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RESEARCH PAPER

Towards a Lean Construction toolbox to improve social projects management*

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ABSTRACT

Goal: Present a toolbox applied to improve the processes related to social housing construction projects using Lean Construction.

Design / Methodology / Approach: The research presents six phases; (1) literature review, (2) analyze record information and data on social projects, (3) design Lean Construction toolbox customized to social housing projects, (4) estimate indicators post application, (5) assessment building process (6) analyze economic outcomes due to toolbox application.

Results: Results showed that it is possible to apply lean construction tools to social projects in the poorest areas of urban districts in Latin America, the efficiency building an emergency house increase to 50% implementing LC tools. In an average of 20 projects a year, where around 150 to 200 houses are built, the reduction of time to build the same number of houses is around 20%.

Limitations of the investigation: The proposed toolbox was studied on housing projects deal by an NGO with operations in Coastal Lima - Peru, it was considered its sources and limitation to operate, and those own from communities located in the Lima slums.

Practical implications: The proposal toolbox can be used as a guide for the construction of housing social projects.

Originality / Value: The paper demonstrates its originality and relevance by presenting Lean Construction practices adapted to apply in social projects; reducing resources and wastes used and improving project productivity.

Keywords: Lean Construction; House Building; Social Projects; NGO; Toolbox.

INTRODUCTION

Lean Construction has been widely disseminated to improve construction projects, eliminating the waste generated in the use of resources, as detailed by (Koskela et al., 2007), this includes non-productive times when there is a poor consumption of materials. This research focuses on social projects, those who aimed at the poorest people in the city of Lima, where a Non-Governmental Organizations (NGOs) intervenes, building social houses made with materials and basic services to families of extreme poverty, providing them a better living conditions that they cannot afford it to themselves.

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There are NGOs which use the collaborative economy model, which has been developing around the world over the last 40 years, based on volunteer management, interchange products and services, collaborative projects, etc. Their intervention covers different sector, some of the best known are education services to poor populations by professional volunteers from the first world health, services for populations affected by disasters (e.g., Médecins Sans Frontier: Doctors Without Borders), consultancy for projects of community social benefit by engineering professionals (e.g., Engineers Without Borders) and support for vulnerable populations (e.g., Alboan.org). Some of them use many sources to intervene in theses social projects, like the publicity that they must optimize in order increase the productivity and efficiency, especially because main sourcing funds are donations and non-profit support which are received from particular and governmental donors. The NGO-case operate is a large Latin-American NGO (https://techo.org/) which participates with other private entities to be able to support the construction of houses for a group of 7 to 10 families, in the poorest zones of urban cities.

The main objective of the research is to demonstrate that it is possible to reduce the time construction of these emergency houses using Lean Construction tools, making realization of these projects more efficient.

HOUSING PROJECTS DEAL BY NGOS

NGOs are conceived like organizations inside the society, a non-profit sector, who is in charge to produce some benefits to the community, who promotes the progressive and continuous participation in the society, an alternative to Government and Private sector (Baca Olamendi, 2004). Even much bigger than a simple third sector, able to fit in business world, they are considerate a complement to governmental activities and not the substitute (Revilla, 2002). Moreover, NGOs evolution come with the time, their development comes independent of Government, since they were an agency to satisfy basic needs, to an organization who search and structural change (Korten, 1990).

An example of this structural change is the Program of Good Practices and Social Leadership from Habitat (dealing by The Center of United Nations for Human Settlements) where are included universities, institutes, and NGOs (García Navarro et al., 2001). This program has two objectives, improve life conditions of the citizens and the sustainability of the cities. Even some criteria to define a good practice in a living place is shown in this program: (1) physical, economic and social accessibility for disadvantaged groups, (2) ecological environment houses, and (3) urban rehabilitation.

In Ecuador, social projects have been worked by NGOs in an innovative credit scheme, to build new houses or improve some ones already existent, besides the support schemes to improvement of recreational spaces and social articulation (Chiriboga, 2014). At the same time, in Costa Rica, FUPROVI, an NGO offers a variety of housing programs for low-income families that include community development, this NGO has been capable of proposing, building, and managing housing projects during thirty-one years of its existence (Chavarría Núñez, 2020).

To develop these social projects, habitants must be part of self-management process linking to habitat evolution, it is important that public policy not only work with communities, but also local authorities support houses projects. Local authorities take part in administrative and financial support, conducting and involving the community.

The fund uTshani, the biggest NGO in South African, follow a housing policy aim for that (Adler et al., 2018). This alliance between NGOs and Government is shown by national governments to promoting and visibility public institutions, and it is considered like good governmental practices, increasing their institutional mechanisms to create capacity to build budget participative (Programa de las Naciones Unidas para el Desarrollo, 2006). According to Inter-American Development Bank (Adler et al., 2018), homeownership strengthens the household's social capital, which contributes to increasing its income level. These peculiarities of the organization of urban space can influence in the pursuit of economic growth (Marcuse and van Kempen, 2011).

LEAN CONSTRUCTION

Lean Construction is a bunch of practices to design a production system which can minimize the waste of materials and reduce significantly the time and effort with the objective of generating the maximum possible value (Koskela et al., 2007), have the purpose to explain how projects are connected in strategy, structure and process (Miranda Filho et al., 2011).

Lean has come from the Toyota Model and extend its benefit through Lean Manufacturing application (Koskela, 1992), but recently have popularized in construction projects with Lean Construction (Green and May, 2005). Lean Construction comes from Lean Thinking, which main purpose is to align activities that generate value for a given task, providing an increasing and sequential improvement in efficiency each time the end user requests the product (Tavares, 2020).

At the beginning, the concepts to Lean had based on studies of Gilbreth and Gilbreth (Gilbreth et al., 1922), application of eliminating of waste in a manufacture line, implemented by Ford (Levinson, 2013). Then was developed 20 years after WWII like a productive process in the Toyota Motor Company by Ohno and Shingo, building the Toyota Production System (TPS) in Japan (Shingo, 2019). Years after, in the 90s, Hopp and Spearman (Hopp and Spearman, 2011), demonstrate with metrics how to achieve the fundamental objective of reducing cost by the definition of Lean. Nowadays, Lean Thinking is used for creating lasting value in any business, from large to small companies (Womack and Daniel, 2003).

Lean Construction tool has been extended in many projects marking problems that involve the construction industry, from numerous environmental impacts to large levels of waste (Tavares, 2020), at the same time able to increase productivity and secure a better health and safety environment to accomplish the client requirements (Marhani et al., 2012).

Lean Construction principles and tools

To mention the importance of Lean Construction, we need to describe the principles that evolve the tool with a general flow process design and improvement, some of them are have been provided by (Brioso, 2015), by implementing these principles in uncertain and quick project, it has shown that the project can gain better results (Salem et al., 2006), including Latin-American countries like Ecuador, Peru, Venezuela or Brazil (Johansen and Walter, 2007). For instance, (1) reduce the share of non-value adding activities, (2) reduce variability, (3) reduce the cycle time, (4) build continuous improvement into the process, and (5) increase output value through systematic consideration of customer requirements.

In addition, it has been proved that putting into practice these principles a customer satisfaction can be gained (Freire and Alarcón, 2002). In order to complete this objective, there are tools that are very useful to help the production process run smoothly (Ahmed et al., 2020). Tools of Lean Construction are split by specific essential elements to achieve this objective, some of them are 5S (Sort, Straighten, Standardize, Shine and Sustain) and Firs Run Studies (Plan, Do, Check and Act) (Salem et al., 2004). Forbes and Ahmed proposed that the application of the 5S technique is totally recommended in activities that do not generate any value to the process (Forbes and Ahmed, 2011), it has had as a direct consequence the improvement of the indicators of accident rate in the system that advocates safe practices and in the construction process (Antillón, 2010). There are also key concepts of Lean Construction in a construction process, these can be broken down both in a design, pre-construction or construction stage; among there are Just in Time (JIT), Total Quality Management (TQM) and Last Planner System (LPS) (Marhani et al., 2012).

Housing projects inside Lean

It is well known that a low productivity and waste in the construction sector are historic, the scarcity of resources forces companies to make constant modifications to survive (Lorenzon, 2008). Apart from that, reworks or projects postponed are the event arisen for the low standard and quality construction works, including the culture of not allowing budget for R&D and for implementing new techniques is the source of many issues for the construction sector, as is mentioned by Ahmed et al. (2020).

A project like a house construction has been recently taken as off-site manufacturing activity that it can be better managed and controlled to reduce the wastages, the application of Lean Construction could help in reducing the time of house construction because installation is done at the site only (Singh and Kumar, 2020). Nowadays, Lean Construction tool is very effective in reducing the life cycle cost of the construction project in a remarkable way (Ansah and Sorooshian, 2017). According to Maguiña (Castillo Maguiña, 2014), Lean Construction application can divide in three phases, first one belongs to (1) Construction phase, the second one to (2) Production control phase and the last one to (3) Structured work.

METHODOLOGY

This study was undertaken as a design-based action research (Andriessen, 2007). In design research, the researchers have the scientific ideal of creating prescriptive knowledge to improve professional practice based on a case project (Vrijhoef and van Dijkhuizen, 2020). The main challenge is to change standard practice and successfully embed a culture of researching based on knowledge utilization (Ridde, 2018).

The research approach followed six stages; (1) literature review, (2) analyze record information and data on social projects, (3) design Lean Construction toolbox customized to social housing projects, (4) estimate indicators post application, (5) assessment building process (6) analyze economic outcomes due to toolbox application.

In this particular project, the working method was as follows, first it began with a time study, corresponding to the real measurements of the construction in the field, then a diagnosis of the construction process was carried out with the evaluation of the main causes of the problems with an Ishikawa diagram, later the stages to be improved were evaluated with a Pareto diagram, finally the reduction of these times was carried out with a Balance chart. All results are estimated based on expert opinion.

In the end, to measure the benefit of these reductions in the project, profitability indicators have been used.

CASE

TECHO aims to contribute to the reduction of poverty in the country, specifically it is working in the districts of Lima, dedicated to providing houses to vulnerable populations, where more than 35,000 volunteers have been mobilized, 5,500 emergency homes have been built and 32 settlements where they have worked together with the community.

These houses are on average 6.0 x 3.1 m2, the set of 7 to 10 houses is considered a project and the average number of projects is 20 to 25 projects per year (pre-pandemic).

A house is composed of 9 panels, which can be seen in next figure, these are a right rear panel, a left rear panel, 2 lateral panels, 3 floor panels, 1 front door / window panel, 1 front window panel, 2 windows and 1 door. Figure 1 show graphically these parts of the house.

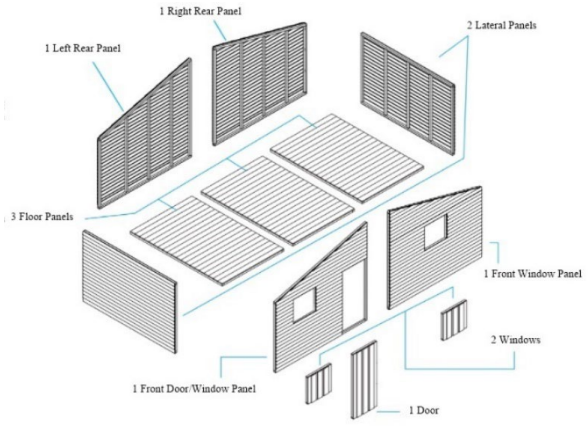

Fig. 1. Parts of an emergency house

The material used is usually prefabricated, and the services provided may vary according to the area (water, electricity, individual or community drainage). The NGO carries out the work with teams of volunteers guided by a permanent staff of the NGO specialized in housing construction. The total of volunteers is variable in each project, around 6 to 10 volunteers led by a team leader from the NGO, between 17 and 50 years, in total a project has from 60 to 100 volunteers working the 2 days of construction.

Analysis and diagnosis

The problems observed in the construction of these houses are that the actual productivity to build the house is low below de expected, the mean time is about 12 hours to finish the house, divided in 2 days of construction. There are processes after building the house, between 2 and 3 houses which have to be remodeled after those 2 days in the next weeks. There is no standardization in the process of the construction of the house, which cause loss of materials and disorder in the ejection of the process.

These problems cause that the actual efficiency in the projects is about 39% (productive work time over total time), a waste of movements of 43% and in consequence some unfinished houses. The historical number of projects realized by the NGO is 422 since 2018.

LEAN CONSTRUCTION TOOLBOX

In this study, the tools corresponding to the construction phase will be used, starting with a First Run Studies, then a creation of Train Activities, following a Balance Chart and finally the implementation of 5S, a flowchart of these steps is presented in Figure 2.

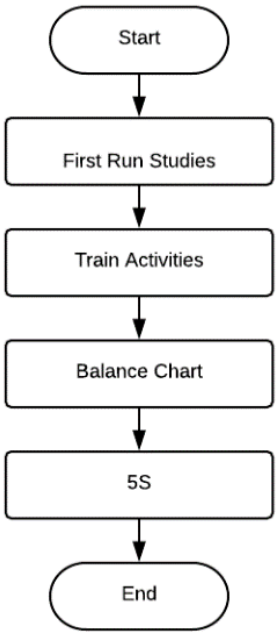

Fig. 2. Flowchart of the application of Lean Construction tools

First Run Studies

Tool that proposes the use of sectorization, a process that details the use of work trains, planning, scheduling and sizing of teams. In our case, an emergency house has a single floor and a duration of two days, for that reason, a tentative number of sectors will not be searched based on factors such as the extension of the project, the project will be represented by only one sector, made up entirely of the activity's volunteers.

As a first operation, the stages (1) Floor Leveling (2) Panels Installation (3) Central Beam Installation and (4) House Culmination are divided each day detailing each activity, most of them can be carried out on the first day, activities start at 9 a.m. each day, while the end time for activities varies between 5 p.m. and 6 p.m. The objective is that all teams of the project can finish construction in these two days.

The stages can be divided depending on the construction process in two fronts, the first corresponds to the vertical elements (columns or vertical panels) and the second to the horizontal elements (beams and floor panels) as indicated by LC. By implementing this division, it will be possible to achieve a similar workload and a continuous workflow in each day and sector. Finally, a sectorization is implemented as shown in Table 1 as these activities are divided into 2 days.

Table 1. Sectorization implemented in the construction project

	Activities		Day	
			1	2
Horizontal elements	Start Floor Leveling	Activity 1, Activity 2, Activity 3, Activity 4, Activity 5	S1	
	Finish Floor Leveling	Activity 6, Activity 7, Activity 8	S1	
	Start Panel Installation	Activity 9, Activity 10, Activity 11	S1	
	Finish Panel Installation	Activity 12, Activity 13	S1	
Vertical elements	Start Central Beam Installation	Activity 14, Activity 15, Activity 16	S1	
	Finish Central Beam Installation	Activity 17, Activity 18, Activity 19, Activity 20, Activity 21, Activity 22		S1
	Start House Culmination	Activity 23, Activity 24, Activity 25, Activity 26, Activity 27		S1
	Finish House Culmination	Activity 28, Activity 29, Activity 30, Activity 31		S1

Train Activities

Given that in the case of the project, the total duration is about 2 days, we will try to cut a train of weekly activities to one that is daily and detailed by hours how each stage of the process is completed. To observe the changes made by the train activities, the current activities of the process are displayed in Table 2.

Table 2. Train activity of the project before the application of Lean Tools

	Activities	Day 1			Day 2		
		9 a.m.	12 p.m.	3 p.m.	9 a.m.	12 p.m.	3 p.m.
Horizontal elements	Start Floor Leveling	S1					
	Finish Floor Leveling		S1				
	Start Panel Installation		S1				
	Finish Panel Installation			S1			
Vertical elements	Start Central Beam Installation		S1				
	Finish Central Beam Installation			S1			
	Start House Culmination				S1		
	Finish House Culmination				S1		

It is observed that there are stages that are with a higher workload compared to others, such as the Floor Leveling and Central Beam Installation between 9 a.m. to 3 p.m. and 12 p.m. to 6 p.m., each of these operations will take approximately 6 hours. Then is shown the upgraded train activity of the process in Table 3.

Table 3. Train activity of the project after the application of Lean Tools

	Activities	Day 1			Day 2		
		9 a.m.	12 p.m.	3 p.m.	9 a.m.	12 p.m.	3 p.m.
Horizontal elements	Start Floor Leveling	S1					
	Finish Floor Leveling	S1					
	Start Panel Installation		S1				
	Finish Panel Installation		S1	S1			
Vertical elements	Start Central Beam Installation			S1			
	Finish Central Beam Installation				S1		
	Start House Culmination				S1		
	Finish House Culmination					S1	

Balance Chart

The first step in observing the differences present in the process is to divide production work into three categories (Oglesby et al., 1989). The first one corresponds to (1) Productive Work or PW, the second one to (2) Contributory Work or CW and the last one to (3) Non-Contributory Work or NCW. Each of them will be used when creating our balance chart, this is understood by the level of work that exists in each activity. The idle time between each activity is the one that generates the highest percentage of TNC, time to be reduced when implementing LC, Table 4 shows the current work distribution in each category versus an updated work distribution after applying the improvements to the project, shown in Table 5.

Table 4. Productivity indicators before the application of Lean Tools

Types of activities	Time	Work distribution
NCW	89.79	33.56%
CW	73.53	27.48%
PW	104.21	38.95%
Total	**267.53**	**100.00%**

Table 5. Productivity indicators after the application of Lean Tools

Types of activities	Time	Work distribution
NCW	30.17	14.51%
CW	73.53	35.36%
PW	104.21	50.12%
Total	**207.91**	**100.00%**

The main objective of the Balance Chart is to analyze the efficiency of the construction method used, even more than to measure the efficiency of the workers, it is not intended that they work more arduously in the process, but in a smarter way (Serpell and Verbal, 1990). This Balance Chart is shown below in Table 6.

Table 6. Balance Chart of the project after Lean Tools

Types of activities	Activities	% Total	% By Group	%
CW	Measure the terrain with the tape measure	5.52%	21.76%	35.36%
	Pre nail the windows and door	2.30%	9.07%	
	Nail the joists to the floor	2.07%	8.16%	
	Join the joist with dowels	2.01%	7.93%	
	Form the U with the panels	1.95%	7.71%	
	Place the wick and measure the plumbness	1.72%	6.80%	
	Attach door hinge	1.72%	6.80%	
	Place ornaments	1.38%	5.44%	
	Attach window hinges	1.21%	4.76%	
	Sort the other panels	1.15%	4.53%	
	Place secondaries	1.15%	4.53%	
	Place the stakes and cut the rafters	1.12%	4.42%	
	Cut secondaries	0.92%	3.63%	
	Move panels that take up space	0.61%	2.42%	
	Mark and cut the floor joists	0.52%	2.04%	
PW	Level the floor with the hose	12.63%	30.37%	50.12%
	Place the central beam	11.41%	27.43%	
	Nail corrugated sheets and ridge	4.61%	11.08%	
	Join two secondary beams with cut dowels	2.01%	4.84%	
	Place door and windows	1.72%	4.14%	
	Measure and nail rafters	1.68%	4.04%	
	Nail the joists to the floor	1.15%	2.76%	
	Nail secondaries	1.15%	2.76%	
	Nail dowels to the floor joists	1.08%	2.59%	
	Join the U with nails	1.13%	2.71%	
	Place and nail cornerbacks	0.86%	2.07%	
	Place and nail windows and door stop	0.57%	1.38%	
	Nail panels to the floor	0.38%	0.92%	
	Join the ridge to the rafters with nails	0.48%	1.16%	
	Join corrugated sheets with caulking nails	0.44%	1.05%	
NCW	Nail intersections	0.29%	0.69%	14.51%
	Between activities	0.00%	0.00%	
	Going to the bathroom	1.65%	4.99%	
	Leisure time	8.31%	25.13%	
	Having lunch	23.10%	69.88%	

For the application of the following tool, Pareto diagrams were also used, another recognized Lean Tool, the purpose is to identify the stages and activities most affected in the project by relation to the idle time that occurs in them.

5S APPLICATION

According to Aldavert (Aldavert et al., 2016), this tool includes 5 main phases, (1) Seiri, (2) Seiton, (3) Seiso, (4) Seiketsu and (5) Shitsuke.

In the Seiri phase, each material or element for the project is inspected, then it is separated the unnecessary from the necessary material, if the material is damaged a repair is considered, and if the material is still damaged, it has been discarded for the project, if not these materials are considered for the next project, materials related in this process are panels, rafters, doors, beams. In the Seiton phase, each element is order depending on if they are materials for construction, divided by size, it could be small or medium (hammers, nails, etc.) and big (panels, beams, etc.) or tools used by the volunteers, if they are tools of safety (helmets, gloves, etc.) or just documents or manuals (the house construction manual).

In the Seiso phase, each dirty element is removed from the workplace, this it is a bit complicated because an emergency housing construction is normally carried out in communities far from the city and in the open air, where dust is common throughout the work. After finishing the first 3S, the Seiketsu phase seeks to be able to standardize the performance of the tasks and procedures already executed, and ensure that the achievements are maintained in the future. Finally, the Shitsuke phase seeks to accustom the volunteers and team leaders to the use of the already standardized methods for order and cleanliness in the work order. In addition to the 5S, it is important to know in which stages the development of these improvements was focused, in Figure 3 is shown the degree of waste at the level of each of them.

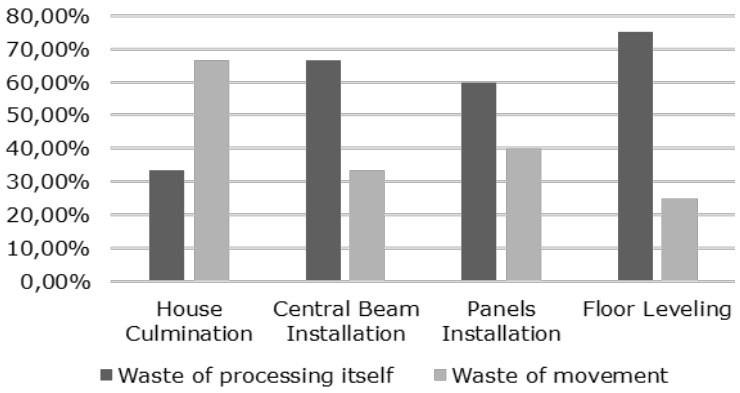

Fig. 3. Wastes of the Project by stage

RESULTS AND DISCUSSIONS

Results

With the implementation of the LC tools is observed that the productivity to build the house increase, the time reduce from 12 hours to only 7 hours to finish the house, divided in 2 days of construction. There is no need to go back to the house to be remodeled, the efficiency in the project implementing LC tools increase to 50%, causing that an effectivity to complete all emergency houses is about 100% in most cases. In an average of 20 projects a year, where around 150 to 200 houses are built, the reduction of time to build the same number of houses is around 20%.

To measure man hour cost, an equivalent table of the salaries of the volunteers and team leaders has been constructed, based on the opportunity cost that these volunteers may receive if they had the chance to have a paid job (Plataforma Constructivo, 2014), that cost per hour is around S/17, an equivalent of $3.2 in the period of the investigation. According to this cost per hour, an estimate has been made of the costs in the implementation of the LC tools. On the other hand, the savings that contribute to the calculation of cash flow income and expenses are shown below in Table 7, they represent the reduction of total times in one project.

Table 7. Savings in three scenarios by implementing Lean Construction

	Current time (h)	Proposed time (h)	$ Hours (Volunteers)	Savings	Total Savings
Optimistic Scenario	15	6.75	$5.31	$43.83	$438.28
Normal Scenario	15	7.2	$5.31	$41.44	$414.38
Pessimistic Scenario	15	7.5	$5.31	$39.84	$398.44

To measure the profitability of these improvements applying the LC tools for the NGO project, the NPV (Net Present Value – 10% of discount rate) and IRR (Internal Rate of Return) tool have been used, it has been considered three scenarios (pessimistic, normal and optimistic). In an optimistic scenario, it is considered that the application of each LC tools is being fulfilled with full responsibility from the volunteers and the team leader, this implies meeting the indicators set out in the goal and the objectives of reducing the amount of unproductive time in the operations that make up the construction of an emergency house. In a normal scenario, it is considered that the application of the LC tools is being fulfilled by the volunteers and the team leader. Finally, in the pessimistic scenario, it is considered that the application of some LC tools is being fulfilled by the volunteers and team leader. Each of these scenarios are presented with their results in Table 8.

Table 8. Profitability indicators of the project

	NPV	IRR
Optimistic Scenario	$3,874.29	81.71%
Normal Scenario	$2,241.31	51.57%
Pessimistic Scenario	$733.94	23.86%

Discussions

With the application of lean tools in the practice of building these houses, we not only support the affected population, but also encourage the connection between communities and society to grow, giving visibility to the problems faced by NGOs from a complementary point of view to what the government is already doing (Revilla, 2002). In addition, it is already known that improving the living conditions of each community contributes to having a more sustainable city (García Navarro et al., 2001). These principles are in relation to the relational map of the NGO as shown below in Figure 4.

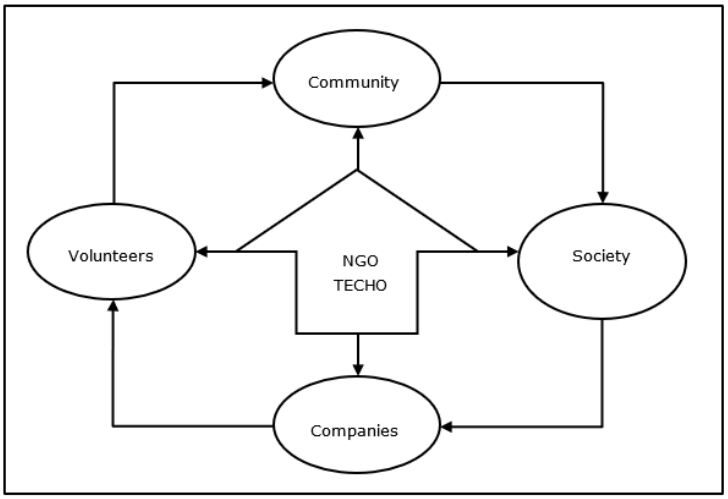

Fig. 4. Relational Map of the NGO TECHO

However, everything described above can change due to the decisions that governments can make, most of these territories do not appear on zonal or district maps, some of them are not recognized by the government since they were born from invasions, therefore achieving sustainability within the city could be more complex than building emergency housing (Arriola Laura, 2019).

CONCLUSIONS

This study has served to demonstrate that it is possible to apply lean construction tools, which are normally used in large projects, such as the construction of bridges or a group of buildings, to social projects like a group of houses located in the poorest areas of the urban districts. Therefore, it could be expected that the lean systems tools could be replicated for other cities in Latin America. Where you can find similar characteristics of a modern city belonging to a developing country, high population density, lack of resources and lack of public services.

The steps to achieve to have a customize toolbox were as follows, first the conditions of the house to be built have been detailed, the activities carried out to build the house have been separated into days, finally a before and after in the time of said activities has been shown. By being able to apply lean construction tools, it has been possible to optimize work efficiency, eliminating waste generated by the misuse of resources, including the time spent by volunteers, and in turn the unnecessary consumption of material resources, (Koskela et al., 2007).

On the other hand, this study has limitations due to the varied geography in the country, they are particular characteristics in different Peruvian regions which require local resource to build house for instance; the mud bricks in the highlands and the wood in the forest. Also, singular service requirement is expected from house, for example; a construction that conserves the temperature in the highlands, where there are usually low temperatures, while in the forest the house is expected to be above the base of the ground to cope with the flooding of the rivers.

To extend the application of this research, it is necessary to record metrics in all the communities where each construction project is planned to do, it is needed time the NGO to visits them and understand local necessities and requirements. For this reason, it is proposed to create a template aligned to particular local conditions housing projects so that they can easily complete the data and thus know which the times are to reduce depending on each community. It is even possible to conduct an upcoming investigation after COVID-19 of another type of construction project, such as a community building, fence building, or wall painting.

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Author contributions: Introduction - JVF and KCC; Housing projects deal by NGOs - JVF and KCC; Lean Construction - CRI and KCC; Lean Construction Toolbox. - CRI, JVF and KCC; Methodology. - KCC; Case - KCC.