earthquakes and are also suitable for bad soils for being lightweight [25]. Future research could determine whether it is possible to make use of these rather new technologies in housing in Pachacútec.

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## 8. Conclusion

The suburban development north of Lima that is concentrated in Ciudad Pachacútec has hardly received any international attention, in contrast to the extensive attention received by Villa el Salvador (VES), which previously went through a similar urban development process. Pachacútec is a self-built city that is not yet considered to be consolidated. It still faces several disadvantages, such as the isolated suburban location, the social insecurity and the lack of greenery, but the basic facilities are largely present. Hereafter is the response to the three research questions as formulated in Section 2.

The article describes roughly how the resident groups in Pachacútec were involved in the housing programs of a leading NGO, and as such, how they have contributed to house construction and the betterment of their living environments. The introduced development model paid attention to ensuring there were adequate group processes and increasing the professionalization of technical assistance. This has led to the construction of a large number of earthquake-resistant homes and the establishment of small-scale family businesses engaged in the production of, among other things, hollow concrete blocks and the sale of building materials to other families.

According to the authors' analyses, more attention should be paid to the general housing quality, including earthquake-resistant housing construction and the possibility of providing technical assistance to homeowners on a larger scale. NGOs with adequate housing programs can be involved, but government organizations (national, regional and local) must also play their specific roles. It has become clear that the national government in particular must fulfill important preconditions. In 2022, encouraging steps are being taken in Peru, such as the proposal for an improved housing law that included targeted financing options for housing construction and home improvements. If more collaborative groups of self-builders can be organized, better results can be achieved than with individual self-construction.

The construction method for housing through mutual assistance in Pachacútec has been tested in practice and can be replicated more widely. The government and local authorities could use this experience to give earthquake-resistant construction and home renovation a major boost across Peru. An important aspect of the training program for the construction of earthquake-resistant housing in and around Pachacútec – and elsewhere – is the significant participation of women's groups in housing construction and home improvements, as well as in community development. This is also seen elsewhere in Peru.

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## Compliance with ethical standards

### *Acknowledgments*

The authors thank persons who had crucial roles in the development of earthquake-resistant housing, among them architect Inés Rivera who supported the housing programs; and engineer Jose Raymondi, who settled the training programs. We also thank other professionals and volunteers who provided additional support.

### *Disclosure of conflict of interest*

The authors declare no conflict of interest.

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