Evaluation of the use of lightweight concrete panels for post disaster house reconstruction using Building Information Modelling

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<th>Description</th>
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<tbody>
<tr>
<td>3D-LPs</td>
<td>Three Dimensional Lightweight Panels</td>
</tr>
<tr>
<td>ACI</td>
<td>American Concrete Institute</td>
</tr>
<tr>
<td>ADRIS</td>
<td>Agency-Driven Reconstruction in site or Donor Driven</td>
</tr>
<tr>
<td>ADRRS</td>
<td>Agency-Driven Reconstruction in relocated site</td>
</tr>
<tr>
<td>AEC</td>
<td>Architecture, Engineering and Construction Industry</td>
</tr>
<tr>
<td>ASCE</td>
<td>American Society of Civil Engineers</td>
</tr>
<tr>
<td>ASTC</td>
<td>American Society Test Materials</td>
</tr>
<tr>
<td>BAPENAS</td>
<td>Badan Perencanaan Pembangunan Nasional (Agency for National Development Planning)</td>
</tr>
<tr>
<td>BIM</td>
<td>Building Information Modelling</td>
</tr>
<tr>
<td>RRB</td>
<td>Rehabilitation and Reconstruction Board</td>
</tr>
<tr>
<td>CA</td>
<td>Cash Approach</td>
</tr>
<tr>
<td>CDR</td>
<td>Community-Driven Reconstruction</td>
</tr>
<tr>
<td>CRR</td>
<td>Cash for Reconstruction and Repair</td>
</tr>
<tr>
<td>DR</td>
<td>Disaster Resilience</td>
</tr>
<tr>
<td>EPS</td>
<td>Expanded Polystyrene</td>
</tr>
<tr>
<td>HC</td>
<td>Housing reconstruction</td>
</tr>
<tr>
<td>KDP</td>
<td>Kecamatan Development Project</td>
</tr>
<tr>
<td>MDF</td>
<td>Multi-Donor Fund</td>
</tr>
<tr>
<td>MICE</td>
<td>Mexican Institute of Cost Engineering</td>
</tr>
<tr>
<td>MPW</td>
<td>Ministry of Public Works</td>
</tr>
<tr>
<td>NGOs</td>
<td>Non-Governmental Organizations</td>
</tr>
<tr>
<td>NM-MD</td>
<td>Natural Man-Made Disaster</td>
</tr>
<tr>
<td>NM-MDs</td>
<td>Natural Man-Made Disasters</td>
</tr>
<tr>
<td>ODP</td>
<td>Owner Driven Programme</td>
</tr>
<tr>
<td>ODR</td>
<td>Owner Driven Reconstruction</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<td>--------------</td>
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<tr>
<td>PIS</td>
<td>Participation Information Sheet</td>
</tr>
<tr>
<td>UDA</td>
<td>Urban Development Authority</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>UPP</td>
<td>Urban Poverty Project</td>
</tr>
<tr>
<td>USGS</td>
<td>United State Geological Survey</td>
</tr>
<tr>
<td>UTC</td>
<td>Coordinated Universal Time</td>
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Abstract

A large number of natural disasters affects hundreds of thousands of people each year in their housing around the world. Therefore, there is a call to find more appropriate strategies for housing reconstruction following a disaster. This study aims to reduce the construction time and cost of housing affected by such disasters.

The academic literature on the 3 Dimensional Lightweight Panels construction system (3D-LPs), Building Information Modelling system (BIM) and experiences gained in post-disaster housing reconstruction strengthens the argument that there is an opportunity to contribute to solve the housing reconstruction problem. The study points out that the combination of these systems and community participation presents an option to produce both affordable and sustainable housing in the shortest time on a large scale by the affected people after overcoming the emergence phase of a disaster.

A holistic philosophy was used to study the housing reconstruction problem as a whole to understand all parts of the problem and three research questions were set up to explore the possible solution to this problem. The research strategy to address the problem was based on a survey of worldwide experts, interviewing a forum of lightweight concrete panel manufacturers and the modelling of a basic housing prototype in BIM. Research question (1) How can displaced people use their own labour to save money and time? and research question (2) How does the 3D-LPs construction system contribute to housing recovery after natural disasters? Research questions (1) and (2) were answered by 17 open-ended questions conducted with 22 housing experts from 11 countries and 7 semi-structured interviews composed of 14 questions with 7 manufacturers of construction materials respectively which collected rich qualitative data (15,419 words) that were analysed in Nvivo 10 through pattern matching and validated by triangulation techniques to give reliability to the study. The housing prototype modelling was used to answer the research question (3) Can the BIM model show the cost-benefit in building housing with the 3D-LPs construction system and displaced people’s own labour?

The main findings of this study are that a housing prototype built with 3D-LPs is 36.82% cheaper in comparison to houses built with bricks and reinforcement elements and could be built by unskilled people in 90 days. The study provides novel in-depth knowledge of how unskilled people from communities affected should participate in housing reconstruction and how new construction systems can be implemented after disasters, which contributes to the body of knowledge. In addition, the study provides guidelines to implement a system directed at unskilled people and also Non-Governmental Organizations (NGOs) in a novel way, to help to solve the housing reconstruction problem and engage the displaced people in the housing reconstruction.

Keywords: 3D-LPs, BIM, community participation, disasters, housing recovery
Declaration

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1 Introduction

1.1 Introduction to the research
Hundreds of thousands of dwellings each year are affected by natural disasters. UKaid, (2011b) and Humanity, (2011b) have claimed that such disasters affect hundreds of thousands of dwellings each year and contribute to exacerbating the shortage of housing. According to United State Geological Survey (USGS), (2004) one of the largest disasters in the last decades has been the Indian Ocean Tsunami. This disaster simultaneously affected 14 countries in the Asian Continent and the African Continent. Lyons, (2009) and Jha et al., (2010) have also stated that a large number of homes were totally or partially destroyed by the 2004 Indian Ocean Tsunami and governments had to implement housing reconstruction programmes with help from International agencies and NGOs. The housing reconstruction took several years and five reconstruction programmes were implemented on a large scale where the community participation was limited by the type of programme and NGOs faced a large number of problems.

Jha et al., (2010) support the proposition that two of these five programmes have been highlighted by the academic literature due to community participation. On one hand is Own Driven Reconstruction (ODR), which is a programme, focused on helping individuals, groups and communities to restore their houses through a systematic framework consisting of financial, technical and administrative support. On the other
hand is Donor Driven Reconstruction (DDR). According to Da Silva and Batchelor, (2010) DDR is a programme, focused on hiring construction firms, builders and contractors to rebuild the damaged dwellings on a large scale. In this approach community participation is excluded and international agencies and NGOs are responsible for looking after the interests of people displaced by disasters.

The academic literature also shows that there are techniques and procedures for construction that have been developed in the last 30 years. According to Kabir and Nasab, (2002) the 3D-LPs construction system is a system based on 3D lightweight panels made of polystyrene core and meshes made of galvanized steel to build a monolithic structure able to bear seismic action, strong winds and tornadoes. CS&M, (1978) and Escrow, (2012) describe that the panels are connected to each other by means of galvanized steel meshes and annealed wires or staples, and covered with mortar and concrete to achieve a resistant structure similar to structures of reinforced concrete.

Byron, (2006) points out that BIM is a platform used in the construction field which provides tools to manage the life cycle of construction projects. It was developed to document, model and visualize projects. BIM allows anticipation of future problems of construction, and displays digital models to allow easy understanding and enable teamwork to share projects.

Summarising the above, first, International Agencies and NGOs play an important role in housing reconstruction on a large scale. They should be provided with more alternatives to manage housing reconstruction after a disaster. Second, there is academic research evidence that suggests that the participation of community members, 3D-LPs construction system and BIM could help in the development, design and construction of appropriate, affordable and sustainable housing. This can contribute to housing construction in a short time to save money. Third, a disaster gives the opportunity to improve the life conditions of the affected people and contributes to building Disaster Resilience (DR) According to Paton and Moore, (2006); the National Academies, (2012) and Gov UK, (2013) DR is defined as the capacity for recovering quickly from a disaster and the ability to return to ordinary life through anticipated actions. The issue outlined forms the basis for this study and the advantages of the 3D-
LPs construction and BIM enable the selection of a suitable methodology to explore the housing reconstruction problem and meet the research aim and objectives.

1.2 Definition of problem statement

As stated by Humanity, (2011) the whole world is suffering a great housing shortage, which is greatly exacerbated when an earthquake, tsunami, hurricane or flood occurs. “Habitat for Humanity” reported that between 2004 and 2011 more than 13 million people lost their homes as a result of the aforementioned natural events. Humanity, (2011) even also reported that Sri Lanka had also been affected by natural catastrophes in the last decades; the estimated housing shortage in 2010 was over 1.2 million households. On the other hand Humanity, (2011) also indicated that before the earthquake it suffered in January 2010, Haiti had presented a housing shortage of 1 million dwellings, which was increased after the natural disaster. It is necessary to find solutions that reduce the housing deficit and contribute to the restoration of housing damaged by such natural disasters in the shortest time possible. Natural disasters present an opportunity to see the mistakes made in the past, as well as the chance to improve the economic, political, and social conditions of the affected countries, given that countries affected by disasters have often been unable to withstand the physical forces due to weaknesses in building materials, regulations, and procedures.

The problems associated with housing reconstruction following natural disasters have identified other factors involved in the rebuilding of a devastated area; these factors are:

a) The lack of recovery plans

Although countries have a national response to natural disaster, they require International aid and NGOs that address disaster management and propose logistical operations to overcome the situation. Nikbakhsh and Zanjirani, (2011) argue that Indonesia in 2004 showed the need for disaster recovery plans, which were developed after the natural disaster with the help of international organizations. Lang, (2011), and City Planning, (2008) describe that after earthquakes occurred in China in 1966, 1975, 1976 and 2008, the authorities developed a national plan for housing recovery based on research obtained after natural disasters. Government of Haiti, (2010) also
developed a plan after the largest earthquake occurred in Haiti 2010 to solve the damage left by the catastrophe.

b) The lack of experience in housing construction

According to Steinberg, (2007) and Ophiyandri, (2011) NGOs and international agencies are responsible for providing help to the countries affected by natural catastrophes. Such was the case in Banda Aceh in 2004, Oxfam and Red Cross, Care and German Agro Aid, Muslim Aid, and many others gave them support in the housing rebuilding without previous experience, and encouraged them to build houses, due mainly to the availability of money donated by countries and organizations; this resulted in poor quality of dwellings.

c) The slow flow of international aid

Van, (2005) suggests that the flow of international aid must be able to respond with efficient manageability of materials, information and economic resources, which include a supply chain and humanitarian logistics. However Nikbakhsh and Zanjirani, (2011) argue that the countries affected by the 2004 Asian Tsunami suffered a slow flow of international aid, owing to little coordination among NGOs and International agencies.

d) The low level of understanding among the parties involved

Chang et al., (2011) emphasise that the parties involved in the housing recovery of Sri Lanka suffered from a lack of understanding, mainly owing to the strong competition for economic resources. Tinguaro et al., (2010) agree that the NGOs have few opportunities to take decisions, and they are restricted because they do not have a system to act after natural disasters. Nevertheless, Coles et al., (2012) in a recent research study identified that NGOs should develop relationships among themselves to strengthen the alliances and help in the housing recovery.

Affected countries tend to focus greater attention on the emergency phase and neglect the true recovery. In conclusion, the fact is that the reinstatement of housing affected by a natural disaster takes from 3 to 10 years; and the displaced or homeless people
remain in shelters for long periods without employment until their new houses become available.

1.3 Justification of the research
This research was strongly focused on identifying solutions for housing recovery following a disaster, given that people need to regain their properties as soon as possible. In consequence, motivated by the need to give housing to the displaced people, and considering that those affected spend much time in shelters unemployed until professionals of the Architecture Engineering and Construction (AEC) industry are able to contribute to the solution of the dwelling recovery problem, this study has designed and proposed a housing prototype built by means of the 3D-LPs construction system in which the displaced or homeless people could be the main builders. The housing prototype could anticipate future disasters and so be ready for implementation immediately after the completion of the emergency phase. The literature review carried out about the housing recovery programmes showed that Ophiyandri, (2011), Jha et al., (2010) and Davidson et al., (2007) concur that community participation has contributed to housing recovery and is a key element for housing reconstruction. This is supported by the World Bank, (2005) since the Owner-Driven reconstruction programme (ODR) launched by the World Bank in Indonesia, Sri Lanka, India and China resulted in a successful programme, this was mainly due to help from the homeless people, who were able to help with their labour after natural disasters occurred in their countries. However Davidson et al., (2007) points out that the lack of guides, manuals and precise instructions has contributed to extending the time and cost of housing recuperation post disaster.

It was also found in the literature review that the housing problem could be mitigated through the use of 3D-LPs, since Bert, (1985) and Escrow, (2012) emphasize that 3D-LPs showed a good response to earthquakes, floods, and hurricanes; furthermore the 3D-LPs could contribute to producing housing both affordable and sustainable given that they have good thermal properties and generate minimal waste of material.

According to Eastman et al., (2008) BIM helps to create models close to real construction. In consequence, a modelling of a basic housing prototype with the 3D-LPs construction system was proposed in BIM Revit 2013, given that it was considered
a suitable alternative to achieve this study. The modelling of the prototype had as objective to explore the use of the 3D-LPs construction system, the economic estimation and the development of guidelines for training unskilled people in the system under monitoring of professionals of the AEC industry.

1.4 Research aim
This research aims to reduce the construction time and cost of housing affected by natural disasters, through the evaluation of the use of lightweight panels type 3D-LPs in order to produce both affordable and sustainable housing in the shortest possible time on a large scale by the displaced or homeless people.

In addition, it will develop training guidelines directed at unskilled people and also at Non-Governmental Organizations (NGOs).

1.5 Research objectives
The objectives of the research are:

a) To evaluate the problems associated with housing reconstruction following natural disasters to offer an early solution for housing recovery.

b) To evaluate and to analyse a suitable panel to build housing after a disaster and to design and to model a housing prototype model with the suitable panel to investigate, the cost-benefit in building housing.

c) To analyse and to investigate how displaced people should participate in housing reconstruction after a disaster to create a novel approach to address the housing reconstruction problem.

d) To recognize and analyse key actions to manage the housing reconstruction problem after a disaster.

The research objectives were achieved by:

- Literature review of the largest disasters that occurred in recent decades (The Indian Ocean Tsunami, 2004).
- A survey with 22 worldwide housing expert,
• 6 semi-structured interviews in a forum of lightweight concrete panel manufacturer and 1 semi-structured interview with an international manufacturer of cement.

• A modelling of a basic housing prototype with 3D-LPs in BIM Revit 2013 developed by Autodesk.

1.6 Research questions
The research questions for this study are:

1. How can displaced people use their own labour to save money and time?

2. How does the 3D-LPs construction system contribute to housing recovery after natural disasters?

3. Can the BIM model show the cost-benefit in building housing with the 3D-LPs construction system and displaced people’s own labour?

1.7 Research methodology

Phase 1: Literature review
The research strategy adapted for this study involved a review of related studies in housing reconstruction programmes used post-the Indian Ocean Tsunami which occurred in 2004. The purpose of the literature review was to evaluate the problems faced by NGOs in the different approaches used for housing reconstruction. Furthermore, the literature review provides the basis for understanding the physical and mechanical properties of the 3D-LPs construction system and presents an overview of BIM. This as a whole helped to identify a suitable research methodology to address the housing reconstruction problem.

Phase 2: Methodology

• Survey and interviewing forum
A survey of worldwide experts and interviewing forum of lightweight concrete panel manufacturers along with an interview of 1 international manufacturer of cement were
used to answer the research questions (1) and (2). The survey was administered by using an online questionnaire with open-ended questions, and the interviewing forum was achieved through semi-structured interviews which explored how displaced people should participate in housing reconstruction and how the traditional construction system can be replaced by 3D-LPs construction system.

- **Computer modelling**

The findings of the research question (2) and the literature review enabled the design of a housing prototype, which was modelled on BIM Revit 2013 with 3D-LPs to answer the research question (3). The modelling was validated by the technical director of W Panel Company by corroborating that the model worked in accordance to technical specifications to design concrete and steel structures.

**Phase 3: Data analysis of survey, interviewing forum and computer modelling**

This phase involved qualitative analyses of more than 15,000 words collected by survey and interviewing forum, which were analysed by pattern matching in Nvivo 10 and validated by triangulation techniques. This phase also included analysis of the cost-benefit of housing prototype with the 3D-LPs construction system modelled in BIM Revit 2013. The findings are displayed in graphics and narrative manner in chapters 4, 5 and 6.

Rich qualitative data from the online questionnaire with open-ended questions and semi-structured interviews were coded to facilitate an interactive analysis process in Nvivo 10 which allowed the reduction and categorization of meaningful and important data in order to enable data analysis by pattern matching to meet the research objectives. The study was validated by triangulation techniques to give reliability and enable generalization of findings.

**1.8 Scope of the Research**

The scope of the study is to explore the possibility to build permanent, sustainable and affordable housing after a disaster by displaced people anywhere in order to meet the
research aim. This research is limited to the use of the 3D-LPs construction, BIM Revit 2013 and here is no consultation with the communities affected by disasters.

1.9 Thesis structure

The thesis is organized into seven chapters.

**Chapter 1 – Introduction:** This chapter presents the introduction to the research, definition of the problem and research objectives, aim and questions. Also it attempts to establish the current situation of housing after a natural disaster occurs, as well as offering a justification of the research and possible solutions in addition to brief details that describe the structure of thesis.

**Chapter 2 – Literature review:** This chapter presents the literature review focused on key concepts and housing disaster programmes used after the 2004 Indian Ocean Tsunami and community participation. This chapter also presents the literature review focused on two aspects of this research study, which are the 3D-LPs construction system and BIM, to underpin the rationale to select these that helped to explore the research question (2 and 3).

**Chapter 3 – Research design and methodology:** This chapter explains in detail the research philosophy, approach, strategy and design, and methods used to address the research questions and meet the research objectives. Both research methodology and method are discussed as well as the rationale for their selection.

**Chapter 4 – Online questionnaire:** This chapter presents the qualitative analysis and findings of the 17 open-ended questions of the online questionnaire with 22 worldwide housing experts conducted in Nvivo 10, that was used to explore how displaced people can use their own labour to save money and time. This corresponds to research question 1.

**Chapter 5 – Semi-structured interviews:** This chapter presents the qualitative analysis and findings of the semi-structured interviews with 6 manufacturers of the 3D-LPs construction system and 1 international manufacturer of cement carried out in Nvivo 10. The purpose of these interviews was to explore how the 3D-LPs
construction system contributes to housing recovery after natural disasters, which is research question 2.

**Chapter 6 – Modelling:** This chapter describes the architectural-structural model of the housing prototype on BIM Revit 2013 with the 3D-LPs construction which was used to meet research aim, question 3 and the objectives.

**Chapter 7 – Conclusion and Recommendations:** This chapter presents the answers to the research aim and objectives. Furthermore, it includes the limitations, recommendations and ideas for further work are also presented.
2 Literature Review

2.1 Introduction

The keywords used in the search for literature were categorized under five subheadings: disasters, housing reconstruction programmes, community participation, BIM and 3D-LPs, in order to add context and greater understanding of the housing recovery problem affected by natural disasters. The major academic databases: Scopus, Science Direct, and official web pages of the United Nations (UN), World Bank, governmental and United State Geological Survey (USGS), as well as in the journals of the American Society of Civil Engineers (ASCE) and Elsevier Habitat international, have been reviewed in the field of project management.

This chapter is presented in three parts, first, disaster concepts and housing reconstruction programmes, second, the BIM system and third, the 3D-LPs construction system, to give a holistic view of the housing reconstruction problem and underpin the housing prototype proposed to address the problem.

The concepts examined in this chapter to understand the housing recovery problems are natural disasters, vulnerability and disaster management.
2.2 Natural disasters

According to Alcántara-Ayala, (2002) a natural disaster is defined as the appearance of a physical event, which causes an economic and social catastrophe. United Nations, (2011) has pointed out that the physical events that most affect hundreds of thousands of people each year in their lives and their properties are earthquakes, tsunamis, floods and hurricanes.

Earthquake

Khilyuk et al., (2000) refer that an earthquake is the release of energy accumulated between tectonic plates and blocks. When an earthquake occurs it generates the focus or hypocentre and epicentre, the focus or hypocentre is the rupture in the crust of the earth at depths of up to 50 kilometres from the epicentre. The epicentre is the point situated above the focus or hypocentre and is used to locate the earthquake on the surface of the earth. Additionally, Khilyuk et al., (2000) argument that the earthquakes are measured with the scales of Mercalli, Richter and Moment magnitude (Mm). The Mercalli scale measures the intensity of an earthquake on the surface of the earth and this is represented by Roman numbers; and the Richter scale measures the energy release and amplitude of waves, this is represented by ordinal numbers. Finally, Hanks, (1979) points out that the Moment scale is used to measure the energy release in the seismic moment, and it is a modification of the Richter scale which gives the most exact result.

Tsunamis

Satake, (2007) suggests that the earthquakes that occur in the seafloor and produce tsunamis are originated by volcanic eruptions, seafloor deformation and landslides. The tsunamis produce gravity waves up to 30 metres high that trigger stronger floods when they touch land; the tsunamis are studied like earthquakes due to energy dissipated into the Earth. According to Ramanujam and James, (2006) the tsunamis are classified as local, regional, and Pacific. Tsunamis that affect small areas are known as local tsunamis, the most common are the regional tsunamis; these are caused by volcanic eruptions, and tsunamis that affect large areas and cause serious damage are called Pacific tsunamis.
The USGS listed the largest earthquakes that occurred in the past decade according to their magnitude. Table 2-1 shows the magnitudes of earthquakes from 8.5 to 9.1 degrees at the moment of greatest magnitude and death toll.

<table>
<thead>
<tr>
<th>COUNTRIES/LOCATED</th>
<th>DATE OF EARTHQUAKE</th>
<th>MAGNITUDES RICHTER</th>
<th>DEATH TOLL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia Off the West Coast of Northern Sumatra</td>
<td>December 26th, 2004</td>
<td>9.1</td>
<td>227,898</td>
</tr>
<tr>
<td>Japan Near the East Coast of Honshu</td>
<td>March 11th, 2011</td>
<td>9.0</td>
<td>20,896</td>
</tr>
<tr>
<td>Chile Offshore Maule</td>
<td>February 27th, 2010</td>
<td>8.8</td>
<td>507</td>
</tr>
<tr>
<td>Indonesia Northern Sumatra</td>
<td>March 28th, 2005</td>
<td>8.6</td>
<td>1,313</td>
</tr>
<tr>
<td>Indonesia Southern Sumatra</td>
<td>September 12th, 2007</td>
<td>8.5</td>
<td>25</td>
</tr>
</tbody>
</table>


Table 2-2 shows the earthquakes from 7.0 to 7.6 degrees at the moment of greatest magnitude and death toll, because despite not having a magnitude greater than 8, they caused a large number of victims, mainly due to their duration, hypocentre and epicentre.

<table>
<thead>
<tr>
<th>COUNTRIES/LOCATED</th>
<th>DATE OF EARTHQUAKE</th>
<th>MAGNITUDES</th>
<th>FATALITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haiti Port-au-Prince</td>
<td>January 12th, 2010</td>
<td>7.0</td>
<td>316,000</td>
</tr>
<tr>
<td>China Eastern Sichuan</td>
<td>May 12th, 2008</td>
<td>7.9</td>
<td>87,587</td>
</tr>
<tr>
<td>Pakistan</td>
<td>August 10th, 2001</td>
<td>7.6</td>
<td>80,361</td>
</tr>
</tbody>
</table>


**Floods**

According to the USGS, (2011) floods are defined as an elevation in the water level that covers the earth’s surface. On the other hand Tariq et al., (2011) refer that floods are caused by tsunamis, hurricanes, cyclones, storms, and high tides. Additionally, the
United Nations (UN), (2011) and Costa, (2004) have reported that floods are responsible for the main human and economic losses throughout the world.

2.3 Vulnerability
According to Wei et al., (2004) vulnerability is defined as the inability to withstand and recover from a disaster. It is considered that the vulnerability of some countries towards natural disasters is increased by the following factors: a). geographic location, b). economic development, c). population growth, d). environmental degradation and climate change, and e). risk.

a). Geographic location
Hays, (2007) describes that the vulnerability by geographic location is due to geographical features of the Earth, since the Earth’s surface consists of 16 tectonic plates that dissipate energy when colliding with each other. This collision produces mountains, islands and geological faults that generate seismic activity. A study by Saldaña-Zorrilla, (2007) has found that countries located near the circum-Pacific belt are the most vulnerable to such physical phenomena, because these countries are located on a chain of active volcanoes and tectonic plates.

b). Economic development
Here was found a controversy, Toya and Skidmore, (2007) argue that developed countries suffer less loss than developing countries when they are hit by natural disasters, given that they have plans of prevention and mitigation that reduce the risks and vulnerability towards catastrophes; whilst Schumacher and Strobl, (2011) suggest that the vulnerability of developed countries depends on exposure to risk level and investment in preparedness. However, Leisnham, 2011 and Strobl, (2012) indicate that developing countries are the most vulnerable to natural disasters, due to economic conditions, education level and the absence of prevention plans.

c). Population growth
Davis, (1980) suggests that the vulnerability to natural disasters is increased by growth in the birth rate and population growth, given that this has been identified as the main cause of problems of overcrowding and poverty that preclude the implementation of prevention plans; another situation that increases vulnerability is the transformation of...
rural areas to urban areas, since Hochrainer and Mechler, (2011) have also identified that the concentration of population in small areas represents a major risk; it is estimated that there are 16 cities with a population of more than 10 million (each) and that the number will be expanded to 27 cities in 2025.

**d). Environmental degradation and climate change**

The research of Yasuhara et al., (2012) and Hans, (2007) suggest that climate change contributes to triggering geo disasters (Typhoon, earthquakes, and inundations) and that the increases in global temperature cause more frequent repetition of disasters.

**e). Risk**

The concept of risk has been defined by Jacobs et al., (2003) as the possibility of loss owing to natural and artificial disasters. While Kazuko, (2005) suggests that the risk of suffering a natural disaster is associated with vulnerability given the risk can be mitigated through disaster education. The following topic will relate risk and vulnerability with disaster management in order to explain the importance of these in housing recovery.

**2.3.1 Management**

After a disaster occurs Tinguaro et al., (2010) argue that NGOs are the first to deploy humanitarian aid coordination together with the government of the country affected, and are responsible for launching actions to restore the normal activity of those affected, as far as possible, given that they do not have a legal personality that allows them to make decisions in the reconstruction process. However, Coles et al., (2012), Steinberg, (2007) and, Chang et al., (2011) in recent studies have found that NGOs suffer from a lack of communication, organization and strong competition between them, and that the aforementioned deficiencies adversely affect the start of recovery of the devastated area; but despite the factors before mentioned to implement aid in areas hit by disaster, NGOs play an important role in the recovery, given that they represent an opportunity to overcome the crisis left by physical events in developing countries.

Two approaches examined concerning disaster management have given an idea of the phases that should be conducted in the recovery. The first approach suggests by
Nikbakhsh and Zanjirani, (2011) and Coppola, (2011) indicates that preparedness actions might contribute to reducing risks of human and economic losses, since these actions are planned in advance of the damage. These measures are: a) practice of drills where there are definite roles for all actors involved, b) training in acting quickly, c) equipment and tools development in order to handle rescue and recovery of services in the short term, as well as d) statutory authority to restore order in the area affected.

The second approach suggested by Seneviratne et al., (2010) refers that disaster management must take into account the following six matters, and proposes to link actions of preparedness with modification of regulations in order to achieve fast recovery after a disaster: a) The use of accurate technology to predict disasters and mitigate damage, b) The participation of all stakeholders in the preparation of prevention plans, c) Environmental protection to reduce damage and changes in the ecosystem, d) The modification to regulations in management of disasters, and, e) economic plans in order to have funds available after a disaster, in addition to appropriate regulations to manage international aid, and f) technical and operational factors which indicate who?, what?, how and when? measures will be taken post-disaster.

On the one hand Kaklauskas et al., (2009) propose to use only the experiences that can contribute to reducing damage according to the characteristics of each country. They point out that economic, social, technological, legislative, ethical and infrastructure constraints should be taken in account on applying the experiences in the same way as in the countries affected, and hence the suggestion to transform each one of these experiences, in order to make rational use of them. On the other hand Bolton, (1996) indicates that the experiences acquired in housing recovery are an opportunity to integrate low-income people in the permanent housing programmes, as well as to improve the resilience and sustainability of housing. Figure 2-1 gives a line of disaster management.
2.4 Disaster Resilience

Disaster Resilience can be better understood if this concept is divided into disaster and resilience. UNISDR, (2009) has defined a disaster as an event, natural or made by humans that produces disruption and loss of goods and human lives and causes severe impact in the economic sector or damage to the environment. People affected are often overwhelmed by the event and unable to recover on their own. Resilience is defined by Paton & Moore, (2006) as the capacity of an individual, group or community to return and to recover in an efficient way in a short time from the damage left by disasters. Therefore, Disaster Resilience according to Paton & Moore, (2006) and Gov UK, (2013) and the National Academies can be defined as the advanced actions to help people to overcome the damage caused by disasters quickly and efficiently to help to restore them at least to their original conditions. It is important to note that according to Paton & Moore, (2006) and Gov UK, (2013) resilience has four criteria for assessing the level of resilience of a country, community, group or individual, and that resilience is linked to the vulnerability of people.

1. **Context.** - Each population is affected in a different way; this depends, for instance, on whether it is an individual, group, community, society or country, region affected and institutional or government system. The most important point is to know against which disaster they will be protected.

2. **Disturbance.** – This determines the type of disaster and what actions should be implemented.
3. **Capacity to deal with disturbance.** - This element is the skill of the system to overcome the adverse situation, taking into account the incidence of the disaster, the vulnerability of the population and its adaptive capacities.

4. **Reaction to disturbance.** – This is the manner in which those affected face the consequences of the disaster and will determine whether the economic social and cultural conditions of the people affected will be better or worse after disasters.

2.5 **Housing recovery**

USGS (2004) reported that Indonesia and 13 other countries were affected by the major tsunami in the last decade the Indian Ocean Tsunami, which triggered earthquakes and floods that caused serious human and economic losses. According to the World Bank (2005) the recovery of these countries could be carried out thanks to international aid, NGOs and governments. However, although these fourteen countries shared the same physical event, the literature reviewed on housing reconstruction programmes show that their economic conditions, social structure, and policies interfered in the reconstruction of each country, and each country looked for a different way to face this problem. According to the World Bank (2014) “By 2030, 3 billion people, about 40% of the world's population, will need new housing and basic urban infrastructure and services.” The World Bank will develop systems to address this problem and indicates that a holistic approach to build affordable housing is necessary. The approach should involve stakeholders and help to manage raw materials, land, skills, and finance. It is important to highlight that the World Bank is responsible for developing systems for housing and these systems should be adequate for housing reconstruction after a disaster, see section 2.5.3. This section of chapter 2 explores the housing reconstruction programmes and the problems in their implementation.

2.5.1 **The Indian Ocean Tsunami and housing reconstruction programmes**

USGS, (2004) reported that the Indian Ocean Tsunami earthquake, which occurred on Sunday, December 26th, 2004 at 07:58:53 Coordinated Universal Time (UTC), was of magnitude 9.1 at 30km depth off the West coast of Northern Sumatra in Indonesia. This was felt by 14 countries in the Asiatic Continent and the African Continent. More specifically, the Indonesia earthquake, also called the Indian Ocean Tsunami, simultaneously affected Indonesia, Sri Lanka, India, Thailand, Malaysia, Bangladesh,
Myanmar and the Maldives in the Southeast of Asia, as well as Somalia, Kenya, Tanzania, South Africa and Madagascar in East Africa; Pilapitiya et al., (2006) indicated that it generated waves over 20 metres high which caused extensive floods. Table 2.3 shows five programmes used for the restoration of affected dwellings after the Indian Ocean Tsunami which occurred in 2004.

Table 2-3 Programmes used for housing reconstruction after the Indian Ocean Tsunami in 2004

<table>
<thead>
<tr>
<th>Housing Recovery Programme</th>
<th>Country</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner-Driven Reconstruction</td>
<td>Thailand, Sri Lanka and India</td>
<td>Hidellague and Usoof, (2010)</td>
</tr>
<tr>
<td>Agency-Driven Reconstruction in site or Donor Driven</td>
<td>India (Tamil Nadu) Sri Lanka</td>
<td>Da Silva and Batchelor, (2010) and Florian, (2007)</td>
</tr>
<tr>
<td>Agency-Driven Reconstruction in relocated site</td>
<td>India and Indonesia (Tamil Nadu and Aceh)</td>
<td>Jha et al., (2010)</td>
</tr>
</tbody>
</table>

2.5.2 Cash approach

The Cash approach has been referred by Aysan et al. (2006) as a programme that provides cash to poor people from developing countries for food, livelihood recovery, temporary and permanent shelters, and helps orphans and provides social protection through grants cash to householders for the construction of permanent houses. According to Lesley (2007) and Aysan et al. (2006), this programme can also be found in the literature as ‘Cash for Reconstruction and Repair’ (CFRR) and was adopted by International agencies and NGOs after the Indian Ocean Tsunami, which occurred in 2004 by International agencies and NGOs who provided cash to the displaced people from Indonesia, Sri Lanka and India to rent provisional houses, to relocate people affected towards safe areas, and to buy household items and housing reconstruction.

Da Silva and Batchelor, (2010) highlighted that after the Indian Ocean Tsunami occurred in 2004, International agencies and NGOs participated as facilitators in Indonesia to implement a Cash approach. NGOs were responsible for selecting householders under the regulations of the Kecamatan Development Project (KDP) and Urban Poverty Project (UPP) to provide them with cash in order that they could build
their houses by themselves under the slogan of self-construction. Houses built through the Cash approach were proposed as “one size fits all’ 36 m² using reinforced concrete and masonry.

Da Silva and Batchelor, (2010) also point out that the selected householders who benefited from a grant were free to look for construction materials and builders to build their dwellings. Additionally, Da Silva and Batchelor, (2010) reported that householders were hindered by their lack of knowledge on administration of construction. The causes were the lack of technical support, training and skills, in addition to the problems of scarcity of construction materials, and shortage of skilled labourers, as a result of which the dwellings were of poor quality and the reconstruction took longer, in addition to the cash being insufficient to build houses. In opinion of Da Silva and Batchelor, (2010) this approach has not been recognized as a successful reconstruction programme. However, despite all the problems faced during the reconstruction, Jha et al., (2010) reported that Indonesian people achieved a sense of belonging, due to their participation in reconstruction and the creation of temporary livelihoods.

2.5.3 Owner-Driven Reconstruction programme

Owner-Driven Reconstruction (ODR) according to Barenstein, (2010) and Taheri seems to have its origin in 1960 when John F.C. Turner, a pioneering architect in housing development started to study how people could self-build their dwellings after the Peruvian earthquake in 1960. Barenstein, (2010) also indicates that ODR is associated with the "assisted self-help" approach used in Latin America to encourage poor people in cities to build houses by themselves.

Barenstein, (2010) also indicates that this approach was used after the Indian Latur earthquake in 1993, and reappeared in 2001 after the earthquake which occurred in Gujarat. ODR according to Barenstein, (2010) was used to help with housing construction on a large scale for the first time due to the magnitude of the earthquake and the support provided by the World Bank and UN-Habitat. On other hand Lyons, (2010) points out that ODR has 10 years experience of large scale housing construction and highlights that after the Asian Tsunami ODR employed the labour of affected
people to reduce the cost of housing; the affected people were able to build their houses under monitoring of the NGOs.

According to Jha et al., (2010) ODR can be also found in the literature as Owner Driven Programme (ODP). The ODR or ODP approach is focused on helping individuals, groups and communities to restore their houses through a systematic framework consisting of financial, technical and administrative support. However, Hidellague and Usoof, (2010) indicate that the technical support offered during the rebuilding of Sri Lanka suffered from weakness, since there were not enough technical personnel to train community members. Despite this, Lyons, (2010) refers that ODR has been recognized for its transparency and encouragement to those affected to participate in the reconstruction of housing to give them a sense of ownership.

2.5.4 Community-Driven Reconstruction

This is supported by Multi-Donor Fund, (2006) that Community-driven reconstruction (CDR) is based on self-build programmes, to encourage those affected to rebuild their housing to give them a sense of belonging. This approach seems had been “developed by the Multi Donor Fund Housing and Settlements” from the World Bank. In line with the Multi-Donor Fund, (2006) Da Silva and Batchelor, (2010) and Barenstein, (2005) indicate that the NGOs act as facilitators to provide cash or aid in-kind and technical support. They point out that CDR is an approach focused on community participation, which was launched by the governments of Indonesia in Banda Aceh and the Maldives. Community Driven Reconstruction is most frequently associated with ODR, but CDR can be distinguished from ODR post-disaster, because the first guidelines for fostering community participation were published by the Indonesian government in July 2005.

As indicated by Da Silva and Batchelor, (2010) Steinberg, (2007) points out that CDR was implemented in Indonesia by NGOs to provide people with financial support donated by international aid, given that the Indonesia Government adopted the motto of “a people-centred and participative process.” This approach was used for housing recovery in the Maldives with the intention to empower those affected post disaster. However, Collier et al., (2003) mention that NGOs were hampered by construction
regulations, so that the quality of houses scarcely met the minimum construction standards, due to the lack of experience of NGOs in housing construction and political conditions. Hence, NGOs decided to change CDR to Donor Driven Reconstruction (DDR) leaving the affected people without the opportunity to participate in housing recovery.

### 2.5.5 Agency-Driven Reconstruction (in situ) or DDR

Donor-Driven Reconstruction (DDR) housing, also called Agency-Driven Reconstruction in situ (ADRIS) was identify by Lyons et al., (2010) as another programme used in Banda Aceh and Nian, India and Sri Lanka. According to Da Silva and Batchelor, (2010) and Florian, (2007) DDR is 40 years old and has been used for housing construction in developing countries to alleviate poverty. This approach was conducted by donors and agencies through hiring builders and contractors to build damaged houses after the 2004 Indian Ocean Tsunami. Donors and governments, by means of more than 100 national and international NGOs, were responsible for safeguarding the interests of the homeless people post-disaster.

In this programme, Steinberg, (2007) indicates that the builders and contractors were free to design, to build and to monitor the housing reconstruction, as a result of which the dwellings suffered from low quality and the homeless peoples were forced to wait for their houses. However, this programme was responsible for building most of the housing after the 2004 Indian Ocean Tsunami.

DDR encountered a large number of problems which have been identified by Chang et al., (2011) and Gaillard et al., (2008). These problems adversely affected housing recovery; some of the problems that occurred are listed below:

1. Competition among NGOs for economic resources and participation. National and International NGOs competed for financial resources to participate in housing reconstruction due to the availability of international financial aid. NGOs were little prepared to face rebuilding on a large scale; NGOs lacked technical experience, professional teams, facilities to carry out their activities and knowledge of social, economic and political problems, as well as local customs.
Hence, NGOs competed among themselves to participate in rebuilding, because they had experience in humanitarian aid and used DDR to overcome their weakness, but the NGOs lacked suitable monitoring of consulters and builders Chang et al., (2011).

2. The shortage of transport and construction materials was another problem that affected housing rebuilding, because the roads were damaged. Construction materials were in short supply, mainly timber that was acquired from the international market; this situation led to delays and housing cost overruns.

3. NGOs faced problems in meeting the minimal construction regulations established by the BRR, because builders were seriously affected by the lack of skilled workers and availability of construction materials (Chang et al., 2011). According to Gaillard et al., (2008) to overcome this situation NGOs hired consultants, builders and contractors as well as skilled works from overseas.

4. Despite the Government and NGOs giving priority to community participation, they were unable to integrate homeless people in rebuilding housing under the DDR, because the reconstruction was controlled by consultants and builders (Chang et al., 2011).

5. The political situation in Indonesia was not stable before the Indian Ocean Tsunami, so that NGOs took several months to implement the first actions to help with rebuilding this region (Gaillard et al., 2008).

2.5.6 Agency-Driven Reconstruction in Relocated Site
Agency-Driven Reconstruction in relocated site (ADRRS) is referred by Jha et al., (2010) as an approach similar to ADRIS. NGOs hired constructors and consultants to rebuild housing in new plots after the Indian Ocean Tsunami. Hidellague and Usoof, (2010) have indicated that homeless people were relocated in safe areas to avoid the possibility of being damaged by future disasters. People who were settled near to the
coastline were relocated to a new area called the buffer zone. NGOs and Agencies bought land to build a new settlement and located displaced people there.

2.5.7 Housing reconstruction examples

Tad et al., describe that the areas that suffered most damage from the Indian Ocean Tsunami were Banda Aceh in Indonesia, Sri Lanka, India, Thailand, and Bangladesh. In order to explain the actions carried out for housing recovery, given that the amount of housing damaged was exponential, the following cases are presented:

- Banda Aceh and Nias in Indonesia.
- Sri Lanka and
- India

2.5.8 Banda Aceh and Nias in Indonesia

The housing damage in Banda Aceh and Nias in Indonesia, caused by the earthquake of 24th, December 2004, was increased by the earthquake that occurred on March 28th, 2005 in the same place, the number of dwellings affected is presented in Table 2-4.

<table>
<thead>
<tr>
<th>Housing</th>
<th>Aceh</th>
<th>Nias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total damaged</td>
<td>88,000</td>
<td>13,000</td>
</tr>
<tr>
<td>Partially damaged</td>
<td>71,000</td>
<td>24,000</td>
</tr>
<tr>
<td>Total</td>
<td>159,000</td>
<td>37,000</td>
</tr>
</tbody>
</table>

According to Steinberg, (2007) housing recovery in Banda Aceh and Nias in Indonesia was carried out by Badan Perencanaan Pembangunan Nasional Indonesian Institution (BAPPENAS) which translates to Agency for National Development Planning and the Ministry of Public Works (MPW); in addition, the aforementioned recovery was continued by Rehabilitation and Reconstruction Board (RRB) who had a big task, given that it was responsible for coordinating 120 NGOs and disaster management.

In the first stage of the RRB Steinberg, (2007) refers that NGOs held up the idea of prefabricated houses to solve the reconstruction problem, but that idea did not prosper and existing housing programmes from the World Bank were implemented through the Multi-Donor Fund (MDF). These programmes were the Kecamatan Development
Project (KDP) and Urban Poverty Project (UPP), which according to the Bank World, (2000) are two housing programmes that consist of providing a subsidy to the homeless people on condition that they buy construction materials as well as hiring and supervising labour in the construction of their homes.

Guggenheim et al., (2004) argument that KDP was a programme developed in 1997 by the World Bank to alleviate poverty in Indonesia in 2004 to help more than 28,000 villages. Similarly, the World Bank, (2005) refers that this programme works closely with the community, who actively participate in projects to improve the education, health and opportunity generation of employment in rural communities. KDP was used after the earthquake occurred to build housing through cash grants, under regulation of KDP.

Chang et al., (2011) identified another programme for housing reconstruction after the Indian Ocean Tsunami which was used in Banda Aceh and Nian which was Donor-Driven Housing; this was carried out by NGOs. According to the research carried out by Chang et al., (2011) the NGOs were responsible for looking for builders to build damaged housing and they implemented their own projects; however, being donor-driven, it encountered a large number of problems that adversely affected housing recovery; the problems that occurred are listed below.

1. Competition among NGOs for economic resources and participation.
2. The shortage of transport and construction materials (Chang et al., 2011).
3. The inability of builders to meet the standards (Chang et al., 2011).
4. The lack of community involvement (Chang et al., 2011).
5. Political problems (Gaillard et al., 2008).

On the other hand, for the rebuilding of countries damaged by the Indian Ocean Tsunami, several housing programmes were launched by 100 agencies. Lyons et al., (2010) argued that those 100 agencies were supported by international donors and that the housing programmes were based on two main programmes: Donor-Driven Reconstruction (DDR) and Owner-Driven Reconstruction (ODR), both are 40 years old and they have experience in dwellings construction to alleviate poverty, although ODR has only 10 years of experience in housing construction on a large scale.
Shaw, (2010) comments that the agencies were free to design housing by themselves and they could choose between DDR and ODR for rebuilding the area affected. However, the Urban Development Authority (UDA) in Sri Lanka and India established a minimal standard to design the houses, which was focused on size and backyard, hence the dwellings were built with different kinds of construction materials and construction processes.

An example of housing used in Indonesia is illustrated below it is based on Shaw, (2010). The dwelling was allowed 46.5 m² which included two bedrooms, a living room, kitchen and bathroom with latrine. “The minimum room dimensions were: bedroom 8m²; kitchen 5m²; store 2.5 m², lavatory 1.36m² (for pedestal WC) 1.04 m²; (for latrine) 1.62 m²” with a minimum room height of 2.8 m in the bedrooms, lounge, kitchen and 2.20 m in the bathroom, lavatory, garage, balcony and terrace. The backyard was dimensioned in relation to storeys; for one-two storey houses: 1m in front and 2.3m backyard; and for three storey houses: 1m in front and 3m backyard. This dwelling is shown in Figure 2-2.

In areas where the land was scarce the dwellings were built in apartments of 22m² which included a bedroom of 15m², a bathroom and a kitchen; the size of the land to build housing or apartments varied from 506m² for areas without hydraulic and sanitary installations to 152m² with hydraulic and sanitary installations Shaw, (2010).
Shaw, (2010) points out that the designs used by agencies faced some problems, mainly due to the characteristics of communities affected. One problem was with the design of the kitchens (Figure 2-3); they were not designed as open spaces which Indonesian people require due to using a bio-fuel cooker. Another problem with the design implemented in DDR was the lack of participation of displaced people, given that the builders built the minimum size housing without previous knowledge of dwellers’ needs.

In relation to construction materials used to build houses Shaw, (2010) mentions that the DDR and ODR used concrete floor slabs up to 10 cm in depth; however the soil conditions, together with bad construction processes, caused cracking in the foundation although sometimes the displaced people looked for extra funds and they made the foundation over 15 cm in depth. The walls were built from timber, masonry, clay blocks and concrete. The roofs played an important role; since asbestos roofs were banned, they were made of clay tiles on a timber frame, concrete and timber rafters. However, the clay tiles presented problems with sealing, since they allowed the passage of water.

2.5.9 Sri Lanka

According to Yamada et al., (2006) the waves produced by the Indian Ocean tsunami were felt in the Bay of Bengal, the Andaman Sea and Indian Ocean; the damage to housing was quantified in billions of dollars and 114,069 dwellings were affected. Jha et al., (2010) have mentioned that the recovery was achieved in 5 years with international aid. On the one hand Lyons, (2009) indicated that for housing recovery
in Sri Lanka, two programmes were carried out: “Donor-Driven Reconstruction” and “Owner-Driven Reconstruction”. In the Donor-Driven Reconstruction programme, the displaced remained in temporary shelters, whilst NGOs were responsible for looking for contractors to build permanent houses. On the other hand Steinberg, (2007) points out that in DDR the main actors were NGOs given that, once government had authorized and processed the regulation of the land, they were free to bring in housing prototypes and labour, which resulted in increases in costs and quality of housing, since building materials and labour were not available, mainly owing to higher timber costs, transport problems and lack of skilled workers.

Lyons, (2009) also highlights that in Owner-Driver Reconstruction programme the homeless people who were owners of land were allowed to repair or rebuild their house on the same site. The government in coordination with NGOs assessed damage to housing and gave economic support to owners to build their housing by themselves. They were free to choose materials and labour, and many people decided to be helped by relatives.

2.5.10 India
A recent study conducted by Mascarenhas and Jayakumar, (2008) found that housing situated along the coast of Tamil Nadu had totally collapsed, and that the sand dunes and dune vegetation had suffered grave damage, because waves of 6.5m had flooded on average 247m of beach. Table 2-5 shows the damage occurring in India in 2004 due to the earthquake off the West coast of Northern Sumatra, Indonesia.

<table>
<thead>
<tr>
<th>The Indian Ocean Tsunami 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Places Damaged</td>
</tr>
<tr>
<td>Villages Damaged</td>
</tr>
<tr>
<td>Houses Totally Collapsed</td>
</tr>
<tr>
<td>Death toll</td>
</tr>
</tbody>
</table>

Kumaran and Negi, (2006) indicated that the areas damaged by the tsunami in the Bay of Bengal were at high risk and reported that the government of Sri Lanka banned rebuilding homes for homeless people in the same place, and the displaced people were moved to shelters to wait for a dwelling located outside the district. In addition, the
government gave encouragement to homeless people to build homes by themselves in areas of low risk through the livelihood programme, which had been previously used to combat the deficit of housing and poverty. This programme was carried out with the participation of community and NGOs as well as by government, and took 5 years.

2.6 Community participation

Community participation has been identified by Jha et al., (2010) as an important component to address the housing reconstruction problem post-disaster. Lyon, 2010 has indicated that community participation help to give a sense of ownership. A similar view is held by Berenstein, (2010) who has recognized that the programmes that encourage the participation of affected people contribute to that those affected can achieve a sense of belonging. The ladder of community participation adapted by Davidson shows five levels to involve affected people in housing reconstruction (See Figure 2-4).

![Figure 2-4 Ladder of community participation adapted by Davidson et al., (2007)](image)

2.6.1 Community participation levels

The ladder shows how community members could participate in housing projects to achieve control over a project (Figure 2-4). The level at the bottom is ‘manipulate’; in this level people do not achieve control over the project. The original ladder indicates that this level was created to have a figure that would protect the right of citizens, since this ladder was created with the idea that citizens could participate in urban renewal plans. Therefore, advisory committees or advisory boards as representative figures emerged, which were established with the purpose of "educating", but members of these committees lack the power to make decisions, so this level does not provide any control Arnstein, (2007).
The following level after ‘manipulate’ is ‘inform’, which is related to providing information about rights, responsibilities and options Arnstein, (2007). This is the first step to carry people towards an active participation Davidson et al., (2007). ‘Consult’ is the third level, this provides a small amount of control; however, it does not guarantee that people’s ideas and concerns will be considered in addressing the situation, given that the opinions of people are collected by surveys, private or public meetings and summarized by numbers rather than actions to be carried out Arnstein, (2007). ‘Collaborate’ is the second level in the ladder adapted by Davidson et al., (2007) which is related to asking people about their needs and wants. Davidson argues that this level still provides no assurance that the wishes and needs will be satisfied. At the top is ‘empower’, which provides control, since this level guarantees that “participants or residents can govern a programme or an institution, be in full charge of policy and managerial aspects and be able to negotiate the conditions under which “outsider” may change them” Arnstein, (2007).

2.7 The BIM system
This section is to explain briefly what the BIM system is, since it was used to model a housing architectural-structural prototype as part of the study to address the housing reconstruction problem.

BIM is defined by Taylor, (2012) as “a process that allows information generated by one party to flow seamlessly to other parties for beneficial reuse” and it is also defined by McGraw, (2012) as “The process of creating and using digital models for design, construction and/or operations of projects”. A similar view is held by Byron, (2006) due to that BIM is also considered a digital technology in the construction industry that is pushing and pulling toward a great shift, because the life cycle of a project is shared and understood by designers, surveyors, architects, engineers and customers.

According to Eastman et al., (2008) BIM was created and known as “Building Information Models” or “Building Information Modelling” fifteen years ago, however it might have been developed many decades ago. In 1975 Charles M. Eastman from AIA journal published information about a “Building Description System” and in the
1970s -1980s appeared “Building Product Models” and “Product Information Models” developed in USA and Finland respectively. In 1980, Germany also developed BauInformatik which was translated into English as “Building Information Model”. But it was not until 1986 that Building Information Modelling was published by Robert Aish who described it as BIM and showed its use in the refurbishment of Terminal 3 at Heathrow Airport.

In an investigation conducted by Byron, (2006), it is suggested that the Architecture, Engineering and Construction (AEC) industry has recently shown a great interest in Building Information Modelling (BIM), due to the fact that BIM adds value to projects, given that it uses computable data to allow building design to be seen before and after implementation of a project, since the projects are presented in virtual form to the stakeholders, thus they can do a best analysis of the cost-effectiveness of the design and anticipate technical requirements.

On the other hand Zhu, (2010) states that BIM is a platform that shares designs and data, and generates logistical, project management and economic estimates. BIM also makes constant assessments of the progress of construction; the modifications are updated allowing the stakeholders to know the shifts and the modifications made to designs, which are intelligently altered in the economic estimations, budgets and logistics. According to Eastman et al., (2008) the designs are displayed in 3D to create an environment more like real construction. BIM can be implemented through different systems: AllPlan, ArchiCAD, Autodesk, Revit, Bentley Building, DigitalProject and Riva are some enterprises that offer this platform.

2.7.1 The dimensions in BIM
Models designed using the BIM according to Chau et al., (2004) can be displayed in 3D, 4D (time) and 5D (cost and time). A 3D design is a geometric representation that can display graphics to visualize structural elements, construction activities and temporary premises. The construction stages of a project can also be presented in graphics to identify the progression and stage of operation. The construction of the main project such as temporary offices, sites to store building materials and assembly of the structure can be also displayed in 3D graphics. Figure 2-5 shows an architectural
3D plan created on the BIM system of detached houses. The houses are at different stages of construction, so that a graphic can show the progression of the project.

**4D in the BIM system**

VICO, (2012) indicates that the graphs obtained from 3D geometry models on the BIM system can be used to create projects in 4D. A 4D model on the BIM system is the graphical representation of sequencing and scheduling of stages of a project for the optimization and control of resources. A 4D schedule displays the quantities and locations where the project is going on, as well as the activities performed and for performing by crews in the site work and their productivity rates. According to Baker et al., (2012) schedules also display prices in specific regions. These actions allow the project to flow appropriately and duration of activities to be defined to optimize the productivity of the crews and reduce project risk, given that the risk activities and delays are able to be identified in the 4D schedules. A summarized 4D is achieved when the 3D models created on the BIM system are associated with time through other software to create scheduling and this is done by the new versions of the BIM system developed by Revit.
The activities scheduling can be modified to achieve optimization, given that the activities impeding the suitable development of the tasks in the worksite can be rethought due to the 4D schedules displaying the bottlenecks and slack values.

- **5D in the BIM system**
  A 5D according to VICO, (2012) in the BIM is the product of drawing, models, quantity takeoff, sequencing and scheduling. The 3D models are the baseline for quantity takeoff, which is used to prepare the 4D schedules and the 5D estimating. The quantity takeoff is multiplied by cost/unit plus mark up in order to obtain the cost, namely, the estimating 5D.

Zhao, (2012) states that a 5D in the BIM system facilitates understanding among constructors, designers, architects and clients, due to the information generated being displayed through graphs and databases. 5D costs or estimation of a project is achieved after obtaining the quantity takeoff from 3D models, as this information is used to plan the construction stages and their durations carry the project to the 4D. Consequently, risk activities can be identified and rethought during the lifecycle. 5D in the BIM system adds value to projects, because any changes performed in 2D drawing are identifiable in 3D models and 4D schedules. So, these contribute to minimizing mistakes not perceived in the 2D drawings. However, the BIM system requires experienced professionals in construction management for projects to flow properly.

2.8 **Lightweight Panels**

This section explains briefly what the lightweight panels are since these were used to model a housing architectural-structural prototype as part of the study to address the housing reconstruction problem.

Before explaining what the lightweight panels are it is important to highlight that in order to generate a housing prototype design able to bear damage caused by natural disasters, the construction materials were sought in the construction market with the following characteristics: resistant to earthquakes, tsunamis, hurricanes and flooding, high quality, low cost and able to replace traditional materials. In this sense the bases suggested by Jha et al., (2010) were consulted in the guiding principles for Housing
Designed Construction Technology (HDCTs) from the handbook for reconstruction after Natural Disaster by the World Bank that all these should be taken into account in a universal design and construction technology for housing recovery.

The HDCTs also suggests that the universal design of housing should be coherent with construction materials. The universal design of housing should be accessible and adaptable to all people to make life easier for users. In addition, it should have adequate size and be flexible to give comfort and efficiency. According to Jha et al., (2010) the universal design should also be able to reduce hazards and damage caused by accidental actions, hence, it is recommend that the construction materials to design the housing should take into account the regulations of construction, the availability of materials, the cost and benefit, as well as mitigation of risk, rapid construction and climatic and social cultural characteristics of the area affected, in addition to environment impact, training to skilled people.

Hence panels from gypsum, polystyrene, and natural fibre with gypsum were found to be a possibility to build the housing prototype. Thus, two panels type are described in this section by using information from suppliers from two enterprise leaders in Mexico and Latin America. The information from suppliers helped to know the physical and mechanical behaviour of the lightweight panels and this information was corroborated with academic literature.

The first panel is manufactured by Panel W an enterprise established in Mexico since 1975. According to W, (2012) the panels from Panel W form part of a construction system composed of polystyrene cores and a three dimensional grid of galvanized steel wires which are joined to build a monolithic structure.

The second panel is produce by Panel Rey. According to Rey, (2012) it is a system of frames of galvanized steel composed of channels which are placed in foundation along with cardboard sheet of different composition.
2.9 Three dimensional lightweight panels construction system

According to the International Conference of Building Official, report 2440 dated July 1978 the company CSM Incorporated located in Chino California presented a construction system based on structural roof and walls panels for commercial and residential construction. It consists of a “Three-dimensional No 14-gauge wire frame utilizing a truss concept for strength and stiffness” provided with a polyurethane foam core which is fixed into the wire frame to allow a space between wire frame and foam core. Such spaces were thought to enable the adhesion of the mortar or concrete on both sides of the panels and to contribute to build structural walls and roofs that work as a monolithic structure. In order to identify this system in the body of this thesis the system produced by Panel W is referred as 3D-LPs construction system.

Moreover, CSM, (1978) also refers that the 3D-LPs can be provided of sheet of polyurethane or polygonal bars made of polystyrene. Thus the studies by Hollaway and Head, (2000) indicate that in order that the cores can be obtained from polymers two stages should be carried out to produce these: in the first stage, a gas is spread in a mass of polymer, and in the second stage a chemical compound is aggregated to increase the original volume of the polymer, until tiny particles are obtained, which are subsequently used in thermoplastic or thermosetting polymer processes. Hollaway and Head, (2000) have also established that the cores of the panels are a result of a mix of polymers in the shape of sheets or bars called cores and a three-dimensional grid of galvanized wires. Figure 2-6 shows the panels composed of cores of sheet and bars as well as grids of galvanized steel.

![Figure 2-6 3D-LPs (core and sheets (5), bars (1, 2, 3, 4) and grids Credit: photo Company W Panel](image-url)
On the one hand, CSM, (1978) refers also that the panels are lightweight, and among their qualities can be identified their fast installation during construction, as well as their low cost and high performance, in as much as they generate minimal waste of material. Additionally, Medina et al., (2008) in their research indicated that the 3D-LPs have low thermal conductivity which reaches an R-value of 2.47 m² K/W, which is low than insulation with fibreglass (1.73 m² K/W). In addition to that, they can reduce by 20% the air passing through them compared with wood panels.

Moreover, the studies conducted by Rezaifar et al., (2007) have shown that the 3D-LPs obtained rigidity and greater resistance to shear forces, due to the characteristics and position of the wires that form the grids of the structure of the panels. These wires of galvanized steel are 2 mm in diameter and these are obtained by a cold rolling method under regulations of the American Society for Testing and Materials ASTM A82; such wires are placed in a three-dimensional grid, forming a welded wire fabric with a resistance to stress of 520 MPa. These wires are more resistant than a steel bar of 10 mm diameter which has a value of 470 MPa. Stevenson, (1986) concludes that the three-dimensional grid is a structure composed of two grids and several welding wires in a V-shape that allows the structure mechanical behaviour; each welding point is a node that provides stiffness to the structure. According to Stevenson, (1998) a number of trusses are placed on a panel according to the spacing of the mesh; these are manufactured in accordance with the patent to build reinforced structural panels. For instance, the panels of 1.22 m length by 2.44 m width and 2” structure thicknesses have a mesh structure of 51 x 51mm. Panels of this size are composed of approximately 24 trusses. Trusses, foam cores, wires and separation of grids can be observed in Figure 2-7.
Furthermore, W, (2012) points out that the polystyrene panels are able to bear load caused by natural disaster and that Panel W Company distributes panels for making structural walls, semi-structural and roof in Mexico and Latin America, which have been recommended by the UN, because the polystyrene used in the panels does not harm the environment. In addition, W, (2012) refers that the panels manufactured by Panel W have obtained a certificate issued by the Florida Approval FL10614 due to the quality of the walls. Besides, has informed that the panels W have been tested by the Architectural Testing under conditions of wind up 320 km/hr. Escrow, (2012) indicates that these panels are manufactured in countries such as: China, India, Spain and USA among others.

CSM, (1978) indicates that the installation of the 3D-LPs to build residential or commercial building should be conducted on several steps: in the first step the panels
are placed on the foundations, this is achieved with a steel bar of 10 mm diameter, which is buried 30 cm deep and placed at a separation of 60 cm interspersed with one another (distances are as a result of a structural analysis), the second step is to connect the panels to provide continuity and ensure structural integrity. Moreover, in accordance to Rezaifar et al., (2007) the connections between panels should be made with ties of annealed wire, which have a resistance to stress of 570 MPa. The walls forming the corners should be connected with steel bars of 18 cm bent to 90 degrees and the longer walls should be connected with galvanized steel mesh, in the last step Rezaifar et al., (2007) and CSM, (1978) indicate that a layer of a water-cement-sand and additives mix should be placed on both sides to build monolithic structure.

As pointed out by Rezaifar et al., (2007), CSM, (1978) and Tecnopanel, (2002) their studies confirm that the layers of concrete or mortar on the panels contribute to creating monolithic walls that act as reinforced concrete walls. According to ASTM, (1996) this mixture must meet mechanical and physical properties such as: strength, elasticity, hardness, and workability. The layers placed on panels for the construction of the roof of a structure under the 3D-LPs construction system are of at least 60 mm of concrete on the superior side to create a compressive layer that acts as a slab, while the inferior side is covered by a layer of a least 20 mm of mortar (Tecnopanel, 2002). Figure 2-8 (a) shows the placement and connection of the 3D-LPs with meshes and steel bars; and Figure 2-8 (b) shows the walls covered by a mortar mixture, additionally it can be seen that the corners do not have columns and that the foundation is a slab of approximately 10 centimetres thickness.
2.9.1 Shear strength

The shear strength is defined by Corrosionpedia, (2014) as: “The material’s ability to resist forces that can cause the internal structure of the material to slide against itself”. Besides, Atkins and Escudier, (2013) refer that “The maximum shear stress that can be withstood by a material either (a) before plasticity occurs or (b) before rupture”.

In consequence and in order to test the shear strength of 3D-LPs Kabir and Nasab, (2002) conducted a study in a 3D-LP of 0.55 metres height by 1.0 m width and 0.16 cm thickness cover of a mortar layer on both faces was stressed firstly up to 6000 kg in the elastic region and 7000 kg in the tension side. The study reported that during this stage the panels showed behaviour similar to cantilever beams and apparition of little cracks without altering the sample. However, when the 3D-LP was tested to more than 7000 kg of stress the apparition of cracks was more evidenced on the panels, but when the panel was loaded to 11,000 kg it suffered from extreme fatigue until breaking. Hence, according to Kabir and Nasab, (2002) a panel collapses when this is loaded to 12,000 kg. These findings suggested that 3D-LPs are able to bear up to 11,000 kg of load. Figure 2-9 shows the assembling of a test to measure shear strength on a 3D-LP.
2.9.2 Bending stress

In accordance with Kabir and Nasab, (2002) who conducted a research on 3d-LPs a wall made of 3D-LP is able to withstand from 1400 to 1600 kg for lateral bending and maximum deflection of 6 to 8 cm while a roof slab panel is able to withstand from 1300 to 2200 kg on a lateral bending test, namely, ultimate load. Figure 2-10 shows the preparation of the test. Figure 2-11 shows the failure horizontally of the panel of 3.00 m height by 1.0 m width and 0.16 cm thickness using mortar $f'c=100$ kg on both sides (Kabir and Nasab, 2002).
2.9.3 Seismic behaviour

The studies conducted by Rezaifar et al., (2007) indicate that the 3D-LPs construction system is able to bear the energy release by earthquakes due to their capacity to withstand the forces produced by dynamic loads. The study indicates that the walls of a room of one story built with 3D-LPs under dynamic loads are susceptible to suffering cracks without damage to the structure. Rezaifar et al., (2007) also point out that the 3D-LPs construction system can perform well in areas prone to suffering earthquakes of grand magnitude, but special attention should be paid to structural calculations using the 3D-LPs construction system. The walls corners require reinforcement with steel bars or meshes made of galvanized steel to avoid cracks. Figure 2-12 shows cracks created by higher dynamic forces.

![Figure 2-12 Cracks on a 3D-LPs after testing in a shaking table under dynamic forces Kabir and Nasab, (2002)](image)

2.10 Gypsum Panels

The gypsum panel is a system of frames of galvanized steel composed of channels which are placed in the foundation and panels composed of a nucleus of gypsum, fibres additives and cardboard or paper treated manufactured by Rey Panel Company. According to Chase, (1997) the process to manufacture gypsum wallboard or panels begins when a semi-liquid composed of calcium sulphate anhydrite \( \text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O} \) or calcium sulphate anhydrite \( \text{CaSO}_4 \) is placed between two layers of paper and subjected to a process called calcinations to obtain maximum hardness. Moreover, the
resistance to fire of gypsum panels is due to amount of water that they contain, given that when the gypsum is subjected to high temperatures the particles of water contained in the panels are displaced and the gypsum is rehydrated for retarding the propagation of fire. Chase, (1997) also points out that in order to provide strength to the gypsum, paper sheet are added on both sides, their main function is to produce bending forces which is accomplished which is accomplished through the tension given to paper.

According to Chase, (1997) in recent years the gypsum nucleus of panels has undergone several modifications that have contributed to the resistance of panels, among these are the addition of natural and artificial fibre, wood, polypropylene, minerals and resins. Also the paper sheets have changed in order to increase their mechanical behaviour.

Mohammad, (1985) indicates that both sides of the panels are covered with fibreglass, cardboard or paper treated to bear humidity, fungi and high temperature, as well as to receive paint, tilling or other finishing. However, Xu and Martinez, (2006) point out that this panels cannot be used in slabs and it is necessary to mix them with steel slabs to complete the housing. The study conducted by Xu and Martinez, (2006) refers that the gypsum panel is resistant to earthquakes, fires and wind, given that the panels are placed in frame of galvanized steel that ensures the structural integrity, however a structural calculation may be carried out by structural engineers.

According to Borreguero et al., (2011) the thermal properties of gypsum panels are acquired from the properties of gypsum since that is able to retain energy. However, Heim and Clarke, (2004) indicate that the thermal behaviour of gypsum panels depends on the season but it estimated that it contributes to saving energy. Figure 2-13 shows water resistant, exterior and fire rated gypsum panels.
Rey, (2012) points out that the gypsum panels have been manufactured since 1986 with highest standards of quality and distributed in Mexico, USA, Canada, Centre and South America. Rey, (2012) also refers that the panels from gypsum manufactured by Panel Rey have obtained certificates and recognition, since the galvanized steel used in the frame and sheet of gypsum passed the test of American Society for Testing and Materials (ASTM) E-19, The Panel Rey has also been classified as non-asbestos containing material, in addition Panel Rey has its own quarries of plaster rock and paper plants.

2.10.1 Mechanical properties of Gypsum panels
The gypsum panels are seismic and fire resistant, due to their composition they are able to bear load up to 3032 kg/m². The table 2-6 shows the properties of gypsum panels. Vc is the seismic shear, resistance to fire and allowable load.

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>GYPSUM PANELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seismic resistant</td>
<td>Vc = 4588 kg</td>
</tr>
<tr>
<td>Resistance to fire</td>
<td>1 to 2 hours</td>
</tr>
<tr>
<td>Allowable load</td>
<td>3032 kg/m²</td>
</tr>
</tbody>
</table>

Figure 2-14 shows the structure composed of channels of galvanized steel which are covered by gypsum panels to complete the structure system developed by Panel Rey.
2.11 Summary and conclusion of the Chapter

The literature review focuses on the context of disasters and housing reconstruction problems after the Indian Ocean Tsunami which occurred in 2004. Focus was made on five housing reconstruction programmes and show the way in which NGOs and governments faced the challenge for housing reconstruction on a large scale.

The literature reveals that there is a gap in construction knowledge of some NGOs for housing reconstruction on a large scale after a disaster. The literature also reveals that the involvement of community members in housing reconstruction is limited by the reconstruction programme and that the participation of the affected people plays an important role in housing recovery. The literature review also focuses on the BIM and on lightweight panels. Two types of panels were reviewed on their physical and mechanical properties: The 3D-LPs and the Panels Rey construction systems for researching how they can be used to address the research aim. It can be concluded that the panels were found an option to design a basic housing prototype.
3 Methodology

3.1 Introduction
This chapter explains the research design, philosophy, approach, and strategy, along with the computer modelling of a housing prototype as part of the research process adopted to study the post-disaster housing reconstruction problem. The research design has been focused to reflect the research process by clarifying the stages that will be addressed. Whilst the holistic philosophy indicates how the research questions were answered and mixed methods chosen emphasize the research strategy. The overall purpose of the chapter is to provide a robust rationale for the selection of the research process in order to meet the research aim and objectives in order to establish the limitations. This chapter has followed the principle established by Redman and Mory, (2005) which indicates that the methodology is a step-by-step procedure to solve the research problem and research methods are the tools and techniques used to conduct the research.

3.2 Research process
The research process consists of several steps to meet the research aim and objectives. According to Fang et al., (2008) a research process can be composed of between seven and fourteen steps, which should be focused on definition of the problem, literature review, ethical and cultural issues, research questions, research approaches, the determination of variables, sample and data collection methods, analysis and interpretation, and writing and dissemination of findings.
The process was composed of seven steps:

- First step, the definition of the problem, which was achieved through reviewing the literature around the approaches used for housing reconstruction after the Ocean Indian Tsunami that affected simultaneously fourteen countries in 2004.

- Second step, the formulation of three research questions.

- Third step, the determination of a qualitative and quantitative approach.

- Fourth step, the submission of an Ethical Approval to apply an online questionnaire, semi-structured interviews with open-ended questions and the modelling of a basic house prototype in BIM with lightweight panels.

- Fifth step, the coding, analysis and interpretation of data collected.

- Sixth step, the validation of results and the verification of the modelling of a basic housing prototype modelled in BIM.

- Seventh step, the presentation of results and conclusions to meet the research aim and objectives.

Figure 3-1 shows the summary of the research process. The steps have been grouped in phases to show how the research study was conducted.
Housing reconstruction problem post-disasters

- Literature review

  Request more research?

    Yes

    Research design

1st Phase to define the research questions and research approach

  Request more research?

    Yes

    Research design

2nd Phase to request an ethical approval for the application of a survey and interviews which included data collection, analysis and interpretation.

  Request more research?

    Yes

    Research design

3rd Phase to model a housing prototype in BIM and to do data validation and verification of the modeling.

  Draw conclusions?

    Yes

    Findings and Recommendations

Figure 3-1 Research process
3.2.1 Research design

According to Saunders et al., (2002) the research design should be used to devise a general plan about how the research questions will be answering, how the data will be collected, analysed and to define constraints and ethical and cultural issues. The study was conducted based on three research questions; data collection was carried out by the application of an online questionnaire and semi-structured interviews. The analytic strategy was a qualitative analysis, conducted by means of pattern matching; and the study validation was conducted by triangulation techniques. Figure 3-2 shows the research design which is explained and justified in subsequent sections.

![Figure 3-2 Research Design](image)

3.2.2 Research philosophy

In order to underpin the research study a research philosophy was sought in the literature to explore the problem outlined in Chapter 2. Mangan et al., 2004 point out that positivism and phenomenology appear to be the research paradigms that are
applied to explore the truth and facts about the world by researchers. These two paradigms are shown as following:

**Positivist paradigm.** - Quantitative, Objective, Scientific, Experimentalist, Traditionalist, Hypothetic deductive and Social Constructionism.

**Phenomenological paradigm.** - Qualitative, Subjectivist, Humanistic, Interpretivist/hermeneutic and Inductive.

Before passing to explain each paradigm it is convenient to highlight the viewpoint of Saunders et al., (2003). He points out that the practical reality is that the research rarely falls into one philosophical domain, and management research in particular is often a mixture between positivist and phenomenological strategies. This is not due to an inability to decide between the various alternatives but due to the reason that all methods are valuable if used appropriately. Consequently, in opinion of Saunders et al., (2003) the researches can include elements of both approaches.

Guba and Lincoln, (1994) point that a positivist is objectivist, due to that positivist researchers believe that their findings to be “true”. Positivist paradigm is focused on verification of hypotheses, and it is usually associated with quantitative methods. A positivist methodology is experimental or manipulative and researchers view reality as independent of, and external to, the observer. Preferred methods include operationalizing concepts so that they can be measured by taking large samples.

Guba and Lincoln, (1994) point out that a phenomenological paradigm is subjective, so phenomenological researchers believe their findings should be “literally created” though the research process as the observer is part of what observed and the science is driven by human interest. Phenomenological paradigm is focused on meanings to try understanding what is happening, looking at the totality of each situation working from a constructivist (or interpretivist) framework holds a relative ontology on a subjectivist epistemology to build ideas trough induction from data. Preferred methods include multiple methods to establish different views of phenomena using small sample investigated in depth or over time.
After reviewing these two paradigms the research problem outlined in Chapter 2 fits on a phenomenological paradigm, as the research focuses on the understanding in depth of housing reconstruction after a disaster and also on a positive paradigm due to the use of a qualitative approach. The conjunction of both paradigms and the viewpoint of Saunders et al., (2003) over mixed methods enabled also the use of a holistic philosophy. Mastin, (2008) indicates that a holistic philosophy seeks to link all of the parts of a problem under study to understand the problem as a whole. So that, it was considered that this philosophy would fit the research aim, objectives and the three research questions, given that the holistic philosophy allow an integral study to be conducted by linking the result of the research questions designed to explore how displaced people should participate in housing reconstruction, how the 3D-LPs could be used for recovery of housing and what is the benefit of using the BIM system for housing reconstruction after a disaster.

According to Mastin, (2008) holism can be defined as a theory where ideas, things, situations and systems are studied as a whole to better understand their nature and purpose. This concept argues that knowing the whole is essential to knowing how the parts behave Harper, (2001) argues that Holism comes from Greek Holos “whole” + ism. Holism has its origin in 1926 when Smuts wrote his book “Holism and Evolution”.

### 3.2.3 Research strategy

According to Saunders et al., (2000) and Yin, (2003) the research strategies can be associated to exploratory, descriptive and explanatory research, and can be also associated indistinctly to different philosophies to enable appropriate conduction of the research. The research study on this thesis is an explorative study that used a survey strategy to explore the problem underlined in the Chapter 2, the rationale was that according to Saunders et al., (2000) usually survey can be used to collect quantitative data which can be analysed qualitatively or quantitatively. Surveys help to create particular relationships between variables and to produce models of the survey can be carried out by questionnaires and structured interview which can be elaborated with
standardized questions. Surveys are used to generate findings that are representatives of the whole population by which the findings can be generalized. In summary, the research strategy used to conduct the explorative research study was based on a survey that involve a mixture of philosophy and methods to link three research questions with the purpose to meet the research aim and objectives, by using quantitative and qualitative analysis which helped to carry out the research process described.

Computer modelling was also chosen integrally to the research study, because the physical construction of the housing prototype planned in the first instance would require economic funds and protocols to show the implementation of the 3D-LPs; and this was not feasible. Computer modelling using BIM allowed a low cost, realistic alternative using the latest state of the art techniques. The design of survey of worldwide housing experts and interviewing a forum of lightweight concrete panels and the computer modelling can be found in sections 3.3 and 3.5 respectively. It should also be emphasized that the researcher made every effort to develop all stages of the methodologies step-by-step, as indicated in the literature by Saunders et al., (2000) to avoid confusion with other methods and methodologies. The information related to online questionnaire, semi-structured interviews and computer modelling appears through chapters 4, 5 and 6.

### 3.2.4 Research methods

An online questionnaire and semi-structured interviews were selected to collect data in order to answer the research questions to meet the research aim. The rationale was that these techniques are commonly used to collect rich qualitative data (Yin, 2003). According to Saunders et al., (2000) questionnaires can be used to answer standard questions that can be administered by different means, namely, face to face, online or by telephone. It was decided that an online questionnaire with open-ended questions was a suitable means to approach housing experts around the world; and semi-structured interviews by telephone were appropriate to contact manufacturers of the 3D-LPs construction system. Thus, two methods were used to collect reliable data to understand the in-depth post-disaster housing reconstruction problem. Saunders et al., (2000) suggest “The use of interview can help to gather valid and reliable data that are
relevant to research questions and objectives when the interviews are consistent with the research questions and objectives, the purpose of the research and the research strategy”.

1. Online Questionnaire.
The online questionnaire was conducted with 22 prominent professionals of the Architecture Engineering and Construction (AEC) industry who generally are not easily accessible because of the nature of their work (Saunders et al., 2000), no sample calculation was done. The number of interviews was set to 30 participants according to the suggestions made by Guest et al., (2006) who point out that “12 interviews should suffice to homogeneous groups” and “25 or 30 to heterogeneous population” in research that does not require a sample calculation. However, after gathering data from 22 worldwide housing experts new data was decreasing and data saturation were reached with more than 10,000 rich qualitative words. The rationale for selecting the online questionnaire was that a self-administered questionnaire over the internet (electronically) would allow the respondents to complete and to submit it via the internet within a suitable time. It was expressed by a participant in the online questionnaire “I am in Lahore and had a few minutes so hope my hasty response to your email is helpful to your research.” (C19). The online questionnaire was used to collect qualitative data, so the questions were designed open-ended to allow participants express as much information as they wished and so enrich the study.

2. Semi-structured interviews
Semi-structured interviews were carried out with 7 representatives of manufacturing companies of construction materials, because interviewees were available via Skype or telephone to share the physical and mechanical properties and the logistical distribution of their products. Another reason was the fact that this type of interview allows the order of the list of themes and questions to be negotiated with the interviewees to meet the objective of the interviews. Semi-structured interviews are characterized by the use of non-standardized questions and audio-recording to collect significant data for qualitative research (Saunders et al., 2000). Consequently, each single word expressed by respondents and interviewees was recorded to enrich the study. The number of participants in the semi-structured interviews was set up
according to Guest et al., (2006) who suggest that 12 interviews should be sufficient to homogeneous groups such it was the case of 3D-LPs manufacturers. However, after collecting data from 7 participants data saturation was reached, so that, it was determined that the participation of 7 interviewers would be suitable to answer the research question 2 & 3 and to meet the research aim.

3.2.5 Quantitative and qualitative strategy analysis
Quantitative and qualitative strategy analysis were chosen to analyse collected data from the online questionnaire and semi-structured interviews conducted with worldwide housing experts and manufacturers of 3D-LPs. Qualitative analysis used simple descriptive numerical values and display graphics to simplify the understanding. Qualitative analysis was conducted by using pattern matching when data saturation occurred, which consisted of searching for similar data throughout all coded data to generalize results (see Appendix 4). According to Rebar et al., (2011) data saturation is achieved when “the researcher finds that no new descriptive codes, categories or themes are emerging from the analysis of data”. Another reason to use this strategy was that according to Ghauri, (1995) and Larsson, (1993) the online questionnaires with open-end questions and semi-structured interviews can provide both quantitative and qualitative data when searching for patterns in actual data and can be used to measure reliability. Reliability according to Joppe, (2000) is defined as: “…the extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable.”

3.3 Online questionnaire and semi-structured interviews
This section focuses on explaining the online questionnaire used to conduct a survey with worldwide housing experts, its application, design and its rationale as well the design of the semi-structured interview with opened questions with manufacturer of construction materials. The opinion of 22 housing experts from 11 countries was used to explore the involvement of the displaced people in housing reconstruction after a disaster. The scenario, namely, the themes to consider into the research were based on
five approaches used for housing reconstruction by Governments affected and NGOs after the 2004 Indian Ocean Tsunami. Since the literature reviewed shown that the community participation on these approaches was determined by the approach and the origin of economic funds, it is imperative to study how the people affected by a disaster can help with housing reconstruction irrespective of the approach used. The viewpoints of worldwide housing experts were found useful to address this problem and offered suitable suggestions to find an early solution. Three research questions were the hub to achieve the online questionnaire and semi-structured interviews as these were linked among themselves to try to generalize the results about the post-disaster housing recovery (see Figure 3.3).

3.3.1 Design of the online questionnaire and semi-structured interview

This section focuses on explain the design and application of the online questionnaire and semi-structured interview. According to Yin, (2003) and Saunders et al., (2000) a survey can be used to study complex social phenomena and can be used under an explorative approach. Two questionnaire were designed to explore the post-disaster housing recovery. The questions to ask were formulated based on the literature review.
referred in Chapter 2 around five housing approaches and 3D-LPs. In order to make sure that the online questionnaire and semi-structured interview were appropriate to conduct the research study the researcher applied for Ethical approval to the University Research Ethics Committee in which were established the criteria to choose participants, methods and guidelines to collect and analyse data (Ethical Approval Form and Approval letter can be found in appendix 1a and 1). The online questionnaire and semi-structured interview were conducted in a real life context during the period from June 2013 to February 2014. The description is presented below.

- **By using an online questionnaire** - The opinion of 22 housing experts from 11 countries was used to explore the involvement of the displaced people in housing reconstruction after a disaster.

- **By using semi-structured interviews** - An analysis of the advantages and disadvantages of the 3D-LPs construction system with 6 manufacturers from 5 countries helped to explore how the system could be implemented to rebuild damaged housing and how it could be used by homeless people to build their own housing. Integral to this application was the modelling of a permanent basic housing prototype on the BIM to show the benefits of using the lightweight panels in 3D. Interviews explored in a real context the possibility to replace traditional construction systems by the 3D-LPs construction system in future disasters after overcoming the emergency phase, assuming that the traditional construction materials are those used habitually for the housing construction by people in the affected places, and remembering that this is a complex situation that needs to be explored. Note: another semi-structured interview was conducted with one manufacturer of cement in the same context.

Two kinds of participants were sought: experts in housing construction and manufacturers of 3D-LPs and cement around the world. The rationale for choosing them was that housing experts around the world can contribute to addressing the housing problem through their experience. Manufacturers of construction materials can share their logistic operations to supply materials in case of disasters and can also
offer their technical support. Another rationale to choose those participants was the scope of the study which was to explore the involvement of the displaced people in post-disaster housing reconstruction and the possibility to change traditional construction systems by the 3D-LPs construction system in a future post-disaster situation. Thus, the participated in the study were:

- 22 Worldwide experts of housing construction.
- 6 Representatives of manufacturing companies of the 3D-LPs construction system and one representative of Cementos Mexicanos (CEMEX, S.A de C.V)

No formal sample size calculation was used for the qualitative data due the study was conducted to expand the knowledge in the housing reconstruction field by using research questions, which use qualitative data (Saunders et al., 2000). Miles and & Huberman, 1994 suggested that the number of participants should be a reasonable number which allowed rich quantitative data. Figure 3-4 shows the design of the online questionnaire and semi-structured interview.
3.3.2 Validation and verification

Denzin (1984) suggests that a data triangulation technique strengthen the reliability, validity and quality of analysed data. Therefore, the motivation to choose this technique was that this allows the elimination of single investigator bias. In addition, reliability and validity of data collected are paramount to give credibility to study findings. Figure 3-5 shows a data triangulation technique which consisted of linking the findings to existing literature and information available from websites.
Reliability and validity definitions help to strengthen the reasoning to use them.

**Reliability** according to Saunders et al., (2000) is given by the quality and rationality of findings, which is related to data collection techniques and analysis procedures. Joppe, (2000) defines reliability as: “…the extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable.”

**Validity** according to Saunders et al., (2000) is to present with precision and truthfulness the real situation of the study and decreasing the chance to obtain the wrong answers. Four points have been identified to increase reliability of data collected.

- **Identify the correct participant** – this was achieved by establishing a criteria to choose participants.
o **Neutral participants** – this was reached by establishing voluntary participation of housing experts and manufacturers in the study.

o **Unification of viewpoints to conduct observations** – this was accomplished by following the collection procedure.

o **Use of a neutral sense to conduct observations** – The researcher student made every effort to avoid bias; in order to achieve this point all data were recorded and transcribed after conducting interviews.

### 3.3.3 The logical linking of the data to the objective or data analysis

Five techniques for data analysis are advisable by Yin (2003) as analytic strategies: “pattern matching, explanation building, time-series analysis, logical models, and cross-case synthesis”. Pattern matching was planned as an analytic strategy which was conducted to identify similar patterns in coded data with help of Nvivo 10. QSR and International (2013) have pointed that this software is a platform that facilitates the analysis of unstructured data by searching, queries and visualization tools. Hak and Dul (2009) and Saunders et al. (2000) suggest also that data collected must be prepared before linking these to the research aim, so that to achieve it a systematic process was conducted and repeated as many times as it was needed, which was composed of:

- **Loading data in a database from the online questionnaire** - These data were collected automatically in a database and converted into a spreadsheet to be handled in Nvivo 10.

- **Transcribing and transferring data from semi-structured interviews to text files** – These points require more management since the data recorded were transcribed after conducting each interview. This was achieved firstly by asking the interviewees for time to make notes during the interviews and clarify information before passing to the next question, and secondly by listening several times to the recording to complete and to verify notes. Finally, the suggestion by
Saunders et al., (2000) was used to prepare a text file which was assigned to each interviewee and transferred to Nvivo 10.

- **Codifying data collection to manage in Nvivo 10** – An alphanumeric code was implemented to identify each bit of the data as there were more than 15,000 words to codify (see appendix 4).

- **Arranging data in matrices to analyse and to interpret** – Patterns identified and codified were arranged in matrices to present the findings. The results were summarized and presented in chapters 4 and 5 with the most representative and meaningful data of each question.

### 3.4 Conducting the online questionnaire and semi-structured interviews

The protocol for data collection by means of an online questionnaire and semi-structured interviews under an exploratory study, in depth interviews according to Robson, (2002) seen in Sanderson et al., (2000) can be very helpful to “find out what is happening [and] to seek new insights.

#### 3.4.1 Data collection procedure

Ethical approval was sought to contact housing experts and manufacturers in accordance with the regulations of the University of Manchester Committee on the Ethics of Research on Human Beings. Ethical approval was used to establish the criteria to choose participants, methods and guidelines to collect and analyse data and enabled the data collection procedure that is explained in subsequent sections.

#### 3.4.2 Questions of the online questionnaire

The online questionnaire was designed based on the post 2004 Indian Ocean Tsunami housing reconstruction programmes. The online questionnaire addressed five themes in 17 open-ended questions. The first five questions explored the experience of respondents in housing construction, post-disaster housing reconstruction and their skills at teaching the building activities. The next eight questions explored whether the unskilled people from communities affected by catastrophes can be included in the architectural design and choice of building materials. Finally, four questions were used to explore the advantages and disadvantages of giving cash to the affected people, and
the possibility of training unskilled labour from communities hit by Natural and Man-Men Disasters. (Online questionnaire can be found in Appendix 2).

3.4.3 Questions of semi-structured interviews
Semi-structured interviews were conducted following five themes related to the 3D-LPs construction system and unskilled people. Questions were designed based on the literature review of 3D-LPs and previous interviews conducted by the researcher in the first year of this study with representatives of manufacturing companies of lightweight panels. Semi-structured interviews addressed five themes in 14 structured questions. The first two questions investigated physical-mechanical behaviour and quality of the panels. The next six questions explored the availability and prices of the panels in the international market. Finally, the last six questions inspected supplier’s capacity and technical support in areas affected by natural disasters. (Semi-structured interview can be found in Appendix 3).

3.4.4 Distribution of the online questionnaire
Participants in the online questionnaire were recruited via Co-operative Network Building Researchers or personal invitation via email. Figure 3-6 shows the collection data procedure for the online questionnaire. Respondents, who agreed to participate in the online questionnaire before receiving the email with the questionnaire, were asked to read the Participation Information Sheet (PIS) and the consent form. Respondents were given opportunities to ask questions about the study for up to one month. Then participants in the online questionnaire were asked to sign the consent form electronically and submit this to the researcher, in order to receive a link to answer the online questionnaire. After that, they were asked to fill in the online questionnaire at one attempt. After this the data was loaded into a database and transferred in Nvivo 10 for analysis and interpretation.
3.4.5 Semi-structured interviews

Semi-structured interviews were conducted with representatives of manufacturing companies of construction materials contacted by the researcher student via email and telephone or Skype. Figure 3-7 shows the data collection procedure, which remained constant and similar to the questionnaire applied online. Respondents took more than
1 hour to complete the interview. All data collected were recorded and transcribed in text files for analysis and interpretation after prior consent, before being introduced in Nvivo10 (Saunders et al., 2000).

The data collection process was conducted several times until achieving data saturation, and some stages in the process were similar between the online questionnaire and semi-structured interviews. The application of the questionnaires...
was carried out simultaneously. Participants in semi-structured interviews were contacted more than once to collect additional data to verify and validate information. In consequence, 22 housing experts participated in the online questionnaire from 11 countries and 7 technical directors from companies of construction materials (6 from the 3D-LPs construction and 1 from CEMEX) and from 5 countries participated in semi-structured interviews; 15419 words were collected to underpin the theoretical proposition and meet the research aim. Additionally, significant data was collected by emails, website, and patents to strengthen the reliability of data collected. These are secondary data, as the main collected data was collected from the online questionnaire and semi-structured interviews.

3.5 Modelling
This section focuses on explaining the computer modelling carried out in BIM Revit 2013 of a basic house prototype with 3D-LPs used to answer the research question (3) through the collected data from semi-structured interviews as part of the integral study. Page, (1994) argues that the models provide early answers that allow assumptions about model behaviour.

3.5.1 Limitation of the modelling
According to Josić, (2001) the limitation of the modelling “...is limited to the world we experience with our senses.” However, the innate ability of the humans to develop models is excellent and allow develop “remarkably precise, yet universally comprehensible models — ones that we can share with other humans, and with computers.” The housing model was limited to BIM Revit 2013 and the 3D-LPs construction system.

3.5.2 Type of problem
The physical construction housing prototype would require economic funds and protocols to involve people in its construction so that to solve this situation a housing model in BIM was seen as a suitable option to address such problem. The modelling of the housing prototype was conducted without involving humans to explore the switching of traditional construction materials after a disaster, since this thesis proposes the use of 3D-LPs construction system to replace bricks and concrete reinforced elements to save money and time. Another, more import reason considered
to carry out a model was: that according Huston, (2000) the involving of humans should be made in a controlled environment to produce successful models, as human behaviour could carry unreal systems.

3.5.3 Availability of resources
The computer modelling required a schedule to be prepared, to give viability and to conduct the modelling effectively. The schedule considered the availability of resources such as data, software and time which is presented in 3.6.2.

3.5.4 Availability of data
As previously mentioned, the collected data from the semi-structured interviews with technical directors of manufacturing companies of the 3D-LPs construction system was the main data to make the computer modelling. However, additional data were used to elaborate the economic estimation of the housing prototype. These consisted of an informal interview with the representative of the W Panel Company in combination with the construction regulations and prices of construction materials, cost of construction activities to create a reliable model.

3.6 The modelling process
The modelling process was composed of several steps, which were carried out systematically to answer the research question (3), to meet the research aim. The computer model was based on a basic sustainable house prototype of 38.5 m² with the 3D-LP construction system, to explore how the system can be adapted for the reconstruction of damaged housing by disasters. The process identified remained constant and it is shown in Figure 3-8.
3.6.1 Statement of the problem

The statement of the problem can be found in chapter 1 section 1.2. However, it is essential to remember that the creation of a virtual model was proposed as a research strategy to answer research question (3), which studies the post-disaster housing reconstruction problem by using the BIM system, the 3D-LPs construction system and displaced people’s own labour in building housing.

3.6.2 Project planning

The planning to conduct the computer modelling started with a housing prototype model of 38.5 m² on plan, collection of data and familiarization with the BIM and the 3D-LPs construction system. The first data collection was conducted by contacting the representative of Panel W Company and consulting the Mexican Institute of the Cost
of Engineering (IMIC) to obtain characteristic of panels and construction materials prices.

A second consultation with W Panel and other manufacturers of the 3D lightweight panels helped to enrich the data; this was conducted under the protocol described in section 3.4. The consultation of Mexican construction regulations and the modelling of the housing prototype were the next stages planned to establish the running of the computer modelling followed by the verification, validation and documentation. Table 3-1 shows the chart planning. The Mexican construction regulations were chosen because these meet the International construction regulation as these have been developed in accordance to ASTM (American Society for the Testing of Materials) and because the 3D-LPs construction system was found that meets regulations in Mexico and world.

<table>
<thead>
<tr>
<th>Activities</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition of the system.</td>
<td></td>
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<td>Pen and Paper</td>
</tr>
<tr>
<td>Formulation of the model.</td>
<td></td>
<td></td>
<td></td>
<td>Pen and paper</td>
</tr>
<tr>
<td>Choosing a suitable construction material.</td>
<td></td>
<td></td>
<td></td>
<td>Interviews with manufactures of panels.</td>
</tr>
<tr>
<td>Data collection-</td>
<td></td>
<td></td>
<td></td>
<td>Panel W company, construction regulation and the IMIC</td>
</tr>
<tr>
<td>Modelling the housing prototype.</td>
<td></td>
<td></td>
<td></td>
<td>The BIM system 2012 and 2013.</td>
</tr>
<tr>
<td>Verification and validation.</td>
<td></td>
<td></td>
<td></td>
<td>Manufacturers of the 3D-LPs.</td>
</tr>
<tr>
<td>Documentation.</td>
<td></td>
<td></td>
<td></td>
<td>Report</td>
</tr>
</tbody>
</table>

### 3.6.3 System definition

The housing prototype model was limited to use panels type 3D-LPs, and to use the BIM system Revit 2012 & 2013 developed by Autodesk. The modelling was also limited to no structural calculation. However, a structural design model was conducted and displayed to give an idea of the assembling. The economic estimation of the model was carried out in Excel by using the take-off of the BIM system.

### 3.6.4 Model formulation

The model formulation was devised after deciding that BIM was convenient to show the use of the 3D-LPs construction system, thus the creation of an architectural design
was the starting point to search for a suitable housing prototype which could be fitted and adapted to build houses after a disaster anywhere affected.

**Procedure:**

1. The architectural housing prototype was designed according to the Mexican construction regulations and modelled in the architectural platform from the BIM system Revit 2012 and 2013 with the 3D-LPs construction system. The architectural model was placed in Sumatra Island Indonesian soil in Revit 2013 via a map integrated in Revit 2013 in order to simulate similar conditions to areas affected by natural disasters. As Revit 2013 modelled through axes, these were placed to limit plot size and draw the foundations, walls, roof, doors and window. The construction characteristics of materials were loaded into BIM to create the architectural-structural model.

2. The structural housing prototype was designed according to specifications of the manufacturers of the 3D-LPs construction system, based on the design regulations for concrete and steel for buildings and modelled in the structural platform from the BIM system Revit 2013 with the 3D-LPs construction system. Therefore, the architectural model was used as a template to model the structural housing prototype and to show the assembling of panels.

3. Sanitary, hydraulic and electric installations were also modelled on the BIM system Revit 2013 to show that a whole project can be developed in the system. Consequently, an architectural model was used as a template to model the installations.

The modelling stages of the housing prototype are shown in Figure 3-9.

a) Architectural model  
b) Structural model  
c) Economic estimation
3.6.5 Input data collection and analysis

The collected data from research question (2) was the input to model the housing prototype in combination with the Mexican construction regulations and list of costs of construction activities from the MICE. The output was a template of the housing
prototype that uses the 3D-LPs construction system, which is easy to modify by means of the functions of the BIM system. The modelling details can be found in chapter 6.

3.6.6 Model translation
The BIM system Revit versions 2012 and 2013 developed by Autodesk was selected as the system to conduct the computer modelling of the housing prototype; the motivation was that this system allows the whole project to be managed in one platform, in addition to the advantage that the models can be displayed in 3D and documented in the same site. The reason to use both versions was that the housing prototype was modelled for first time in Revit 2012 (at this time only that version was available), because the modelling was made for separate aspects (architectural, structural, mechanical, etc.) and linked after modelling each one to complete the task, in other words, the models were created more than once in that version. Moreover, the 2013 version allowed the creation of a template to be used as a base model to create structural and mechanical designs among others.

3.6.7 Verification and Validation
Validation and verification was achieved by sending the design housing prototype to the representative of Panel W Company to ask for technical support, before and after modelling the prototype on the BIM system to have a real reference about the construction of housing through the 3D-LPs construction system, which was the base to compare and verify the housing prototype model simulated in the BIM system. According to Sterman et al. (1993), verification and validation take a different meaning in the technical jargon so that is important to highlight that verification is related to testing the truth while validation is related to the amounts of acceptance testing. However, Sterman et al. (1993) advise using only one term in order to avoid confusion.

3.6.8 Experimentation and analysis
The housing prototype was modelled several times until the prototype behaved as planned and looked similar to the real housing built by using the 3D-LPs construction system. A problem faced during the modelling was that the BIM system lacks the 3D-LPs construction system, so the research devised a way to adapt the characteristics of the system in the BIM to existing types of walls. Finally, documentation was carried out.
3.6.9 Summary
A mixture of methods was selected to address the housing reconstruction problem after a disaster. An online questionnaire and semi-structured interview with open-ended questions were employed to answer research questions (1 & 2) and a computer modelling was used to answer research question (3) in order to meet the research aim and objectives.
4 Analysis and Findings of the Online questionnaire

4.1 Introduction
In this chapter the qualitative analysis of online questionnaire conducted with 22 housing experts from 11 countries, as well as the analytical process, the coding process and the results obtained are presented. The purpose is to present the results related to the research aim and objectives and answer the research question (1) How can displaced people use their own labour to save money and time? In the following sections, the results of the five themes tackled with the housing experts by the online questionnaire are systematically presented.

4.2 Analytic process
Qualitative data analysis was conducted through an interactive process that involved data coding and interpretation along with writing up of findings. Coding consisted of arranging collected data from the online questionnaire and semi-structured interviews in themes, categories and patterns after importing data to Nvivo 10. The process also included a stage to reflect on what the data was showing; in consequence, an additional coding helped to clarify and manage data, as the data volume was reduced and allowed clearer analysis. Then the meaningful and representative data were arranged in
matrices to start the interpretation and to write up the findings. Quantitative data analysis is presented in either numerical or graphic formats to enable better understanding of the information.

4.3 Data coding process
An alphanumeric coding system was used to classify more than 15,000 words in Nvivo 10 which were collected from the online questionnaire and semi-structured interviews conducted with 22 housing experts and 7 technical directors of companies manufacturing construction materials. The process was devised to identify and to group similar data in theme, categories and patterns in order to enable the interactive analytical process that would address the post-disaster housing reconstruction problem. The coding process was achieved after establishing nodes in the hierarchies to enable moving from themes at the top (the parent node) to more specific topics by using categories (nodes) and patterns (child nodes) (Figure 4-1).

![Figure 4-1 Nodes in hierarchies](image)

Thus, 10 themes (parent nodes), 31 categories (nodes) and 56 patterns (child nodes) created in Nvivo 10 contain the coding data which help to facilitate the analysis. The coding process can be consulted in appendix 4. Figure 4-2 shows a summary of the data analysis.
Data analysis

Methods

22 online questionnaires
Consisted of
17 open questions
5 Themes
10527 words transcribe

6 semi-structured interviews
Consisted of
14 semi-structured questions,
5 themes
4892 words transcribe

22 Experts of housing construction
From:
- Australia - EEUU
- Canada - Indonesia
- Chile - Italy
- England - Mexico
- New Zealand - Palestine
- Turkey
From:
- Universities
- Construction Industrial
- NGOs Other sources:
website, papers and patents.

6 Manufacturing Company of the 3D-LPs construction system
From:
- Chile
- China
- Costa Rica
- Spain
- Mexico
Other sources
- Patents
- Quotes

Analysis by pattern matching

Answer research questions

Meet the research aim

Figure 4-2 Data analysis
4.4 List of the questions asked in the online questionnaire

This section presents the list of the questions asked in the online questionnaire conducted with 22 housing experts used to explore how the community members should participate in housing reconstruction after a disaster in order to answer research question (1). The qualitative analysis was conducted through pattern matching to increase the generalization of the study in Nvivo 10. Seventeen open-ended questions were analysed in five themes, and then each theme was divided into categories to identify similar patterns (see Figure 4-3), so that the findings are presented in the next sections by themes, categories and identified patterns. Further details regarding themes, categories and patterns can be consulted in Appendix 4 and the online questionnaire can also be found in Appendix 2.

![Nodes Diagram](image)

Figure 4-3 Themes and categories
Table 4-1 shows the long names of themes and categories used in the next sections to explain data coded.

**Table 4-1 Themes and categories explored with housing experts**

<table>
<thead>
<tr>
<th>Themes</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Personal Data</strong></td>
<td>• Years and experience in housing construction.</td>
</tr>
<tr>
<td></td>
<td>• Participation in housing recovery.</td>
</tr>
<tr>
<td></td>
<td>• Activities developed in housing post-disasters.</td>
</tr>
<tr>
<td></td>
<td>• Experience in teaching the construction activities.</td>
</tr>
<tr>
<td><strong>Architectural design</strong></td>
<td>• People’s opinions.</td>
</tr>
<tr>
<td></td>
<td>• People’s feelings.</td>
</tr>
<tr>
<td></td>
<td>• Involvement of displaced people in architectural design.</td>
</tr>
<tr>
<td></td>
<td>• General participation of affected people in architectural design.</td>
</tr>
<tr>
<td><strong>Choice of building materials</strong></td>
<td>• Preservation of the traditional housing construction.</td>
</tr>
<tr>
<td></td>
<td>• New construction materials.</td>
</tr>
<tr>
<td></td>
<td>• Inclusion in choosing of building materials.</td>
</tr>
<tr>
<td></td>
<td>• Participation in choosing of building materials.</td>
</tr>
<tr>
<td><strong>Management of financial resources</strong></td>
<td>• Self-construction.</td>
</tr>
<tr>
<td></td>
<td>• Hiring builders.</td>
</tr>
<tr>
<td><strong>Unskilled labour</strong></td>
<td>• Professionals.</td>
</tr>
<tr>
<td></td>
<td>• Training for unskilled people.</td>
</tr>
</tbody>
</table>

4.5 Personal data

The first theme analysed corresponds to personal data; this theme was developed to find out the involvement level of respondents in matters of housing construction and housing reconstruction. Four categories were set up to examine:

- Years and experience in housing construction.
- Participation in housing recovery.
- Activities developed post-disasters.
- Experience in teaching construction activities.

This section focuses on quantitative and qualitative analysis of personal data; the results are shown by graphics, followed by qualitative explanation.
4.5.1 Years and experience in housing construction

As can be seen from Figure 4-4, all respondents have worked in HC for more than one year. The figure highlights that 18 of them (81.8%), have worked for more than 5 years in this field. In relation to the experience of respondents in HC, Figure 4-5 indicates that 11 respondents (50%) are experienced, 5 respondents (22.7%) are inexperienced and 6 (23.7%) other.

![Figure 4-4 Years working in HC](image)

![Figure 4-5 Experience in HC](image)

In order to find out more about the experience of the last 11 housing experts who evaluated their experience as inexperienced, a deep analysis all around the questions in this category revealed that the reason for their answers was that 5 respondents (22.7%) developed theoretical rather than practical work on HC and 6 respondents (23.7%) worked in the design of construction materials for housing and shelters through research studies. In consequence, they considered that they lacked practical experience in HC, but did not have too limited knowledge to address this problem. A verbatim quote is shown to underpin the statement above.

“Other I don’t work in housing construction, but have been researching post-disaster reconstruction for 10 years.” (C5)

4.5.2 Participation in housing recovery

In relation to the participation of respondents in housing reconstruction 11 respondents (50%) reported having participated in housing reconstruction and 11 respondents (50%) mentioned not having been involved in this. A similar explanation was found to justify this. It seems that the predominant pattern of measuring the experience and
participation of respondents either in housing construction or reconstruction is given by the nature of their work rather than lack of experience.

4.5.3 Activities developed post-disaster

At this point of the analysis it can be stated that 16 respondents (72.7%) were experienced in HR. Of these, 11 respondents (50%) had participated directly in the place of disaster and 5 respondents (22.7%) by means of research studies. Therefore, it is not surprising that 27.3% respondents had replied "not applicable", when they were asked how they had participated in housing reconstruction, because their activities had been related to the design of construction materials for housing and shelters post-disaster. As a result of this, Figure 4-6 shows the activities developed by 16 respondents after disasters; these were focused on the construction and design of housing, disaster management, technical advice and housing recovery programs.

A detailed analysis case by case discovered that C18 and C16 were the most experienced participants in the study, followed by C3, C5, C6, C7, C11, C14, C15, C17, and C21 due to their activate participation post-disaster. They reported:

“*I have worked on assistance to victim organizations post-earthquake of 1985 in Chile to rebuild their housing.*” (C3)

“*I have done research on the long-term outcomes of natural disaster resettlements.*” (C5)
“I got involved in reconnaissance activities after disaster and also involved in the design process for retrofitting the existing buildings.” (C6)

“Monitoring the house design and model which had been done by the laboratory for housing and Human settlement for Tsunami disaster victims.” (C8)

“I have acted as a researcher and as an academic advisor in an informal basis.” (C14)

“Work with Habitat for Humanity in the Gulf Coast region after Katrina.” (C16)


4.5.4 Experience in teaching construction activities

As can be seen from Figure 4-7, 16 respondents (72.7%) were experienced at teaching the construction activities. These data are significant because this indicated the capability of respondents to express their views about giving training for the unskilled affected people by N and M-MDs.

![Experience in teaching construction activities](image)

Figure 4-7 Experience in teaching construction activities

4.5.5 Validation personal category

Validation of the personal data collected was conducted by using personal emails received by the researcher and data collected from university websites (secondary data). As a result of this, it can be said that the respondents appeared to provide highly
reliable main collected data through the online questionnaire when matched with the secondary data collected. Data triangulation allowed the personal data of respondents to be expanded, and gave a full snapshot of participants. Table 4-2 shows that 13 PhDs, 5 MEng and 2 BEng participants were recruited from 11 countries: Australia, Canada, Chile, EEUU, Indonesia, Italy, Mexico, New Zealand, Palestine, Turkey and the UK, coming from 17 universities, one Institute and from the Construction Industry, and were developing their careers in the construction project management, disaster risk management, housing design and structural design fields.

<table>
<thead>
<tr>
<th>No. Participant</th>
<th>From</th>
<th>Country</th>
<th>Field</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>University of Melbourne</td>
<td>Australia</td>
<td>Construction project management</td>
<td>PhD</td>
</tr>
<tr>
<td>C2</td>
<td>Pontificia Universidad Católica de chile</td>
<td>Chile</td>
<td>Construction Engineering and Management</td>
<td>PhD</td>
</tr>
<tr>
<td>C3</td>
<td>University of Wellington</td>
<td>New Zealand</td>
<td>Construction project Management</td>
<td>MEng</td>
</tr>
<tr>
<td>C4</td>
<td>University Polytechnic Di Bari</td>
<td>Italy</td>
<td>Housing design (Materials)</td>
<td>PhD</td>
</tr>
<tr>
<td>C5</td>
<td>University of Canterbury</td>
<td>Australia</td>
<td>Disaster Risk Management</td>
<td>PhD</td>
</tr>
<tr>
<td>C6</td>
<td>University of Manchester</td>
<td>The UK</td>
<td>Housing Design Civil Engineering</td>
<td>PhD</td>
</tr>
<tr>
<td>C7</td>
<td>Institute of Technology Sepuluh Nopember</td>
<td>Indonesia</td>
<td>Housing and human settlement</td>
<td>PhD</td>
</tr>
<tr>
<td>C8</td>
<td>University of New Brunswick</td>
<td>Canada</td>
<td>Construction Engineering and Management</td>
<td>PhD</td>
</tr>
<tr>
<td>C9</td>
<td>Loughborough University</td>
<td>The UK</td>
<td>Disaster Risk Management</td>
<td>PhD</td>
</tr>
<tr>
<td>C10</td>
<td>Northumbria University</td>
<td>The UK</td>
<td>Disaster Risk</td>
<td>PhD</td>
</tr>
<tr>
<td>C11</td>
<td>The University of Sydney</td>
<td>Australia</td>
<td>Disaster construction Management</td>
<td>PhD</td>
</tr>
<tr>
<td>C12</td>
<td>Islamic of University of Gaza</td>
<td>Palestine</td>
<td>Disaster construction Management</td>
<td>PhD</td>
</tr>
<tr>
<td>C13</td>
<td>Victoria University of Willington</td>
<td>New Zealand</td>
<td>Architectural Design</td>
<td>MEng</td>
</tr>
<tr>
<td>C14</td>
<td>University of Minnesota</td>
<td>EEUU</td>
<td>Housing and human settlement</td>
<td>PhD</td>
</tr>
<tr>
<td>C15</td>
<td>University of Central Florida</td>
<td>EEUU</td>
<td>Housing Design (energy)</td>
<td>BEng</td>
</tr>
<tr>
<td>C16</td>
<td>University of Central Florida</td>
<td>EEUU</td>
<td>Housing Design (energy)</td>
<td>BEng</td>
</tr>
<tr>
<td>C17</td>
<td>Construction Industry</td>
<td>Not data</td>
<td>HC</td>
<td>No data</td>
</tr>
<tr>
<td>C18</td>
<td>University of Cambridge and NGOs</td>
<td>The UK</td>
<td>Housing Reconstruction</td>
<td>MEng</td>
</tr>
<tr>
<td>C19</td>
<td>Queen’s University Belfast</td>
<td>Turkey</td>
<td>Housing Reconstruction</td>
<td>PhD</td>
</tr>
<tr>
<td>C20</td>
<td>Not data</td>
<td>Chile</td>
<td>Housing Reconstruction</td>
<td>No data</td>
</tr>
<tr>
<td>C21</td>
<td>Construction Industry</td>
<td>Mexico</td>
<td>HC</td>
<td>MEng</td>
</tr>
<tr>
<td>C22</td>
<td>Construction Industry</td>
<td>Mexico</td>
<td>HC</td>
<td>MEng</td>
</tr>
</tbody>
</table>

### 4.5.6 Summary and Discussion

This section presented the personal data of the respondents to show their involvement level either in construction or reconstruction of housing and their activities performed
after a disaster. 16 respondents (72.7%) were experienced in either theoretical or practical issues of housing after a disaster and 6 respondents (23.7%) were experienced in the design of housing and shelters construction materials. In consequence, the study gained the participation of prominent researchers and practitioners in the AEC industry who offered their valuable viewpoints to address the post-disaster housing reconstruction after the emergency phase.

4.6 Architectural design
The analysis of this theme starts with the housing reconstruction programmes used post-the 2004 Indian Ocean Tsunami (see chapter 2). The objective of this theme was to find out how the people affected by a disaster should be involved in the architectural design of their own houses after a disaster.

4.6.1 Quantitative analysis
The analysis was focused on the following categories.

- People’s opinions.
- People’s feelings.
- Involvement of displaced people in architectural design.
- General participation of affected people in architectural design.

The quantitative analysis revealed that 21 housing experts (95.5%) agreed that the opinions and feelings of the people affected by a disaster should be considered in the architectural design of their houses (Figures 4-8 and 4-9).
Likewise, 20 housing experts (91.0%) concurred that people should participate in some way in architectural housing design (Figure 4-11). However, this response changed when housing experts were asked about whether people should be involved in housing design. Here 11 housing experts (50.0%) agreed with the idea, 9 housing experts (41.0%) totally disagreed and of the 2 remaining housing experts (9.0%), one was unsure and another did not reply (Figure 4-10).

![Figure 4-10 Involvement of displaced people in architectural design](image1)

![Figure 4-11 Participation of affected people in housing design](image2)

### 4.6.2 Qualitative analysis

This section presents the qualitative analysis of the architectural design theme composed of four categories. Quotations are presented along with all results to show the opinion of housing experts.

- **People’s opinions.**
- **People’s feelings.**
- **Involvement of displaced people in architectural design.**
- **General participation of affected people in architectural design.**

#### 4.6.2.1 People’s opinions

The keywords used to show the patterns of agreement and disagreement in this category were: participation, needs, experience.

**a. Participation**

In term of participation, housing experts highlighted that it is essential to consider the affected people's viewpoints in the architectural design of their own houses. The fact
that people can provide suggestions to improve and to build appropriate housing after a disaster was referred to, since the people who have lost their houses will be the residents of the new or rebuilt houses. Housing experts based their opinion on the idea that collaboration between construction professionals and the affected people can help improve housing in future post-disaster situations.

“Yes. Architectural design must always address user's needs and opinions.” (C2)

“Yes, absolutely. I would think their involvement would both provide closure and give them something to rebuild their lives around.” (C17)

“Yes, it is imperative to consult with affected communities in order to design homes that are appropriate in terms of habitability and culturally.” (C18)

The means proposed for respondents to reach people’s opinions were:

- Brainstorming with selected people from the communities,
- Application of questionnaires,
- Other survey methods including focus groups and model/test homes.

b. Needs

In terms of needs, housing experts emphasized that people’s opinions should be considered in architectural design, because people know what their needs are in the matter of dwellings, and given that people need to replace their houses quickly. The tendency of this theme was that construction professionals should learn and understand how people live in their dwellings in order to design houses that fit the needs of those affected people.

“Yes, they should as they can define their needs better than the architect. From their previous experience they can discuss with the architect his design for them and he should follow their comments as these people who will live inside the house not the architect.” (C16)

“Yes, definitely the architectural design of the interpretation of needs user is the success of the architectural space. It depends on how those needs are resolved. Therefore, I am certain that the views of those affected should be the starting point for purpose of housing recovery.” (C22)

c. Experience

In terms of experience, housing experts emphasized that people’s opinions should be considered because people can say what the structural behaviour of their houses was during the disaster, in addition to people being a valuable source of information because they have experienced the effects of a disaster and also because some people
are experienced in housing construction, as in developing countries people often repair their housing by themselves.

“Yes, to some extent. They can share their experience during natural disasters and why they have been affected, they can talk about the failure systems in their properties during natural disasters.” (C11)

“Yes, they should be listened to, maybe not acted on, but listened to. These people have had an experience that most home owners will not have. Their insights can be valuable. That said, if a homeowner in New Orleans wants his house built at ground level, for some silly reason, like they don't like going up and down stairs, they should be ignored. If the homeowner doesn't like windows on the south side, or some other trivial request, why not comply” (C15)

“Yes, of course, because they have experience in the behaviour of the house during the disaster.” (C21)

4.6.2.2 People’s feelings

The keywords used to explain the patterns of agreement and disagreement in this category were: participation, needs, experience.

a. Participation

In terms of participation, housing experts underlined that similar to the opinions, it is essential to consider the feelings of the affected people in the architectural design as they can provide suggestions to address this. Housing experts based their opinions on a scheme where the affected people can explain the type of home or space required on an everyday basis, just as a customer does with an architect. The reason was also that it can help to minimize the aftermath caused by disasters, since people can say what worked well and how they want to see their houses built.

“Yes, sure, they suffer from the disaster. Expressing their feelings will minimize the effect of the disaster on them. And residents’ needs should be considered in all cases.” (C12)

“Yes, by asking their previous space available and their future expectation for the house after disaster.” (CP8)

b. Needs

Housing experts emphasized three points in terms of needs by which people’s feelings should be considered in the architectural design of their dwellings:

- A disaster is a unique opportunity to improve the systems that perform poorly.
- People have different needs from affected place to place.
- The architecture can address this problem.

“Yes, of course. Who are you doing the work for, if not the affected people? After a disaster is a unique opportunity to make a major impact on construction techniques and improve the life of the occupants.”
If the homeowners are not "on board" the whole effort is for nothing. Further, after a disaster there is an opportunity to build housing that really fits the homeowners' needs, handicapped, allergic, etc. these may not be the "feelings" you are referring to. " (C15)

As can be seen from the quote above, a disaster is a unique opportunity to improve the life of the affected people and to build housing that really fits the homeowners’ needs. However, as C7 argued “The culture/social routines/norms/customs of people vary from country to country and even religious beliefs. Understanding space requirements for daily routines must be appreciated and planned for, otherwise we will create spaces which are either inadequate or overly adequate (in the latter, people might fail to maintain these spaces.” Therefore, many factors should be considered before designing and building an appropriate dwelling that fits the needs of those affected, due to the fact that each place affected by a disaster is different. In consequence, a consultation is the means suggested to tackle this problem and take advantage of this unique opportunity.

“Houses are part of human culture. They reflect our values and our cultural practices. Houses (design) should take into consideration what will make the house feel like a home in that particular culture.” (C16)

The importance of people’s feelings in the architectural design after a disaster can be summarized by the following comment:

“The architecture not only meets the physical needs of the user, it has much of its fundament in the solution to spiritual needs, it has to do with feelings and comfort in their homes.” (C22).

c. Experience

The point emphasized by housing experts about people’s feelings in relation to their experience was based on the idea that the affected people occupy a dwelling in different ways, which entitles them to be considered in the architectural design of their own houses.

“If, through a study that reveals to us the habits and customs of people in terms of housing and thus make the design of the spaces and facades.” (C21)

4.6.2.3 Involvement of displaced people in architectural design

The keywords used to explain the patterns of agreement and disagreement were: participation, needs and experience. Regarding the inclusion of people in architectural design (architectural design refers to the participation of affected people in the internal
distribution of their own houses) there was a significant split in the opinions of experts (Approximately 50-50).

a. Participation
The main reason for which housing experts agreed to incorporate people in the architectural design seems to be linked with the idea that people can help designers to find solutions that are more suitable to their personal view of what risks and security are.

“Yes, Where-ever possible, but noting that it really comes down to funding mechanisms.” (C5)

In relation to those housing experts who disapproved of the idea, the main reason was that architectural design of housing involves several facets at the stage of conception and constraints which are known by the professionals rather than by people. Therefore, people lacked the technical experience to address this problem and they should not participate.

“I would say they should not be included. Architectural design in post natural disasters need to meet many many constrains. Speed of construction, use readily available materials, budget, etc. To include too much people input might impose too many restrictions making the solution unfeasible. The feelings and opinion of people needs to be included more lightly as expressed in answer #6.” (C2)

“No I don’t think this would be realistic, they would be lacking the technical skills needed. Although involvement with the design process would be essential.” (C17)

“No, I’m absolutely against the idea that people, since they are generally unskilled people, should build their houses back on their owns.” (C19)

“No, because they lack of technical knowledge to perform this task.” (C21)

However, it was highlighted that the lack of technical experience of those affected can be overcome by training.

“They should be given the opportunity to see their houses in "under construction" period. So, as I believe, they will learn how a building should be constructed, what details are beyond their knowledge, so they can agree on that they are not fulfil the requirements for a proper housing construction when they build it by themselves. Nevertheless, they may be given an opportunity to build a common house/ or a gathering shed in their settlement under the supervision of experts. So, they will understand the importance of having consultation and meeting the building codes.” (C19)

“Yes, technically trained and assisting in the development of evolutionary houses or growing over time in successive stages. Ie, flexible design characteristics of adaptation.” (C20)

b. Needs and experience
The attribute underlined by the housing experts in terms of needs and experience was still the need for technical skills to include people in architectural design. This concern was focused on the need for building resilience in future situations.
“.. their contributions are valuable to the overall process of recovery, but the design process should take into consideration design features that increase durability of the home.” (P16)

4.6.2.4 General participation of affected people in architectural design

The keywords used to explain the patterns of agreement and disagreement in the participation of affected people in the architectural design of their own houses after a disaster were: participation, needs and experience.

a. Participation needs and experience.

The opinion of housing experts remained constant with relation to the participation of the affected people in architectural design. The tendencies were that feelings and opinions should be considered to give a sense of belonging to people, but that architectural design should be carried out by technical professionals; however, in the opinion of housing experts, those affected should be given the opportunity to be involved in housing reconstruction, since a disaster can give them control over the construction of their houses.

4.6.2.5 Summary and Discussion

Before moving toward, the summary and conclusion is important to keep in mind that the level of participation of affected people after a disaster can be measured by the ladder of community participation in reconstruction adapted by Davidson (2007). This involves five levels: at the bottom manipulate, followed by inform, consult, collaborate and empower at the top. The last two allow control of the affected people over “decision-making” about the reconstruction (Davidson et al., 2007). The programme type used for housing reconstruction post–the 2004 Indian Ocean Tsunami (See Chapter 2) also influences community participation.

- Cash Approach: an approach which allowed total control over housing reconstruction to those people affected (Da Silva and Batchelor, 2010),

- Donor Driven Reconstruction approach excluded the participation of people in the reconstruction process (Karunasena and Rameezdeen, 2010)

- Owner Driven Reconstruction empowered people by means of training.
In consequence, summaries and conclusions along online questionnaire categories are presented in terms of community participation ladder and housing reconstruction programmes.

Housing experts suggested a close cooperation level between designers and affected people to build better dwellings that fitted their needs. Related to the inclusion of affected people in architectural design the level suggested was the third ‘consult’ because people lacked technical skills to perform that task, for which reason, in the opinion of respondents, they should not participate in the technical process, as architectural design involves several technical stages. However, respondents commented that the inclusion of affected people in the architectural design could reach up to the fifth level if they are trained in this matter, since it is important to give them a sense of belonging and control over their houses.

The participation of the affected people in housing construction was limited by the programme type used post-disaster (see chapter 2). The housing experts think that the displaced people could participate in architectural design over a scheme similar to the Owner Driven Reconstruction programme, if people are provided with a training programme in order to give them a sense of belonging, which could help them to overcome the aftermath left by the disaster. These findings are meaningful, given that respondents were not provided with any information related to the post-disaster housing programmes to avoid bias.

4.7 Choice of building materials

The third category of the online questionnaire was the choice of building materials. The objective of this category was to explore the replacement of the traditional construction materials after a disaster and how the homeless people should participate in the choice of building materials in order for them to be involved in housing reconstruction. The shortage of construction materials post-the 2004 Indian Ocean Tsunami led to delay and excessive cost of housing (Chang et al., 2011) and the displaced peoples who participated in the Cash Approach programme used to rebuild houses in that tsunami lacked the technical skills to buy construction materials to self-build their own houses (see chapter 2). The houses were therefore of poor quality and the cash was insufficient to build better dwellings (Da Silva and Batchelor, 2010).
4.7.1 Quantitative analysis

The results of the analysis obtained by pattern matching from the choice of building materials theme were focused on the following categories:

- Preservation of the traditional housing construction.
- New construction materials.
- Inclusion in choosing of building materials.
- Participation in choosing of building materials.

The quantitative analysis showed that 13 housing experts (59.1%) concurred with the idea of the preservation of traditional housing construction, while 5 housing experts (22.7%) disagreed with the idea and 4 housing experts (18.2%) were unsure (Figure 4-12). Moreover, 19 respondents (84.4%) agreed with the use of new construction materials after a disaster, 1 respondent (4.5%) rejected the idea and 2 respondents were unsure (Figure 4-13).

Inclusion and participation in choosing of building materials were reported with similar results: (Figure 4-14 and 4-15).

![Figure 4-12 Preservation of traditional housing construction](image)

![Figure 4-13 New construction materials](image)
The next section shows the findings of the qualitative detailed analysis of each one of the categories in the choosing of construction materials theme.

4.7.2 Qualitative analysis
This section presents the qualitative analysis of choice of building materials theme composed of four categories.

- Preservation of the traditional housing construction.
- New construction materials.
- Inclusion in choosing of building materials.
- Participation in choosing of building materials.

4.7.2.1 Preservation of traditional housing construction
The keywords used to explain the patterns of agreement and disagreement with preservation of the traditional housing construction were: workability, improvement, heritage.

a. Workability
There were three tendencies which explained the viewpoints of the housing experts on whether to preserve housing construction after a disaster in terms of workability. On
the first tendency, the respondents who reported that traditional systems should be preserved to build housing based their opinion on the fact that these buildings had been able to withstand a disaster, so that there was no reason to change them. They think that those buildings performed appropriately during the disaster, so they should not be changed.

“... Traditional methods are there for one very good reason - they work...” (C1)

“...ideally yes if it appropriate. Many traditional housing types have survived for decades/100 years in hazard prone areas and these need to be protected and suitably maintained. If necessary some structures will need to be sympathetically retrofitted.” (C9)

“Yes, if traditional housing has being able to withstand a disaster then it is clearly a form of construction that is both culturally appropriate and resilient...” (C18)

“Yes, to the degree possible while making improvements in durability. It is culturally important to be tied to the past, but also important to advance survivability which conserves community resources in the future and can increase hope for the future.” (C16)

On the second tendency, housing experts who were in disagreement with the idea based their opinion on the fact that traditional housing techniques failed during the disaster, and therefore these should be changed.

“The traditional housing techniques on the Gulf Coast were responsible for much of the damage. houses were not raised high enough above flood levels, houses were not anchored sufficiently, and houses were not very forgiving to water intrusion, if they remained standing......” (C15)

The technique is a way to do unfortunately in traditional construction systems have taken a long time to learn from trial and error.” (CP22)

On the third tendency, those housing experts that were unsure about the idea based their opinion on the fact that changing traditional housing techniques depended on a number of significant variables, which included among others the nature of disaster, damage caused, risk and capacity to withstand future disasters and these variables should be considered to decide on the preservation of the buildings.

“It depends. Traditional housing may not be able to withstand future natural disasters, especially with increasing numbers and intensities of disasters. If traditional housing no longer keeps people safe, it should be replaced.” (C2)

“It depends. If place of construction is declared as not habitable for future construction, people need to move away and start from scratch and the best housing system need to be chosen for the new situation. If the affected place is still viable for housing, the best performance housing systems should be kept and the ones that performed poorly should be discontinued.” (C14)

“The answer to this would depend on a number of significant variables, including the nature of the natural disaster, for instance, if an earthquake, it would be realistic to expect the materials specification to be modified to one which could withstand such disasters. However, this would ultimately be a trade off between tradition, design, conservation and safety.” (C17)
b. Improvement
In terms of improvement most housing experts who were either in agreement or disagreement with the idea of preserving housing construction commented that housing construction techniques should be improved for building disaster resilience. Moreover, their agreement was related to the evaluation and fit of these materials to work properly during future disasters. However, housing experts who were in disagreement with the preservation of these techniques reiterated that there was an opportunity to change what had performed poorly, and more structured modern techniques could help to build appropriate housing that would fit the needs of those affected, since the most important priority was to provide a dwelling as quickly as possible.

c. Heritage
Heritage was mentioned as an important factor to preserve the housing construction by housing experts; this was due to two ideas: old houses are a fundamental part of the culture and these have a value in history. They highlighted that traditional construction methods/techniques should be preserved to avoid losing them for younger generations.

“In some cases (especially in indigenous communities) construction of traditional housing is a skill with specific tools/techniques unused in other communities. These skills/techniques should identified/catalogued to avoid losing them for younger generations.” (C7)

4.7.2.2 New construction materials

The keywords used to explain the patterns of agreement and disagreement with new materials were: workability, improvement, use.

a. Workability
Although the qualitative data shows an agreement to use new materials, housing experts suggested that the use of these materials should be decided based on structural behaviour, their availability in the area affected, and training of local builders. This suggestion matched the answer expressed by the housing experts who dissented and with those who felt unsure regarding this idea. In addition, housing experts commented that new construction materials should be accessible at a cost and technological level consistent with the culture of the place affected, to increase the strength and resilience of the place.

“Yes, if their availability/durability and workability are sustainable to the local community, then yes...” (C7)
“Yes, it's appropriate to introduce new technologies such as reinforced masonry which are proven in seismic areas in preference to perpetuating un-safe construction e.g. unreinforced masonry. But only if there is investment in training local builders so the technology is adopted as standard practice longer term. Alien materials and technologies - notably pre-fab systems - which local people cannot adapt, maintain or modify are not advisable.” (C18)

Housing experts also thought that people should be further informed about the advantages and disadvantages of materials in order that they could decide which one best fitted their needs; and people should be trained about the maintenance of new materials to use them in the best way.

“....But if the community cannot maintain it due to lack of training/knowledge of the materials maintenance requirements, the using new construction materials will be wasteful and unsustainable.” (C7)

Housing experts suggested that new construction materials are more resistant, durable and able to resist loads; whereas old materials require the skilful people to build and repair buildings.

“Yes, new construction materials must be used because they are often more resistant than the traditional ones, provided that the intervention respects the conditions of reversibility and minimum invasivity.” (C5)

b. Improvement
In terms of improvement, housing experts believed that new construction materials should be used, because they would give an opportunity to build more efficient houses by using more up-to data materials with better performance, both in terms of energy and durability. However, it was reiterated that people and builders should learn the construction process with new materials so that they would be able to repeat it. Other important points emphasized by housing experts can be generalized by means of the quote below, which comments that new construction materials should not be ignored, since these emerged from the evolution of traditional materials, so that these should be given the opportunity to prove their benefits to rise above the stereotype around them.

“Yes, industrial materials and prefabricated products generally are a technological evolution analysis and traditional materials. This has led them to more easily position mounting, less weight, greater strength and faster among many other benefits. A disaster situation is an opportunity to overcome many prejudices from the user base for resolving their needs assertively.” (C22)

c. Use
In terms of use, housing experts mentioned two factors to be considered on the use of new construction materials: ease of construction and maintenance in the place where
they will be used, which were often matched with workability and improvement to ensure sustainability and for building disaster resilience.

4.7.2.3 Inclusion in choosing of building materials
When housing experts were asked about the active inclusion of people in some stage of the housing reconstruction, C2, C6, C15, C19 and C22 rejected the idea. The data analysis shows that the pattern to explain their viewpoints is associated with their background: they are Civil Engineers or Architects, who consider that the technical stages should be performed by professionals, as C15 and C19 said:

“No, their wants and desires in the home should be implemented if possible, but leave the design to professionals that can mitigate the impact of future disasters.” (C15)

“Civil engineers and architects hold a key role to impress people’s mind by impressive designs or innovative use of materials, rather than simply drawing copy-of-copy plans and buildings.” (C19)

Moreover, C17, C18 and C21 tended to condition the inclusion of people in the housing reconstruction. Here the pattern explaining this is linked to their experience in housing reconstruction, given that respondents reported themselves to be experienced and to have worked in housing reconstruction for a period of 11-15 years. However, the remainder of respondents expressed their viewpoint based on their knowledge and personal viewpoints. The keywords used to explain the pattern of agreement and disagreements in this category were: workability, accessibility and means.

a. Workability
In terms of workability, housing experts who accepted the idea of consulting the displaced people about construction materials tended to say that people should be consulted after they have been given an explanation about the features and properties of the construction materials, in order that people can choose an appropriate material to reduce risk in future disasters.

“The community can help by helping choose and learning about sustainable alternative materials they can use which will withstand future disasters/reduce the effects of it.” (C7)

“Yes, but in a way that also educates them as to the pros/cons of different systems.” (C18)

“Yes, but only within reason. In some parts of the Indian subcontinent there is an overly interest in reinforced concrete structures (to replace timber framed ones that perform well in seismic zones) but in many case the structures are not built correctly or the materials are not used appropriately. Therefore, professional judgement and a preference for locally sourced materials is the key.” (C9)
Housing experts who rejected the idea based this on people not knowing the mechanical properties of the materials, so that their choices could risk not withstanding disasters in future situations. However, they considered that people should be consulted in finishes or elements that were purely visual, namely, those elements that were not related to the structural behaviour of housing.

“They are not familiar in this case, their decisions would be risky.” (C11)

“The simple answer here is no, just choices in finishes...” (C15)

“The choice of materials is rather technical in situations of risk of natural disasters. People affected by natural disasters should not be consulted...” (CP2)

b. Accessibility and means
Housing experts reported accessibility as another important factor about which people should be consulted; they added that those people have easier access to local materials and designers and builders could take advantage about this. Moreover, respondents who were in disagreement thought that the accessibility could bring more complication during a disaster, because people affected tend to want the same materials that they know and reject new construction possibilities that could be used for building resilience.

“This can be tricky a bit, cause they mostly stick to their traditional and local materials, or just want a simple update for the material used...” (P, e.g. if the collapsed building was stone masonry, then they want to switch the choice of material to concrete, since this is the main material they see all around the urban areas.” (C19)

Housing experts either in agreement or disagreement suggested that a criterion for the choosing of materials or finishes should be set up through a friendly and interactive database or by a questionnaire, but the final decision should be made by housing experts.

“...A quality contractor will work with the customer, suggesting alternatives and justifying them, with skill and persuasiveness convince the affected person to take his advice and do it correctly.” (C15)

However, special attention should be given to designs or innovative use of materials to avoid the reconstruction programmes making use of copy-of-copy plans without previous analysis of the adaptation of materials in affected areas.

“Evaluating previously constructive workplace culture and detecting innovation available.” (C20)
4.7.2.4 Participation in choosing of building materials

The keywords used to explain the patterns of agreement and disagreement with participation in the choice of building materials were: participation, funds.

a. Participation
As established, participation includes the consultation, so that in general terms housing experts highlighted that the ideal would be that the affected people could work in conjunction with the stakeholders involved in housing reconstruction to empower people. However, as people are unskilled to choose construction materials they should only be informed about the properties of materials and allowed the opportunity to choose from limited options of materials to give them a sense of ownership. In the opinion of respondents, the participation should be limited to signing off materials certificates and approving the quality of materials on delivery which can be used as an effective way to engage them in ensuring the quality of construction.

b. Funds
In terms of funds, housing experts emphasized that people should participate in choosing building materials when they or their insurance are paying the cost of rebuilding. Moreover, the housing experts’ argument was that people in developing countries habitually received funds up to 50% of the cost of the construction in housing reconstruction, motivating them to practice self-building so that they should participate.

4.7.2.4 Summary and Discussion
More than 13 housing experts (59.1%) concurred to preserve traditional housing construction materials when these showed good workability toward disaster and contributed to building disaster resilience.

Moreover, more than 19 housing experts (86.4%) accepted the use of new construction materials after a disaster, due to the fact that those materials are the product of technological advances based on the traditional techniques and systems of construction. However, new construction materials should be matched with the site where they will be used, to preserve culture, customs and habits. In addition, this should develop a culture of the use of new materials and involve all stakeholders in the rebuilding, given that a disaster should be seen as an opportunity to improve the
current construction systems.

In relation to the inclusion of people in choosing of building materials, this can be summarized by using the ladder of community participation. Housing experts think that people should not be included in the choosing of the building materials, but that they should only be informed, so this falls in the second level ‘inform’, as the respondents highlighted that people are unskilled in selecting appropriate construction materials able to withstand disasters. However, housing experts highlighted that people could participate in the selection of construction materials in a limited scheme established by construction professionals to give them a sense of belonging, by which it could be brought up to ‘consult’ level.

When recalling the Cash Approach mentioned above (where homeless people were given the opportunity to build their houses), it can be seen that housing experts dissented with this programme because people lack technical knowledge, which could lead to poor quality and low structural resistance of housing. Moreover, housing experts in the choosing building materials category do not approve of the use of Owner Driven Reconstruction; they tend to favour the Donor Driven Reconstruction programme where the decisions are made by technical experts.

4.8 Management of financial resources

The fourth theme of the online questionnaire was the management of financial resources, composed of two categories. The objective of this theme was to explore whether the homeless people should receive cash to build their own houses by themselves and to hire builders. This Cash Approach consisted of granting cash to households for the construction of their permanent houses (Steinberg, 2007). However, this approach has been criticized for poor financial management.

4.8.1 Quantitative analysis

The results of the analysis obtained by descriptive statistics and patterns matching from management of financial resources are focused on:

- Self-construction.
- Hiring builders.
The quantitative analysis showed that 6 housing experts (27.3%) concurred with the idea to giving cash to people after a disaster to buy construction materials, whereas 14 housing experts (63.6%) opposed the idea and 2 housing experts (9.1%) were unsure (Figure 4-16). Moreover, 4 housing experts (18.2%) accepted giving cash to people after a disaster to hire builders to build their own houses, while 16 housing experts (72.7%) disagreed with the idea and 2 respondents (9.1 %) were unsure (Figure 4-17).

4.8.2 Qualitative analysis

This section presents the qualitative analysis of management of financial resources theme composed of two categories.

- **Self-construction.**
- **Hiring builders.**

4.8.2.1 Self-construction

The keywords used to explain the patterns of agreement and disagreement with giving cash to buy constructions materials were: use, building, quality.

a. **Use**

Housing experts, who were in agreement with this idea, thought that people could be able to manage the cash to build affordable houses. But they agreed with those housing experts, who were uncertain because people must be monitored and guided to ensure that the cash is used as planned. Housing experts suggested similar monitoring must
be made of state bodies and NGOs to avoid fraud, corruption, misuses and waste of financial resources.

“I agree, since in many cases the resources granted in this way are diverted.” (C21)

“It's a very good option if done properly. Cash is the most flexible so people maximise their utility. To avoid wastage or improper use, voucher systems are often used in lieu of cash.” (C1)

Housing experts expressed that cash should not be given to people due to the fact that they can use the cash for other purposes, they cited that people could buy a car or migrate to other cities and end up without a home. But, the main reason to avoid this was related with that here is a potential risk about people looking for cheap construction materials or that the cash cannot be enough to buy them due to unexpected inflation or shortage, which can create collateral risks in terms of security.

“Not sure of wisdom of this. Many affected people need some guidance, best provided by a trusted contractor.” (C15)

“This would lead to other socio-economic issues.” (C16)

“How much? What for? For how long? Cash can be a very effective short term solution when there are multiple options e.g. to build, to rent etc. With cash do they have the means to purchase and transport materials? It might be better to purchase materials or skilled labour on their behalf.” (C18)

b. Building

Two factors were mentioned about building, housing experts considered that it was more practical that the cash was managed by governments or NGOs to avoid incomplete building or delays. The second factor was associated with the idea that the production on a large scale can be achieved in less time and low cost.

“No, I think that mass production is cheaper and can be done faster. In addition, when the government is responsible about the whole project some unity can be noticed in the form of the project which will make it look nicer.” (C12)

“People may end up with excessive use of materials, expenditure on construction or so on, which makes them to live in an incomplete building, or in a half good half bad building. So, in my opinion, this choice is not working.” (C19)

c. Quality

Reiterative mention was made of the lack of technical skills of people through all categories by which it is not surprising that housing experts commented that the quality of houses is at risk of being poor quality when people are responsible for buying construction materials.
4.8.2.1 Hiring builders

The keywords used to explain the patterns of agreement and disagreement with giving cash to hire builders were: use, building, quality.

a. Use

Use of the cash was the element more frequently mentioned by housing experts, they thought that it was adequate to give cash to people to hire builders, because it helped people to have control over housing reconstruction. However, in the opinion of housing experts who reject the idea, allowing people to hire builders could bring collateral problems, such as delays to completion, incomplete dwellings, and poor quality houses. In addition to these problems, the builders could abuse the system by taking advantage of the situation after a disaster and overcharging the cost of housing. Moreover, housing experts who were unsure commented that it could work if an efficient control was implemented to monitor builders.

“I would disagree. To supervise a construction it is not easy and the use of the money can be ineffective if spent by each person. In that case global solutions at a higher scale are preferable.” (C1)

“Sufficient fraud prevention and quality control mechanisms need to be in place. It all comes down to be a well-informed client - and whether the affected people are or can become informed enough to be well-informed clients.” (C4)

This could work but not if the contractors become too expensive in the aftermath of the disaster (i.e. They see a money maximising opportunity). This could be difficult to manage.” (C8)

b. Building

The argument used to give cash to people is associated with the idea that builders must be the ones who build the houses; hence, in the opinion of housing experts people could put this idea into practice through schemes where people could be informed about how to hire a builder and requirements to meet the construction regulations.

“It depends on how much people know and are aware of the technical issues involved. A good coordination group composed by professionals may instruct them on how to make the best choices.” (C3)

c. Quality

Housing experts, who were opposed to the idea, thought that there was a potential risk in terms of quality, given that when people were granted cash to hire builders, this would not guarantee that the builders were qualified. In consequence, this would bring collateral risks for future disasters. However, it highlighted that some housing experts suggested the possibility to look for a system to address this problem and to empower
the affected people. Moreover, housing experts mentioned that a programme of housing reconstruction on a large scale is more suitable than giving cash to people.

“Again, I think that most people would like the control. Many people have relationships already with contractors. There is always a danger of less than reputable people entering the market in the overheated building environment following a disaster so energies might be best engaged with working out an easy system of qualifying contractors or establishing an online rating/referral system.” (C2)

4.8.2.2 Summary and Discussion

In terms of the community participation level it can be concluded that housing experts tended to accept the participation up to the second level (‘inform’) in management of financial resources, given that buying construction materials and hiring builders are activities that should be performed by technical professionals and people should be only informed about that. However, there was a potential tendency to look for the participation of the affected people by training them.

Management of finance after disasters can be summarized by saying that housing experts fixed their preference on the Donor Driven Reconstruction by rejecting the idea of giving cash to people to buy construction materials or to hire builders, because people required training to manage financial resources and to monitor builders in order to guarantee completion of dwellings under high standards that allow for building disaster resilience.

4.9 Unskilled people

The fifth theme of the online questionnaire is the unskilled people; this is composed of two categories. The objective was to find out whether the respondents considered that the construction activities should be performed only by construction professionals of the AEC industry. Also the objective of this theme was to explore the possibility of training people in construction activities in order that they could participate somehow after overcoming the post-disaster emergency phase, given that the Owner Driven Reconstruction Programme encouraged the community participation after the Indian Ocean Tsunami disaster, while the Donor Driven Reconstruction rejected the help of members of the community for housing reconstruction.

4.9.1 Quantitative analysis

The results of the analysis obtained by a descriptive statistic and patterns matching from the unskilled people are focused on:
• Professionals.
• Training for unskilled people.

The quantitative analysis showed that 9 housing experts (40.9%) agreed that construction activities should be exclusive to professionals of the AEC industry, whereas 10 housing experts (45.5%) opposed the idea and 3 housing experts (13.6%) were unsure (Figure 4-18).

Moreover, 18 housing experts (81.8%) accepted the idea of training people after a disaster under supervision of professionals of the AEC industry, 3 housing experts (13.6%) disagreed with the idea and 1 housing expert (4.5%) was unsure (Figure 4-19).

4.9.2 Qualitative analysis
This section presents the qualitative analysis of the unskilled people theme composed of two categories.

• Professionals
• Training for unskilled people

4.9.2.1 Professionals
The keywords used to explain the patterns of agreement and disagreement with construction activities being exclusive to professionals of the AEC industry were: skills, training, type of activity.

a. Skills
Housing experts who concurred that the construction activity should be exclusive to professionals commented that the professionals are skilled in tackling the challenges caused by N and M-MDs and they have the technical knowledge to address the technical stages necessary to build housing which must be able to withstand disasters.

“Yes I do. The construction need to be performed by skilled labour and professionals that might assure an acceptable performance of housing in natural disasters. The risk of poor performance and failure of self-construction in high under extreme environments” (C2).

Moreover, in the opinion of those housing experts in disagreement, they commented that the construction activities are not exclusively performed by professionals and that unskilled people can be trained to participate in activities of construction post-disaster to provide ownership, better quality of houses, skills training and livelihood opportunities.

“No, professionals must be employed by those affected and may be paid by the State. Those affected are part of the solution.” (C19)

Housing experts who felt unsure stressed that the construction activities should be exclusive to professionals, but community members should be included, given that they should be given the opportunity to participate somehow in housing reconstruction based on realistic expectations.

“Construction management (managing design, procurement and construction) should be done by professionals. This does not mean communities are excluded.” (C1)

b. Training
In terms of training, housing experts linked monitoring and availability of unskilled people from the community; they commented that professionals should be able to supervise the work developed by people to save money, and when the human resources are limited to learn the construction activities the work should be left to professionals.

c. Type of activity
Another factor pointed out by the housing experts to determine whether or not the construction activities should be exclusive to professionals was associated with the type of activities, since the technical stages need to be conducted by professionals and non-technical activities such as finishes can be performed by unskilled or semiskilled people under supervision to guarantee high construction standards.
“Not in all areas. People want and need opportunities for DIY work and building sweat equity. However, there are limits to this and there are items that require professional attention. Control systems need to be put in place that stop dangerous activity but permit homeowner engagement should that be desired.” (C3)

4.9.2.2 Training for unskilled people

The keywords used to explain the patterns of agreement and disagreement in this theme were: skills, training, experience.

a. Skills

Most of the housing experts agreed with training unskilled people; three arguments were associated with this point. First, housing experts suggested that the training would contribute to creating a building culture, due to people achieving a sense of belonging by participating in housing reconstruction. Second, the cost and time for housing recovery could be reduced, since people could use their labour to build their dwellings and could be involved after the disaster. Third, maintenance was often mentioned by housing experts, who argued that people could develop new skills by being trained to correctly maintain their houses, due to the experience developed during their participation in housing reconstruction.

“If is a must! On the condition that these "professionals" are ethical and accountable and are not under the belief that they "know it all" and ignore local customs/traditions. To be truly effective one must fully understand his environment so they can adapt to changes. Many professionals try to "impose" their own ideas/construction techniques/methods, etc. on people with a culture unlike theirs and in many case they fail to be effective at what they set out to do.” (C7)

“This is an excellent idea; this can provide new skills to the local communities and can also give the householders skills to maintain their home.” (C9)

“It can be done. If this happens the residents‘ feeling of belong will increase. They will like it more, maintains it in the future as they participated in building it.” (C12)

“This is the best way to get the most accomplished in the shortest amount of time, as well as increasing the affected people’s skill set. Many HFH homeowners have gone on from their sweat equity work to a job in construction. In disaster affected areas, there is PLENTY of work in construction available.” (C15)

“It’s good, it can be a source of labour for the benefit of immediate reconstruction and that is able to undertake future initiatives built once resolved reconstruction.” (C20)

“I agree, because this way it is possible to recover housing at a lower cost, while employing people affected.” (C21)

The reasons expressed by housing experts to disagree with training were two: occasional disasters are not viable to train people because training requires a long time.
Housing reconstruction should be conducted by technical professionals of the AEC industry, as far as possible.

“It may take a lot of time to train people properly, so it may not be an effective and efficient solution to communities' problems after an occasional natural disaster.” (C4)

Finally, training unskilled people was accepted when it was aligned to architectural and structural designs, since it was important to prevent mistakes in the worksite, over costing and interruption of the housing construction process, given that this could lead to poor housing.

b. Training
Realistic expectations were a factor often mentioned by housing experts around other categories so that special attention should be given, since unskilled people lacked the technical knowledge to perform all phases of the construction process to build houses. In the opinion of respondents, the training should be offered keeping in mind the quality and safety to reduce the risks in future disaster and for building Disaster Resilience.

c. Experience
In terms of experience, it can be said that housing experts thought that training was viable because nowadays both rich and valuable information is available to train people, in addition to experts who are able to provide personal assistance and expertise. The housing reconstruction and training of unskilled people should be coupled with local customs, traditions and care of the environment.

4.9.2.3 Summary and Discussion
Regarding the community participation ladder used to measure the participation level, the training unskilled people category achieves the maximum level, namely ‘empower’. However, culture, customs and environment should be considered to achieve an effective reconstruction which considers the limitations of unskilled people in the housing reconstruction, namely realistic expectations about what they can achieve after training, as it has been highlighted that technical stages should be developed by technical professionals of the AEC industry.
The training unskilled people theme can be summarized by using the Owner Driven Reconstruction programme, given that housing experts suggested that people should be trained in construction activities such as were carried out after the Indian Ocean Tsunami for the ODR. This resulted from the opportunity to use their labour to rebuild housing in the shortest time and to save money.

4.10 Summary and Conclusion of the Chapter

Twenty two online questionnaires were administered; 22 individual viewpoints were analysed on the inclusion of unskilled people in architectural design, choice of building materials, management of financial resources and labour. Solid qualitative evidence was collected, analysed and interpreted by pattern matching to build up a generalization of the study. Since the study sought for qualitative data no formal sample size calculation was used. The findings were triangulated by using the literature, finding of data collected and websites to give validity and reliability to the study. It is important to highlight that the findings of this chapter enable the design of the guidelines directed to construction professionals to train unskilled people from communities affected by disasters in housing construction with the 3D-LPs construction system which are presented in Appendix 6. The guidelines include technical support to construction professionals provided by manufacturers and the guidelines to provide training to unskilled people by construction professionals.
5 Analysis and Findings of the Semi-Structured Interviews

5.1 Introduction

This chapter presents the results of 7 semi-structured interviews conducted with six manufacturers of the 3D-LPs construction system, from six different companies and one technical director of a cement company from Mexico. The objective was to answer research question (2) related to how the 3D-LPs construction system can contribute to housing reconstruction after a disaster and research question (3). Collected data by semi-structured interviews were analysed by pattern matching to increase the generalizability of the study and the validation was carried out by triangulation techniques.

The chapter also presents the interview with the representative of the cement company from Mexico. The objective was to show how the concrete and mortar can be supplied in areas hit by a disaster, in order to complete housing reconstruction with the 3D-LPs construction system. The researcher considered that an international producer of cement with commercial operations around the world could show the process to supply this material in areas struck by disaster since they work under the same protocol throughout the world.
5.2 Analytic process

Qualitative data analysis was conducted through an interactive process that involves data coding and interpretation along with writing up of findings. Coding consisted of arranging collected data from semi-structured interviews in themes, categories and patterns after importing data to NVivo 10 (see Appendix 4). The process also included a stage to reflect on what the data was showing, in consequence, an additional coding helped to clarify and manage data, as the data volume was reduced to facilitate its analysis. The meaningful and representative data were then arranged in matrices to start the interpretation and to write up the findings. The interviews with technical directors are presented in two parts:

- 3D-LPs technical directors.
- Cement company representative.

The rich qualitative data from six technical directors of six companies, manufacturers of the 3D-LPs construction system were collected from 5 countries (Table 5-1). The objective was to strengthen the theoretical proposition and answer research question (2) related to how the 3D-LPs construction system can contribute to housing reconstruction after a disaster.

<table>
<thead>
<tr>
<th>Technical Director</th>
<th>Country</th>
</tr>
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<tbody>
<tr>
<td>R1</td>
<td>Chile</td>
</tr>
<tr>
<td>R2</td>
<td>Costa Rica</td>
</tr>
<tr>
<td>R3</td>
<td>Spain</td>
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<tr>
<td>R4</td>
<td>Mexico</td>
</tr>
<tr>
<td>R5</td>
<td>China</td>
</tr>
<tr>
<td>R6</td>
<td>Mexico</td>
</tr>
</tbody>
</table>

The experiences of six technical directors of the six manufacturers of the 3D-LPs construction system were analysed by fourteen questions which were analysed in five themes, and then each theme was divided into categories (see Figure 5-1 and Table 5-2) to identify similar patterns. The findings are presented by themes, categories and
identified patterns. Further details regarding themes, categories and patterns can be consulted in Appendix 4 and semi-structured interviews can be found in Appendix 3.

Table 5-2 shows the long names of the themes and categories used in the next sections to explain data coded.
Table 5-2 Themes and categories explored with housing experts

<table>
<thead>
<tr>
<th>Themes</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Features of the construction materials</td>
<td>• Physical and mechanical behaviour.</td>
</tr>
<tr>
<td></td>
<td>• Quality control of materials.</td>
</tr>
<tr>
<td>Availability in the market</td>
<td>• Availability of panels.</td>
</tr>
<tr>
<td></td>
<td>• Customers in the international market.</td>
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<td></td>
<td>• Supply of panels.</td>
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<tr>
<td>International prices</td>
<td>• Competitive market price.</td>
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<td></td>
<td>• Negotiation of prices.</td>
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<td></td>
<td>• List of prices.</td>
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<tr>
<td>Capacity to supply construction materials</td>
<td>• Supply.</td>
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<tr>
<td></td>
<td>• Charge and type.</td>
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<tr>
<td></td>
<td>• Time.</td>
</tr>
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<td></td>
<td>• Production.</td>
</tr>
<tr>
<td>Technical support</td>
<td>• Technical support.</td>
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</table>

5.3 Features of the construction materials
The analysis of this theme started with housing reconstruction programmes used post-the 2004 Indian Ocean Tsunami (see chapter 3). The objective was to find how the 3D-LPs construction system can contribute to building affordable houses in the shortest possible time following a disaster. The first theme analysed corresponds to features of the construction materials. Two categories were set up to examine:

- **Physical and mechanical behaviour.**
- **Quality control of materials.**

Quotations are presented through all results to underpin the explanations of the technical directors.

5.3.1 Physical and mechanical behaviour
The three keywords used to explain the patterns found in this category were: system, structure, workability.

a. System
The qualitative analysis revealed that 6 technical directors (100%) commented that the panels are part of a system which was designed to build housing up to two stories without resorting to the use of additional steel. Technical director (1) disclosed that his system was developed by the University of Berkeley in the US, whereas technical director (4) showed a report dated July 1978 published by the International Conference of Building Officials to explain that his system consists of structural roof and wall panels for commercial and residential construction. This clarification was important
because 5 out of 6 manufacturers (83.33%) commented that their system is composed of one unidirectional panel, which is used to build roofs and walls of houses or commercial constructions. They explained that the panels are adapted to build roofs by placing steel bars on panels; by which can be said that the system produced by all manufacturers is uniform, as the difference of the roof panel mentioned by technical director (4) was that his panels have integrated these steel bars to perform as beams.

The manufacturers also explained that the system is composed of V trusses made of galvanized steel wires of gauge 14 linked to form 3D panels and polystyrene cores. The main advantage highlighted by the technical representatives was the fact that the system enables the building of customised designs, which contributes to building faster with high quality and considerable saving of time. Technical directors emphasized that designs built by means of the system are up to 50% faster than those built with standard methods. The system was described as being of easy installation due to the reduction of heavy equipment on worksite and the easy connexion among panels. The system uses meshes and annealed wires or galvanized steel staples to connect panels to each other, which contributes to saving money and time. Technical director (2) commented that “The market nowadays demands more slim walls, so we have three widths of panels that allow building walls from 12 to 20 centimetres of thickness.” This means that slim walls can be built using the system, which allows efficiency of space. Non-combustible structures and resistant to insects, termites, rodents, mildew and mould growth were added as other advantages of the system by technical directors.

b. Structure

Technical directors explained that they produce two kinds of panels: structural and semi-structural panels. The first kind is used to build structures able to bear tension and shear loads and the second is used to build dividing walls. These data were important because the system can be used in combination with other traditional systems. However, keeping in mind the research aim, the research focused the questions on the structural panels. Thus, technical directors explained that the 3D-LPs are composed of several trusses made of galvanized steel wires which are connected by welded points to create a frame which contains the polystyrene bars or cores, (The frame was also referred as meshes). The separation between galvanized steel wires in
structural panels’ meshes is 5.1 x 5.1 centimetres to bear tension and shear load. However, this measurement changes depending on the type of panel.

Technical directors explained that structural panels are resistant toward earthquakes due to the system behaving as reinforced concrete walls, which work as monolithic structures because the panels are covered by mortar layers on both faces to achieve the advisable thickness; for example, panels of 5.04 cm must reach 8.32 cm thickness. They also emphasized that the system has been tested by mechanical tests under regulations used to design concrete and steel structures, because there is no special regulation to test the panels. They also explained that the systems that do not have their own Norms must meet the building regulations. They explained that the load capacity depends on panels’ thickness, thus a structural panel of 5.04 cm thickness and 1.22 x 2.44m is able to bear an axial load for design up to 6880 kg/m. The representatives also commented that the system is able to bear hurricanes up to 225 mph wind load and one and/to two hours fire resistance (CS&M, 1978).

c. Workability

In terms of workability technical directors commented that the 3D-LP construction system is able to show good performance in earthquakes, because panels work monolithically due to the mass composed of polystyrene, galvanized steel wires and mortar reducing up to half the inertia forces on panels faces. A picture was shown by the representative (6) to highlight that the system is able to bear the loads caused by rocks of several tons, without leading the system to collapse. The picture showed that the system suffered only deformation (Figure 5-2).

Figure 5-2 Housing built with the 3D-LPs construction system hit by a rock Photo credit: Convintec Mexico
“When an earthquake hit the walls made of panels the forces are distributed on the face of the panel and damped because all elements have the same stiffness which allows minimal tension.” (R3)

“Panels had good physical and mechanical behaviour during the earthquake occurred in 2010 in Chile, the buildings built with our panels resisted an earthquake of 8.1 degrees on the scale of Richter.” (R1)

5.3.2 Quality control of materials

Quality control of materials was explored by asking how the quality control is done on materials in their company before they are put on the international market. The explanation offered by the six manufacturers was uniform and is summarized by two keywords to show the patterns found: product, raw material.

a. Product

Respondents focused their answers on explaining that the quality control on panels is done in the manufacturing plant and worksite under national and international regulations.

“Quality control is done under the regulation of ISO 9000 2001-2008 these rules are very strict and are continuously improved to ensure customer satisfaction. Our products must meet the loads that are established by the Mexican Institute of Cement and Concrete (IMCYC). Our product is certified by the National Agency for Standardization and Certification of Building and Construction (ONNCCE).” (R4)

“The panels are certified by the National Agency for Standardization and Certification of Building and Construction (ONNCCE).” (R6)

“The panels have been certificated in Europe for their quality.” (R3)

Technical directors indicated that the inspection on panels at the manufacturing plant is carried out by means of an automatized process which consists of ensuring that the welding points meet construction Norms and that the separations between wires of meshes are placed in accordance with specifications and type of panel.

“Our quality control includes verifying the correct place of wires and welding to ensure avoiding tension forces. Hence, we conducted tests in nodes and welding points.” (R3)

Regarding the quality control at the worksite they disclosed that it is done by engineers who validate that installers have done homogeneous installations in accordance with the construction specification designed by the manufacturers of the 3D-LPs construction system.
b. Raw material
Technical directors explained that the raw materials are under strict quality control before starting the production and that suppliers are asked to meet high standards to guarantee the quality of their products. Additionally, they carry out a pre-inspection of steel and polystyrene to be sure that the raw materials meet the standards require by the international Norms.

5.3.3 Summary and Discussion
The shortage of construction materials, the lack of quality materials and excessive cost of them was a constant problem after the 2004 Indian Ocean Tsunami for housing recovery in the affected countries (Chang et al., 2011). In consequence, summaries and conclusions of the themes of semi-structured interviews are presented in terms of those problems and unskilled people.

Technical directors of manufacturing companies explained that the system behaves as a monolithic structure which allows it to resist inertia forces and distribute the stiffness on the faces of panels. Moreover, the resistance toward earthquakes and load capacity of the panels can be measured by mechanical tests as was reported by Rezaifar et al. (2007) (see chapter 2) and mentioned by interviewees. In terms of resistance towards hurricanes the system resists up to 225 mph wind load and one and/to two hours fire resistance (CS&M, 1978). These findings are significant because 19 housing experts (86.4%) consulted by the online questionnaire commented that after a disaster new construction materials should be chosen based on structural behaviour to strengthen disaster resilience.

Regarding the quality control done on panels, it can be concluded that the inspection of the 3D-LPs construction system is carried out at the manufacturing plant and the worksite, to guarantee high quality. Also it can be said that quality control of raw materials is conducted in accordance with the International Organization for Standardization (ISO), which ensures that products and services are safe, reliable and of good quality (ISO, 2013). Accordingly, the technical directors think that the 3D-LPs construction system is an option to build affordable housing in a short time after a disaster, since their system is 50% faster than other systems, safer and economic;
moreover, the system enables the building of customised designs, which meets suggestions made by housing experts consulted by the online questionnaire.

5.4 Availability in the market
The second theme of the semi-structured interviews was the availability of 3D-LPs in the international market. The objective was to explore the capacity of manufacturers to supply panels in the international market. This is because a large proportion of construction materials used for housing recovery post-the Indian Ocean Tsunami in 2004 were imported, due to lack of capacity of local suppliers (Chang et al., 2011). Three categories were analysed by pattern matching to show the patterns of theme which are listed below:

- Availability of panels.
- Customers in the international market.
- Supply of panels.

5.4.1 Availability of panels
The explanation given by the manufacturers regarding the category the availability of panels in the national market was summarized by one keyword to show the patterns found: national.

a. National
Technical directors explained that their main market is national; that they manufacture the panels and have a network of distributors around their countries, by which they have a presence in many places to supply panels quickly. Technical directors (R1), (R4) and (R6) revealed that they have already supplied panels after a disaster, even when the roads were damaged, as their panels are lightweight (15 Kilograms) and easier to transport. Technical director (R4) provided a couple of photographs to show how light the panels are and that they can be transported in places of difficult access, see Figures 5-3 and 5-4.
5.4.2 Customers in the international market

The explanation offered by the manufacturers regarding the availability of panels in the international market was summarized by one keyword to show the patterns found: international.

a. International

All 6 technical directors (100%) explained that their panels are available in the international market, and that they can supply panels anywhere required. Manufacturers in the American Continent mentioned that they have already exported near to their region. A Technical Director from Mexico (4) said that his company has customers in Europe, Africa and Central America. Moreover, Technical Director (3) commented that his company has supplied panels from Spain to Africa, India, Northern Morocco, Togo, and Nigeria; and his company is thinking to expand to Asia and Arabic countries soon. Technical Director (5) explained that as their product meets the international standards they have exported panels for many years from China to other countries.

5.4.3 Supply of panels

The keywords used to explain the patterns found were: immediately, schedule.

a. Immediately

In term of supplying, technical directors explained that all of them (100%) have stocks by which they are able to supply panels immediately after a customer places an order. Technical director (2) explained that his company has stocks which can be used to build 10 houses of 42 m² on a surface. Moreover, technical director (4) said that his company is ready to supply panels even in areas affected by disaster, because his
company has already experienced this before.

“Our company is ready to supply panels in areas affected by disasters. We have done it before. We had an experience in Oaxaca Mexico and our materials have contributed for rebuilding of housing. As our panels are 1.22 x 2.44 metres and 15 kilograms on weight they are easier to transport even in Oaxaca as the roads were damaged the panels were transported by donkeys.” (R4)

“Usually we have enough material in stock to avoid some uncontrolled factors such as the natural disasters. We have good partners to supply raw material anytime.” (R5)

b. Schedule
Technical directors revealed that 100% of them can duplicate even quadruplicate their production easily in order to provide a constant supply of panels in the region affected by a disaster. They mentioned also that they are able to install a manufacturing plant in the areas affected to use local labour and raw materials.

“Later we can supply 3500 panels every month, because our production can be easily duplicated even quadruplicated in such way we can produce panels to build 40 or 50 houses monthly.” (R2)

Technical director (6) disclosed that the production of his panels can also include installation, which could be useful to save time and money.

5.4.4 Summary and discussion
Recalling the problem suffered by the NGOs regarding the construction materials, post-the 2004 Indian Ocean Tsunami, it can be said that technical directors of the 3D-LPs consider themselves able to supply their products after a disaster because they have a reserve of panels in their manufacturing plants, which is available immediately after they receive a purchase order, in addition they can expand up to four times their normal production. Moreover, they suggested placing their manufacturing plants in the affected place to use local raw materials and labour after the emergency phase has been overcome. However, they did emphasize that the panels are lightweight and can be transported easily by different means.

In terms of new construction systems, housing experts consulted via the online questionnaire in this study commented that new construction systems should be given the opportunity to show their benefits to build housing, because new materials are the product of analysis and evaluation of traditional materials, so that the 3D-LPs construction system meets the aforementioned points in the opinion of technical directors.
5.5 International prices
The third theme explored with manufacturers was international prices of the 3D-LPs. The objective was to explore how willing the companies are to negotiate new prices and what their prices in the international market are. Three categories were set up to examine:

- Competitive market price.
- Negotiation of prices.
- List of prices.

5.5.1 Competitive market price
The keywords used to explain the patterns found were: yes, unsure.

a. Yes
5 technical directors (83.33%) claimed that their prices were competitive in the international market, because they have found that their prices are lower than the local prices of the countries where they have exported their products. Technical director (2) said that his prices are cheaper because they obtain raw materials at low cost. However, technical director (3) considered that the constructors take advantage of the prices, because they can reduce the construction time with his system and earn more money because the constructions built with the 3D-LPs construction system are possible to build in half the time of traditional construction systems based on reinforcement concrete and bricks.

“Let me give you an example if a construction is built with traditional materials from 8 to 12 months with our system this can be built from 4 to 6 months which represents a considerable saving of time and money.” (R3)

“I can say 3 m² are sold in 30 dollars which is a good price. Our prices are enough competitive with relation to local prices in some countries like those from South America and Central America.” (R4)

b. Unsure
However, technical director (R5) commented that it is a hard question because the prices should be coupled with quality. They do their best to meet client demands.

“...We are very competitive because we are the original manufacturer but if you compared us with the bad quality, you know that...” (R5)
5.5.2 Negotiation of prices
The keyword used to explain the patterns found was: discounts.

a. Discounts
5 technical directors (83.33%) manifested their willingness to negotiate new prices in order to achieve the award of a supply contract.

“We have already negotiated our prices before. After the earthquake occurred in Chile in 2010. The company negotiated a discount of up to 10% with the Government of Chile to supply panels.” (R1)

“We are willing to negotiate prices, because we have studied costs to national and international level.” (R2)

Technical directors (3, 4 and 6) stated that they were ready to negotiate their prices because they can reduce their profit so that customers can afford transport costs. However, technical director (5 from China) said that they negotiate with quality; her company provides products of the highest quality.

5.5.3 List of prices
The explanation given by the manufacturers regarding the list of prices of panels was summarized by two keywords to show the patterns found: yes and no.

a. Yes and no
5 technical directors (83.33%) offered to send a list of prices to the researcher after interviews. 1 technical director (16.67%) said that they do not have a list of prices because they make customized products.

5.5.4 Summary and discussion
As mentioned, the Cash approach was an approach used after the 2004 Indian Ocean Tsunami to allow people affected by the disaster to buy construction materials. The academic literature indicates that people affected and NGOs faced excessive costs of construction materials and incomplete dwellings. On the other hand, when housing experts were consulted by the online questionnaire in this study about giving cash to those people affected to buy construction materials in a similar way to the Cash approach, they commented that people should not buy the construction materials, but they should be informed to enable their participation somehow in this activity, and that the final decision to buy construction materials should be made by experts. Hence, the willingness of technical directors to negotiate new prices and the competitive prices
offered by them offers a new way to solve the problems faced by the affected people and NGOs to make an appropriate decision regarding construction materials that can contribute to maintaining a constant supply of materials and a guaranteed price during the reconstruction process.

5.6 Capacity to supply construction materials

The fourth theme explored with manufacturers was capacity to supply 3D-LPs. The objective was to explore how manufacturing companies of the system can supply their panels in affected places by N and M-MDs. The analysis was focused on five categories:

- Supply.
- Charge and type.
- Time.
- Production.

5.6.1 Supply

The explanation offered by the manufacturers regarding the supply of panels in areas hit by disasters was summarized by two keywords to show the patterns found: easily, via.

a. Easily

In terms of supplying of the 3D-LPs and their accessories 6 technical directors (100%) commented that they can easily supply 3D-LPs in areas hit by disasters for two reasons, first they have greater production capacity than normal, and second because they can increase their production to 400% by producing panels 24 hours a day by enabling additional production lines. Technical director (2) said that “their geographic location of his company allow them to provide panels easily by Caribbean Sea and the Pacific Ocean.”

b. Via

All of the technical directors (100%) argued that they are able to supply the panels by sea and road, because their panels are surprisingly lightweight (10 to 15 kilos each one), therefore, they can transport them in containers. Technical director (5) added that her company can even supply panels by air. Technical director (3) reported that their panels can be transported by means of their own transport up to terminals to send them
by cargo in containers to the required place; he explained that his company has already sent panels to other countries before by this system.

5.6.2 Charge and type
The explanation gave by the manufacturers with regard to extra charges for supplying panels in areas hit by disasters was summarized by three keywords to show the patterns found: Yes, no and export, which are presented together.

a. Yes, no and export
4 technical directors (66.7%) reported that their company had an extra charge for transportation of panels from the manufacturing plant to the affected site. This is because their quotes are independent of the transportation costs, given that their products are distributed by the national channels to be close to customers and the distributors are responsible for the transportation of the panels, but in the case of export their companies are charged for delivering the product in the area requested. The customers are requested to pay an extra charge for the transportation of panels.

“We have 500 points to distribute our panels.” (R2)
Whereas 2 technical directors (33.3%) expressed that they do not have extra charge.
“No, there are not extra charges. We work under a subsidy scheme which is larger than discounts to encourage customers to buy with us.” (R1)

“No, same as usual.” (R5)
Reiteratively, 5 technical directors (83.33%) commented that the transportation costs can be reduced by installing a manufacturing plant of panels in areas affected to use local materials and labour.

“However, we can enable a manufacturing plant in affected areas to use local materials and reduce cost and give better prices.” (R3)

5.6.3 Time
The explanation given by the manufacturers regarding the time for supplying panels in areas hit by disasters was summarized by two keywords to show the patterns found: days and transport, which are presented together.

a. Days and transport
As commented in section 5.4.3 the panels can be ready immediately after placing a purchase order. The time to make the panels and their accessories available depends
on the place where the panels are required and type of transport. Manufacturers commented that they are able to deliver the panels to ports and railway terminals immediately, but it is important to take into account the time that the transportation chosen takes. Manufacturers (3 & 4) commented that in their experience the delivery process takes 40 days when it is carried out by ships and trains. As commented in section 5.6.1 (b) the panels can be transported by sea, road or railway.

5.6.4 Production
The keyword used to explain the patterns found was: monthly.

a. Monthly
As can be seen from Figure 5-5, the capacity to supply panels of company (4) is higher than the capacity of company (3) and the other countries. In terms of amount of houses that can be built it can be said that manufacturer (4) can supply panels for building 533 houses monthly of 50 m² on a surface with a height of 2.44 m, whereas manufacturers (2 & 5) can supply panels to build 44 houses monthly. The production displayed in Figure 5-5 is for the normal production line, which can be increased up to four times by manufacturers.

“Depends on the quantity you booked. Usually 20 days/20 containers.”

![Production of panels monthly](Figure 5-5 Monthly production of manufacturing companies)
5.6.5 Summary and discussion
Given that the NGOs faced construction material supply problems after the 2004 Post-Indian Ocean Tsunami, the housing experts consulted by the online questionnaire in this study thought that new systems of construction should be implemented after a disaster. It can be concluded that the findings of this category show that the 3D-LPs construction system can be delivered in areas hit by a disaster within an average time of 40 days by sea, road or railway to build new housing for the affected people. Technical directors commented that their companies can place from 10,000 to 120,000 panels for the construction of houses at maritime and railway terminals to build from 50 up to 533 houses monthly with one production line. However, they estimated that the production can be increased four times to constantly supply panels to affected areas. They also suggested installing a manufacturing plant after overcoming the emergency phase to use raw materials and local labour to save money, which was advised by a housing expert consulted by the online questionnaire in this study, who highlighted that new construction materials should be coupled with local materials and labour.

5.7 Technical support
The fifth theme explored with manufactures was technical support in areas affected by disasters. The objective was to explore how manufacturing companies of the system can give technical support in areas struck by disasters. One category was set up to examine:

- Technical support.

5.7.1 Technical support
Three keywords show the patterns found: technical department, worksite, unskilled people.

a. Technical department
5 technical directors (83.33%) stated that they have a technical department to teach their system and provide technical support to customers, whereas 1 technical director (16.67%) reported that her company does not take action in this area. Technical director (1) said that the technical support is offered at their facilities and at the customer facilities. Technical director (4) said:
“Technical support is a service that distinguishes us from other companies. We also give advice to help for quantification, estimation of cost, details of construction”

Technical directors explained that they provide technical support to professionals and unskilled people. The training for professionals is with the aim to achieve high quality, while training for unskilled people is focused on teaching the construction system.

b. Worksite
Five technical directors commented that they offer technical support in the worksite, because special attention must be given to the supervision of stages of transition between connections of panels and placing of mortar on both faces of the panels to ensure that the structure works monolithically. They commented that their technical support is focused on installing and choosing appropriate panels, and the explanation of how the construction process works.

c. Unskilled people
Technical directors who offer technical support revealed that most of the time their customers do not have experience in their system and require training. Hence, they offer technical support and didactic material to teach the correct installation of panels and optimization of materials, since the panels do not produce waste during their assembly. Technical directors explained in detail their experiences training people, which are summarized by saying that anybody who is interested at learning the system can be trained in 10 days.

Technical directors shared their experiences in training people, they highlighted that they have trained people with good results and that unskilled people are able to build housing with high standards; that they have detected aesthetic mistakes in the work of unskilled people, but these mistakes do not represent structural risks. They emphasize that their system is user-friendly and easy to assemble, so that unskilled people can become skilful after participating in the building of two houses, given that the process is repetitive.

5.7.2 Summary and discussion
It can be concluded that unskilled people can be trained by the manufacturers in a short
period of time in the 3D-LPs construction system, to enable them to help in housing recovery after a disaster. Additionally, there is the fact that professionals of the AEC construction can be advised by the manufacturers to achieve higher quality construction. This also given that 18 experts (81.8%) accepted the idea to train people after a disaster under supervision of professionals of the AEC industry.

5.8 Results of the semi-structured interview with the Cement Company

The analysis of the semi-structured interview conducted with the technical director of the cement company was with the objective to collect data to support the use of the 3D-LPs construction system following a disaster. The system requires concrete and mortar to achieve the monolithic structure which behaves as a reinforced wall able to withstand dynamic actions caused by earthquakes, hurricanes and tornadoes.

The starting point of this interview was the ethical approval, since this supplier was asked under the same process as all of the participants in this study. The questions asked to manufacturers of the 3D-LPs construction system were also used to interview the technical director of the cement company. The results of the analysis obtained from the semi-structured interview are summarized by five themes since there are no data to compare with.

1. Features of the mortar and concrete.
2. Availability in the market.
3. International prices.
4. Capacity to supply mortar and concrete.
5. Technical support in areas hit by natural disasters.

5.8.1 Features of mortar and concrete

The first theme is composed of two categories to find the resistance toward earthquakes and quality control carried out on mortar and concrete of concrete and mortar. The analysis was focused on the following categories:

- Physical and mechanical behaviour.
- Quality control.

a. Physical and mechanical behaviour
The Technical director explained that mortar and concrete are different products. The concrete is manufactured industrially at the manufacturing plant to guarantee the correct resistance required for customers. The concrete is perishable when handcrafted, because aggregates are not measured correctly and do not achieve appropriate resistance. The maximal resistance of concrete is achieved after 28 days. However, there are additives which are retarders and accelerators. Additives are chemical components that modify the resistance curve. The cement is a chemical and works with water, because gravel and sand are added to avoid elements becoming solids. In the case of mortar, the technical director explained that it has different physical and mechanical behaviour which depends on where this is manufactured. He commented that the concrete has good physical and mechanical behaviour towards earthquakes.

b. Quality control

The Technical director explained that they have a technical department that is in charge of making the dosage to manufacture concrete in accordance with resistances required. The concrete is placed in mixer trucks to transport up to the worksite. He said that they consider it impractical to sample all materials and products manufactured. Hence, they take random samples to verify resistance, fluency and slump. Samples are taken in the manufacturing plant by technical personal, because the concrete must meet the Norm NMX C 414 from the American Concrete Institute (ACI). Concrete of 40 mega Pascales (Mpa) in accordance with ACI must meet three relevant elements; the first element is compressive strength (f’c). The second element is the slump which is a measure of fluidity or workability and the third element is standard deviation. The process for testing these elements is carried out internally at the manufacturing plant and involves taking samples of concrete in cylinders at 1, 3, 7, 14 and 28 days. The cylinders are prepared with sulphur to create uniform surfaces at the top and bottom and are placed in a hydraulic ram to test compressive strength.

The Mortar quality control is done by another company division due to the strength of mortar being different to the concrete. He explained that when they supply mortar at the worksite they place a silo in order to keep a constant supply and avoid stopping the production. The silo is placed at a strategic position to supply materials easily.
5.8.2 Availability in the market

The second theme is composed of two categories to explore the capacity of manufacturers to supply mortar and concrete in the international market. This is because a great amount of construction materials used for housing recovery after the 2004 Indian Ocean Tsunami were imported due to lack of capacity of local suppliers (Chang et al., 2011). Findings of the analysis are presented together. The analysis was focused on the following categories.

- Availability of mortar and cement.
- Customers in the international market.
- Supply of mortar and cement.

The technical director commented that mortar and cement are always available, and that they are ready to supply their products easily because they have aggregated banks everywhere, which allow them to quickly supply their products around the world.

5.8.3 International prices

The third theme of the semi-structured interviews was international prices of the mortar and cement. The objective was to explore how willing the cement company is to negotiate new prices and how its prices compare in the international market. The theme is composed of three categories focused on:

- Competitive market price.
- Negotiation of prices.
- List of prices.

The technical director expressed that it is a sensitive theme, but their prices are competitive, that they follow a protocol to sell their products and have a specialized department to make negotiations. He also said that there was no price list because each project is quoted by a marketing manager to provide personal attention.

5.8.4 Capacity to supply cement and concrete

The fourth theme of semi-structured interviews was capacity to supply concrete and cement. The objective was to explore how the cement company can supply their
products in affected places by N and M-MDs. Findings of the analysis are presented together. The theme is composed of five categories focused on:

- Supply.
- Charge and type.
- Time.
- Production.

The Technical director explained that they are ready to supply their products immediately because they have business operations around the world by which they can supply immediately by sea, road and railway. He commented that there are no extra charges, because they have business operations in 250 locations in the world, which allow them to supply their products without extra charges. He also detailed that they can supply ready-to-use mortar or place up a manufacturing plant of mortar in three or four days anywhere. He said that the concept involves setting up a silo to store mortar which is monitored by skilled specialists to avoid interruption in the worksite, given that they have electronic sensors to monitor the use and schedule of deliveries. In terms of production he divulged that the national monthly production is 1 million cubic metres (Mexico).

5.8.5 Technical support in areas hit by natural disasters
The fifth theme of semi-structured interviews was technical support. The objective was to explore how the Cement Company provides technical support in affected places by N and M-MDs. The analysis was focused on the following category.

- Technical support.

The Technical director was concrete in this answer, he said that the consortium provides technical support to their customers and encourages customers to use it, one of their goals being that their products will be used efficiently and that their company is interested to implement actions that contribute to environmental protection. He comments that they have two research centres where they develop products and alternatives for their customers. He added that they are willing to supply their product anywhere affected by a disaster under the highest standards of quality.
5.8.6 Summary and Discussion
Integral to the 3D-LPs construction system is supplying of concrete and mortar, since to build a monolithic structure able to behave as a reinforced wall it is important to choose the appropriate concrete and mortar. Hence, considering that CEMEX is a corporate with business operations around the world and that several interviews with representatives of the same company would lead to data saturation, it was decided to conduct a unique semi-structured interview.

The findings were that cement and concrete are two different products; the cement company produces concrete at their manufacturing plants under the resistance required for the customers; the concrete is delivered by trucks and is monitored by mechanical tests to guarantee the resistance solicited. The mortar is supplied at the worksite through the placing of a silo to provide the product continuously and avoid interruptions. The prices of concrete and mortar are quoted for the type of project and include the transportation cost. The Technical director highlighted that they can supply their materials easily anywhere because they have 250 locations around the world and they are owners of material banks. Related with the technical support, they provide wide support through their technical department and two research centres.

This interview showed that the issues suffered by NGOs after the 2004 Indian Ocean Tsunami in supplying construction materials can be overcome by using the 3D-LPs construction system and the CEMEX product to produce affordable and sustainable houses, as housing experts confirmed in this study.

5.9 Summary and conclusion of the chapter
4892 words collected by 7 semi-structured interviews (open-ended) from construction manufacturers were analysed in five themes: features, availability in the market and international prices of the 3D-LPs construction system and Cement along with capacity to supply construction materials and technical support in areas hit by natural disaster. Collected data were analysed by pattern matching to answer the research question (2) How does the 3D-LPs construction system contribute to housing recovery after a disaster? Chapter 5 has summaries at the end of each analysed category, these are summarised at 5.3.3, 5.4.4, 5.5.4, 5.6.5, 5.7.2 and 5.8.6. The findings of this chapter
enable the design of the guidelines directed to construction professionals to train unskilled people from communities affected by disasters in housing construction with the 3D-LPs construction system which are presented in Appendix 6. The guidelines include technical support to construction professionals provided by manufacturers and the guidelines to provide training to unskilled people by construction professionals.
6 Analysis and Findings of the Computer Modelling

6.1 Introduction

This chapter presents the modelling of the basic permanent sustainable housing prototype of 38.5 m² plan, along with an economic comparison between the 3D-LPs construction system and the traditional construction system based on bricks and reinforced concrete elements. The objective of the modelling was to explore the cost-benefit in building housing with the 3D-LPs construction system for housing recovery after a disaster by means of the BIM system, in order to answer research question (3), can the BIM model show the cost-benefit in building housing with 3D-LPs and displaced peoples’ own labour? and to meet the research aim. The computerized modelling was the experimental vehicle to replace the physical construction of the housing prototype which would require economic funds, protocols and the involvement of people. The BIM Revit 2012 and 2013 by Autodesk was the platform chosen to simulate the housing prototype. It is noteworthy that until 2013 the systems developed to use BIM were restricted to modelling each part of a project in completely independent templates. Therefore, it seemed convenient to use the technological advances of the Revit 2013 version, as this version allowed architectural, structural and mechanical models in one template. BIM Revit 2013 by Autodesk was
the platform used to develop and refine a basic housing prototype, because it is composed of tools and functions that allow the modelling of all the different parts of a structure. The 2013 version has integrated the structural, architectural and mechanical tools and functions in one template, so that when the architectural template of the housing prototype was done it was possible to work structural and mechanical models in the same template. This characteristic also enabled the researcher to integrate sanitary-hydraulic-electrical models, which, together with the architectural and mechanical model, were refined by using the 3D views that helped to verify that the housing prototype behaved as planned and described in Chapter 3.

6.2 Modelling process
The modelling process was composed of several steps, which were systematically conducted to model the construction of the housing prototype proposed for housing recovery in the BIM. The first step was the definition of the problem, namely the post disaster housing recovery, which is aligned to the research aim. Then a project plan was developed to keep in mind the resources needed during the process. A third step was to establish the limitations and scope of the modelling. The fourth step was to formulate the architectural and structural design of the prototype and the fifth and sixth steps were to model the architectural and structural design on the BIM system together with the economic estimation. The seventh and eight steps were to verify and to validate the modelling as many times as was needed, so that these last steps were conducted in an interactive process; finally step nine was to document the modelling.

6.3 Architectural design formulation
This section presents the formulation of the housing prototype design for housing reconstruction. This was according to the definition established for housing by the United Nations (UN), which states “The human right to adequate housing is more than just four walls and a roof. It is the right of every woman, man, youth and child to gain and sustain a safe and secure home and community in which to live in pace and dignity” UN, (2006). The design sought to meet the guiding principles for Housing Designed Construction Technology (HDCTs) from the handbook for reconstruction after Natural Disaster by the World Bank, which indicates that the universal housing design should be coherent with construction materials, accessible and adaptable to all
people to make life easier for users. In addition, it should have adequate size and be flexible to give comfort and efficiency; it should also be able to reduce hazards and damage caused by accidental actions Jha et al., (2010). HDCTs also indicate that the construction materials to design the dwellings should take into account the construction regulations, the availability of materials, the costs and benefits, as well as mitigation of risks, rapid construction and climatic and social-cultural characteristics of the area affected, in addition to environmental impact, and training to skilled labour Jha et al., (2010).

Consequently, a construction material was sought for meeting the definition of the UN and indications suggested by the HDCTs. Thus, the 3D-LPs construction system was found as a possibility to fulfil the suggestions of the guidelines for housing design and fit the needs of the affected people, since the academic literature and semi-structured interviews confirmed that the 3D-LPs construction system is able to withstand earthquakes and hurricanes. 3D-LPs are high quality, low cost and able to replace traditional building materials, do not produce waste, are easy to assemble and adapt to customised architectural designs, and are thermal so that they save energy. In addition, the new technologies should be given the opportunity to be used after a disaster to improve resistance capacity and reduce future risks, as was argued by housing experts consulted via the online questionnaire in this study.

The construction standards and technical regulations for the Federal District of Mexico were used to design the spaces of the basic prototype housing. The dimensions of the housing prototype were designed with minimum dimensions allowed by the building code for the Federal District, but these can be modified and adapted to meet the needs of the affected people anywhere. Design regulations of the affected place are strongly recommended for the architectural design in order to fit the needs of affected people.

The China building code was used as a benchmark to show that not only the Mexican construction code meets the requirements established in the HDCTs. As these and other codes could be used to model the housing prototype designed in this study for housing reconstruction. As this was mentioned in chapter 4 by the housing experts consulted; housing must be designed according to the characteristics of each affected area. The minimum measurements used in this housing prototype were compared with
the minimum measurements of the China Building Code because these. The China Building Code was found to be similar to the Mexican Building Code, for instance, it was found that the minimal measurements of bedrooms in China for the main bedroom are 3.00m x 3.00m and for the second bedroom are 2.50m x 2.50m. This shown a difference of 0.50m in relation with the main bedroom suggested for the housing prototype (2.50m x 3.00m) and one coincidence in the second bedroom (2.50m x 2.50m), the lounge, kitchen and bathroom meet the minimum dimensions of the both Building Codes MIT Building, (2000). The measurements allowed by the China Building Code for residential houses suggest that the review of design regulations of the place affected can help to fit and implement the housing prototype anywhere affected by disasters by adapting the measurement to local building regulations. The comparison between China and Mexico was made because both countries share some characteristics, such as earthquakes, floods and large populated cities, in addition to the production of 3D-LPs. As mentioned in Chapter 5 China produces 3D-LPs made of foam and meshes made of the steel. Currently, researchers such as Dai et al., (2015) have dedicated their studies to investigated the mechanical behaviour of the component of such panels. According to Waiel, (2010) “Recently in some countries such as USA, Italy, China and Turkey; a new building system called 3D wire panel building system use prefabricated lightweight panels to construct low-rise buildings up to three stories.” The following section describes the architectural design of the housing prototype.

The prototype housing model is on one level of 5.50m wide x 7.00m long (see Figure 6-1), which includes:

- Two bedrooms of 2.50m x 2.50m and 2.50m x 3.00m.
- One lounge 3.00m x 4.50m.
- One kitchen 2.50m x 2.00m.
- One bathroom 2.50m x 2.25m.
The proposed measurements of this design can be changed according to the available area and the needs in the affected area, since the panels can be adapted to build a permanent house up to two levels; but for the purposes of this study only one level was examined. The housing prototype can also be built on a large scale by reproducing the models many times in the available areas.

Additional Standards for Architectural Design (ASAD), Chapter 2, which relate to "Habitability, Accessibility and Functioning of the local building", were used for housing design; these establish in paragraph 2.1. the dimensions and characteristics of local buildings, as well as minimum measurements of a housing unit. Here is a summary in Table 6-1 of the dimensions allowed to design a housing unit (Government of Mexico., 2004).
Table 6-1 Summary of Table 2.1 Additional Standard for Architecture Design

<table>
<thead>
<tr>
<th>HOUSING</th>
<th>MINIMUM AREA (In m² or minimum indicator)</th>
<th>SIDE MINIMUM (metres)</th>
<th>HEIGHT (metres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main bedroom</td>
<td>7.00</td>
<td>2.40</td>
<td>2.30</td>
</tr>
<tr>
<td>Bedroom</td>
<td>6.00</td>
<td>2.20</td>
<td>2.30</td>
</tr>
<tr>
<td>Lounge and dining room</td>
<td>13.00</td>
<td>2.60</td>
<td>2.30</td>
</tr>
<tr>
<td>Kitchen</td>
<td>3.00</td>
<td>1.50</td>
<td>2.30</td>
</tr>
<tr>
<td>Bathroom*</td>
<td>-</td>
<td>2.55</td>
<td>2.30</td>
</tr>
<tr>
<td>Washing room</td>
<td>1.68</td>
<td>1.40</td>
<td>2.30</td>
</tr>
</tbody>
</table>

The housing prototype Figure 6-1 was designed in accordance with the above Table 6-1. The main bedroom was planned at 3.00m x 2.50m equal to 7.5 m²; the second bedroom was designed at 2.50m x 2.50m and gave 6.25 m²; the lounge and dining room were considered as a room at 3.00m x 4.50m, namely, 13.50 m² and the kitchen was suggested to be 2.50m x 2.00m, incorporating a clean area at 1m x 1.25m resulting in 5 m²; finally, the bathroom was proposed to be 2.50m x 2.25m, since the measurements of the bathroom fixtures were taken into account, which gave 5.60 m². Therefore, the total surface area was seen to be 5.50m width x 7.00m length, namely 38.5 m². Table 6-2 shows areas of the housing prototype model.

Table 6-2 Areas of housing prototype model

<table>
<thead>
<tr>
<th>HOUSING</th>
<th>MINIMUM AREA (m)</th>
<th>AREA (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main bedroom</td>
<td>2.50 x 3.00</td>
<td>7.50</td>
</tr>
<tr>
<td>Bedroom</td>
<td>2.50 x 2.50</td>
<td>6.25</td>
</tr>
<tr>
<td>Lounge and dining room</td>
<td>4.50 x 3.00</td>
<td>13.50</td>
</tr>
<tr>
<td>Kitchen and washing room</td>
<td>2.50 x 2.25</td>
<td>5.63</td>
</tr>
<tr>
<td>Bathroom</td>
<td>2.25 x 2.50</td>
<td>5.63</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>38.50</strong></td>
</tr>
</tbody>
</table>

The bathroom was designed with consideration to the dimensions of the bathroom fixture, according to Table 3.3 and paragraph 3.3.2 (ASAD) shown in Table 6-3; they were fitted in a room of 2.25m x 2.50m.
The toilet and hand basin were fitted in order to maximise the space in the bathroom, the shower was proposed to be 0.80m x 0.80m (see Figure 6-2). In addition, the door was designed to allow easy access to the next bedroom (Government of Mexico., 2004).

Table 6-3 Minimum dimensions of the spaces for sanitary furniture (Table 3.3 from ASAD)

<table>
<thead>
<tr>
<th>FIXTURE</th>
<th>WIDTH (m)</th>
<th>LENGTH (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toilet</td>
<td>0.7</td>
<td>1.05</td>
</tr>
<tr>
<td>Basin hand</td>
<td>0.7</td>
<td>0.70</td>
</tr>
<tr>
<td>Shower</td>
<td>0.8</td>
<td>0.80</td>
</tr>
</tbody>
</table>

The minimum height of the rooms was proposed to be 2.44m; lighting and ventilation for the housing prototype were designed according to paragraph 3.4 "Lighting and ventilation" from (ASAD), which indicates, in subparagraph 3.4.2.1, that the area of the window for lighting should not be less than 17.5% of the housing area (Government of Mexico., 2004). Therefore, the windows were designed at 1.20m width x 1.20m height, resulting in 18.7%. The window in the bathroom should be replaced by a dormer in the roof, when the houses are next to other housing. AutoCAD12 by Autodesk was used to draw the housing prototype shown in Figures 6-1 and 6-2.

The doors of the bedrooms and main entrance were designed at 0.90m and 2.10m in height and the doors in the kitchen and bathroom were dimensioned at 0.75m and 2.10m in height, according to paragraph 4.1.1 of the (ASAD), which establishes the dimensions of the doors in Table 6-4 (Government of Mexico., 2004).
The prototype housing is a basic unit to accommodate a family of up to 4 people. However, this could grow to two storeys, since extra panels can be fitted and installed, but this depends on economic resources and needs. Therefore, this study suggests leaving the prototype housing prepared for future extensions.

### 6.4 Modelling and analysis of the architectural phase

This section shows the computer modelling corresponding to the modelling of the architectural design in BIM Revit 2012. This was modelled with the objective to explore the benefits of building housing after disasters with the 3D-LPs construction system. The architectural computer modelling started with the placing of the housing prototype model shown in Figure 6-1 at the latitude -0.16534686088562 and the longitude 100.596611022949, which corresponds to Sumatra, to show that the housing prototype can be placed in any place affected by disasters. This was achieved by using an internet map service integrated in the BIM system Revit. Figure 6-3 shows the primary and secondary axes which were to draw the limit the plot and to model the architectural distribution in accordance with the formulation of the architectural design referred to in section 6.3. While Figure 6-4 shows the placing of the architectural floor, which consists of a foundation slab of 10 cm thickness with perimeter and horizontal beams of 20 x 20 cm of reinforced concrete embedded at -30 centimetres on the finished floor level.
Figure 6-3 Placing of primary and secondary axes
The next step was to model the walls of the housing prototype with 3D-LP panels of 5.08 cm in BIM. An existing template BIM to model walls was duplicated and the characteristics of 3D-LPs were loaded to start the modelling of the walls in the axes drawn. Figure 6-5 shows the walls made of 3D-LP in the BIM system for the housing prototype which are 1.22m wide x 2.44m long and 0.095 m thick. The walls are composed of a structural panel of 5.08 cm thickness composed of a core made of polystyrene and meshes made of galvanized steel on both faces, a layer of mortar on both sides of the panels of 0.02m (interior and exterior) and 0.004m thickness of paint, which gives 0.073m, because the panels have a space between polystyrene and meshes to allow the adherence of the mortar, (which is not reflected in Figure 6-5).
Consequently, after creating the 3D-LP walls in the BIM, the next step was to model the walls at axes and prepare the square openings on the walls to place windows and doors. This was achieved by placing the walls at the axes corresponding to architectural distribution (see Figure 6-6). Subsequently, in order to make sure that the model was properly working, the first verification was conducted by activating the 3D view of the BIM system. As can be observed in Figure 6-7, the walls are in the axes and connected at a height of 2.44m. It can also be observed that the walls are connected to the architectural floor, from which it can be said that the model performed well.
The following step was to model the roof slab on the BIM system, which was achieved by modifying a roof template created by BIM with the characteristics established by the manufacturers of the panels. Figure 6-8 shows the composition of the roof corresponding to the 3D-LP of 10 cm thickness. It is composed of a core made of polystyrene and meshes made of galvanized steel on both faces; between the polystyrene and meshes of the panel there is a space to allow for adherence of the mortar, (which is not reflected in Figure 6-8), and a layer of concrete of 0.06m at the top, in addition a bottom layer of 0.02m on the roof to achieve a total thickness of 0.20m.
After modelling the roof, the following step was to simulate the placing of the roof at the top of the walls. The roof was modelled with 2 degrees of slope and a parapet at the top to facilitate future extensions and runoff of water which can be used to capture rain water in order to have sustainable housing (see Figure 6-9).

Figure 6-8 Composition of the roof corresponding to the 3D-LP of 10

Figure 6-9 Roof and parapet of the housing prototype model built with 3D-LPs
The following step was to model the placing of window and doors on the walls. During the modelling of windows placed on the square openings the BIM system prevented the placing of windows. This was due to the thickness of the window frames being greater than the thickness of the wall. The constraint was solved by changing the measures of the window frame to model windows with slimmer frames. However, it is proposed to change panels from 5.08 to 7.62cm to build walls with more width, namely of 0.1208m thickness and negotiate the prices of the panels with the suppliers, since the difference in the price of panels is approximately 11%, which could be amortized by suppliers (The price of the structural panel of 5.08cm was 28 dollars and the panel of 7.62cm was 31 dollars (W, 2012)). Suppliers interviewed in this study manifested their willingness to negotiate prices, which would contribute to keeping down the total cost of the housing prototype and to improving the resistance of the prototype.

The problem found in this stage of modelling was useful and helped to think how the windows and doors should be supplied in the disaster site. It is proposed to identify manufacturers of windows and doors in the disaster area to order a unique design in accordance to measurements established in the architectural design section 6.3 of the housing prototype or building regulations of the affected place, (windows of 1.20m x 1.20m, interior and exterior doors of 0.90m x 2.10m, and toilet door of 0.75m x 2.10m) or design code of the affected place, that can be assembled easily on the walls; as can be observed in Figure 6.9, after placing the roof slab on the walls they are ready to receive windows and doors.

6.4.1 Verification and validation
The verification of the housing prototype corresponding to architectural design was carried out through activating the 3D view to check that the 2D plan worked as planned, see Figures 6-10 and 6-11. The architectural computer model behaves as was expected, since all walls appear aligned to axes and foundation and the flat roof slab is in the correct place. 2D and 3D views also show that all architectural elements were modelled in accordance with section 6.3.
Figure 6-10 Architectural housing prototype in 2D
The validation of the housing prototype was achieved by comparing the computer architectural model against real models obtained by the suppliers and by showing the model to a technical director of W Panel Company. He agreed with the structural-architectural modelling on the BIM system and suggested specifying that the panels have a space free to receive the mortar by which the thickness is measured from mesh to mesh. The results of the architectural design formulated in section 6.3 by the computer modelling of the architectural housing prototype of 38.5 m² are shown in Figure 6-10. This includes foundation slab and flat roof slab, walls, parapet walls on the top and windows, doors, and furniture in all the rooms and painting.
The hydro-sanitary installations of the housing prototype were also modelled on the BIM system (Figure 6-12). The architectural model of 38.5 m² was slightly modified in its facade and added a rear patio to show how the same model can be modified without needing to model a new design, which can be useful after a disaster to save design time. The dimensions or areas can be modified by moving the axes, and heights can be modified by adapting the model to the needs of the affected people (Figure 6-13).

Figure 6-12 Housing prototype hydro-sanitary installations 3D
6.4.2 Summary and discussion

Keeping in mind the research question (3) Can the BIM model show the cost-benefit in building housing with 3D-LPs and displaced people’s own labour? and the aim of the research, the computer modelling of the architectural housing prototype in the BIM system with the 3D-LPs shows that the housing reconstruction after a disaster could be managed in the BIM system if an architectural design is modelled and documented in this platform. It found that the BIM system is not only a platform to model a building, BIM is a platform to create lists of materials, schedules of activities and phases of construction to manage the whole construction process. Therefore, the managing of housing reconstruction could be implemented through BIM to save design time and have control over the reconstruction process. It is important to mention that professionals should be experienced in the BIM system to optimize results.

Moreover, the architectural housing prototype simulated in the BIM system shows that housing can be modelled with the 3D-LPs construction system under specification established in building codes regarding the housing design. The most important point discovered is that the housing prototype model can be modified and fitted to different dimensions through modifying axis and height levels without the need to design a new
model. So the housing prototype could be used as a template or a guide to produce housing in accordance with the conditions and characteristics of the affected people and places.

Recalling the HDTC, it can be said that the modelling offers a housing prototype built with a coherent material which is available at least in three Continents, which is easy to adapt to different models that could fill the needs of people affected by a disaster and contribute to making their life easier. Regarding the size, the prototype was designed based on a building code which met the requirements to build appropriate housing. However, it is flexible and easier to change to improve the comfort of the affected people.

6.5  **Structural model**
This section shows the structural model of the housing prototype which was suggested in accordance with the Additional Technical Regulation on Criteria and Actions for the Structural Design of Buildings to Federal District, Mexico for structures of concrete and steel and technical specifications to build houses. The structural model is focuses on answering the research question (3) can the BIM model show the cost-benefit in building housing with the 3D-LPs construction system and displaced people’s own labour? The structural behaviour of the 3D-LPs construction system can be found in chapter 2, which outlines the construction process of the housing prototype modelled in BIM as part of the computer modelling.

6.5.1  **Structural design formulation**
The structural design of the housing prototype corresponds to the architectural design shown in Figure 6-1. A patio was added to the housing prototype to show that the model can be modified easily in the BIM system by adding an area and changing the facade. The structural design consists of one foundation slab of reinforced concrete with beams, walls and roof slab made of 3D-LPs.

The foundation is composed of a foundation slab and ground beams all made of reinforced concrete. The foundation slab was proposed to be of 10 cm thickness of reinforced concrete $f'c 200 \text{ kg/cm}^2$, steel bars of 0.79cm of diameter and welded mesh of $15\times15\times0.635\times0.635\text{cm}$ of 2.5m width. Perimeter and horizontal beams were
proposed to be of 20 x 20 cm made of 4 longitudinal reinforcements steel bars with 0.79cm diameter and stirrups/transversal reinforcements made of steel spaced @ 30 cm.

The structural walls were proposed to be of 5.08cm thickness made of structural panels (3D-LPs) to build a monolithic structure. The 3D-LPs were proposed to be of 1.22 m width x 2.44 height made of polystyrene cores and galvanized steel meshes. The separation between the wires of the galvanized steel meshes is of 5.1 x 5.1 cm. The placing of the structural panels in the foundation slab was based on the 3D-LPs construction system to build structural walls which is the result of structural analysis. It consists of embedding steel bars of 10mm diameter x 60cm length in the foundation slab at 30 cm depth to one separation of 60cm interspersed with one another.

The flat roof slab was proposed to be of 10.8 cm thickness made of 3D-LPs to build a monolithic structure. The 3D-LPs were proposed to be of 1.22m width x 4.50m height, made of polystyrene cores and galvanized steel meshes. The separation between the wires of the galvanized steel meshes was of 5.1 x 5.1 cm. The panels have integrated a longitudinal steel bar of 10 mm diameter and 4.50 m length, which allows them to behave as reinforced concrete slabs.

The process to connect the panels to provide continuity and ensure the structural integrity is based on technical specifications of manufacturers of the 3D-LPs construction system. The walls forming the corners are connected with steel bars of 18 cm bent to 90 degrees and the longer walls are connected with galvanized steel mesh. The connections must be made with ties of annealed wire, which have a resistance to stress of 570 MPa (Rezaifar, 2007) or galvanized steel staples. When three walls converge in a node these should be connected with steel bars of 25 cm bent in a “U” shape.

6.5.2 Modelling and analysis of the structural phase
The BIM system Revit 2013 was the platform to model the structural housing prototype model. The modelling process started with the importation of the
architectural model from the Revit 2012 to the Revit 2013. However, this step can be omitted if the modelling starts in Revit 2013. After importing the architectural model to the structural template, the modelling was carried out by using the structural functions of Revit 2013. Thus the first step was to model the foundation slab in accordance with the formulation of the model described in section 6.3.

The modelling of the foundation consisted firstly of creating beams of 20cm x 20cm at a depth of -30 centimetres in relation to the level of finished floor and a foundation slab of 10 centimetres at the top. The foundation beams were modelled in the plot perimeter and horizontal axes because the structure was designed to work based on load walls. Consequently, the following element to model was the welded mesh which was placed at the top of the beams. Subsequently, the steel bars were anchored to the foundation beams, which was achieved by modelling a steel bars blend in shape of “L” to 90 grades, the longitude of the steel bars was 60 cm. The last element modelled at the top of the foundation was the foundation slab on top of the ground beams, which was of 10 centimetres thickness (see Figures 6-14 and 6-15).
As can be observed from Figure 6-16, the beams were modelled with stirrups/transversal reinforcements with 20 cm spacing and 4 longitudinal reinforcements with diameter 0.39cm Figure 6-16 and 6-17 show the anchoring of the steel bars to the beams. These steel bars were modelled to enable the modelling of the structural walls made of the 3D-LPs.
The second stage in the computer modelling of the structural design consisted of modelling the placing of the structural panels of 5.08cm in the foundation slab. A structural wall template was modified with the characteristics of the 3D-LPs; thus the panels were placed in the axes and connected by means of steel bars and galvanized meshes in accordance with technical specifications of manufacturers of the 3D-LPs construction system.

Figures 6-18 and 6-19 show the assembling of the structural walls with 3D-LPs in the foundation slab and the connections between panels with steel bars and meshes.
The structural roof was modelled by placing panels of 10.16 cm thickness at the top of the walls and they were connected with galvanized steel meshes on both sides of the panels, namely the meshes in “L” shape were placed in the interior and exterior of the
panels to join the roof to the panels. The roof was also anchored to the interior walls through steel bars in a “U” shape to create the monolithic structure.

6.5.3 Verification and validation
The verification of the housing prototype corresponding to the structural design was carried out through activating the 3D view to check that the 2D plan worked as planned. Figure 6-18 shows that the structural computer model behaves as expected, since all walls appear aligned to axes and foundation and the flat roof slab is in the correct place. Also 2D and 3D views show that all structural elements were modelled in accordance with section 6.3. The validation of the model was achieved by comparing the computer architectural model against real models obtained by the suppliers and by showing the model to a W Panel company representative.

6.5.4 Summary and discussion
In terms of HDCT it can be said that the housing prototype in the BIM system could help to reduce hazard and damage caused by accidental actions, because the structural model BIM of the housing prototype shows a monolithic structure. Such a structure appears to acquire stiffness from the steel bars and meshes made of galvanized steel; however, in order to confirm this, it would be convenient to run a structural analysis.

Triangulating the academic literature of the 3D-LPs, the structural model of the housing prototype, and the explanation of the manufacturers of the 3D-LPs construction system, it can be said that the prototype is a monolithic structure because it is strongly connected by steel bars and meshes made of galvanized steel. Furthermore, from the architectural model it can be said that the prototype is a monolithic structure, because the panels are covered on both sides by mortar and concrete where appropriate.

The structural design of the housing prototype modelled with the 3D-LPs construction system in BIM allowed visualization of all of the structural elements. In consequence, the 3D view could be used to provide training to unskilled people from the community affected.
6.6 Economic estimation

This section presents the economic estimation of the housing prototype model which corresponds to the construction of a basic housing unit of 5.50m x 7.00m, namely 38.5 m² of construction unfinished and consisting of five concepts: preliminary, foundation slab, walls, flat roof slab and parapets. To estimate the total cost of construction of the housing prototype, the method of a floor area (m²) was used, which takes into account the total cost (TC) of the structure multiplied by the surface area (S) of the floor with the average cost per square meter built (P) (Pettang et al., 1997).

\[
(TC) = S \times P
\]

The economic estimation is presented in two tables, the first shows the total cost of the housing prototype which considers the use of the 3D-LPs, and the second table shows the total cost of the housing prototype with traditional construction materials based on bricks and reinforced elements in order to show the benefit in housing construction with the 3D-LPs construction system.

6.6.1 Economic analysis with the 3D-LPs construction system

This section presents the economic analysis which corresponds to the area proposed 5.5m x 7.0m equal to 38.5 m² to build a housing prototype with 3D-LPs. The construction stages estimates were: preliminary, foundation slab, walls, flat roof slab and parapets. A breakdown of activities, materials, labour equipment and tools gave the average cost per square meter built on floor area. The prices used to calculate the average cost were obtained from the database of the Mexican Institute of Cost Engineering and the breakdowns can be consulted in Appendix 5.

Preliminary

The preliminary concept includes the activities of cleaning, terrain tracing and levelling. It also involved excavation and preparation of ditches to place the foundations. The average cost per square meter built on floor area was calculated at £ 4.26.

Foundation

The foundation consists of a 10 cm thick slab of reinforced concrete f'c 200 kg/cm² with the appearance of a finished floor and structured beams 20 x 20cm. This includes
formwork, steel, concrete placement, vibration and compaction, grading and finishing, curing and demoulding. The average cost per square meter built on floor area was calculated as £16.50 including materials, labour equipment and tools.

**Walls and parapet**

The concept of the walls consists of the supply and construction of structural walls with panels of 5.08cm thickness type 3D-LPs and meshes made of galvanized steel with wires separated @ 5.1cm. This includes the placement of a structural layer of mortar on both sides up to a maximum wall thickness of 8.89cm. Joints and anchoring of panels is accomplished with steel bars and mesh tied with annealed wire and placing reinforcing mesh on the windows and doors. The walls concept includes materials, equipment and labour, as well as wall parapets of 40 centimetres. The average cost per square metre to build the wall was calculated as £16.80.

In order to quantify wall areas of the housing prototype shown in Figure 6-6, the quantification was created in BIM to obtain the gross area of interior and exterior walls, which take into account the height and width of all walls to calculate the areas. The result of the walls material takeoff was 83.45 m². The window and door areas were discounted and the walls’ height was considered to be 2.44m; hence, the surface area of the housing prototype walls of Figure 6-1 was calculated as 83.45 m² (see Table 6-5).

<table>
<thead>
<tr>
<th>Vertical axes</th>
<th>Horizontal axes</th>
<th>Length of walls (m)</th>
<th>Total area walls (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axis A</td>
<td>Length 1-3</td>
<td>5.41</td>
<td>10.54</td>
</tr>
<tr>
<td>Axis B</td>
<td>Length 1-3</td>
<td>5.41</td>
<td>9.18</td>
</tr>
<tr>
<td>Axis B’</td>
<td>Length 2-2’</td>
<td>1.00</td>
<td>2.44</td>
</tr>
<tr>
<td>Axis C</td>
<td>Length 2-3</td>
<td>2.44</td>
<td>5.73</td>
</tr>
<tr>
<td>Axis D</td>
<td>Length 1-3</td>
<td>5.41</td>
<td>8.42</td>
</tr>
<tr>
<td>Axis 1</td>
<td>Length A-D</td>
<td>6.91</td>
<td>16.62</td>
</tr>
<tr>
<td>Axis 2</td>
<td>Length A-B</td>
<td>2.44</td>
<td>5.73</td>
</tr>
<tr>
<td>Axis 2’</td>
<td>Length B’-D</td>
<td>3.19</td>
<td>5.67</td>
</tr>
<tr>
<td>Axis 2’’</td>
<td>Length B-B’</td>
<td>1.27</td>
<td>1.53</td>
</tr>
<tr>
<td>Axis 2’’’</td>
<td>Length C’-D</td>
<td>0.95</td>
<td>2.21</td>
</tr>
<tr>
<td>Axis 3</td>
<td>Length A-D</td>
<td>6.91</td>
<td>15.41</td>
</tr>
</tbody>
</table>

83.45
Parapet walls were quantified as 9.85 m², the parapet walls were considered to be of 0.40m height (see Table 6-6). It is located on the flat roof slab.

<table>
<thead>
<tr>
<th>Vertical axes</th>
<th>Horizontal axes</th>
<th>Length of walls (m)</th>
<th>Total area walls (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axis A</td>
<td>Length 1-3</td>
<td>5.41</td>
<td>2.20</td>
</tr>
<tr>
<td>Axis B</td>
<td>Length 1-3</td>
<td>5.41</td>
<td>2.16</td>
</tr>
<tr>
<td>Axis B'</td>
<td>Length 2-2'</td>
<td>6.91</td>
<td>2.72</td>
</tr>
<tr>
<td>Axis C</td>
<td>Length 2-3</td>
<td>6.91</td>
<td>2.76</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>9.85</strong></td>
</tr>
</tbody>
</table>

**Flat roof**

The concept of the flat roof slab consisted of the supply 3D-LPs of 10.16cm to build a structural slab at the top of the structure. This includes the placement of a concrete structural layer of 6 cm thickness with compressive strength of f'c 200 kg/cm² at the top. The concept includes materials, equipment and tools, labour and the activities of placement and removal of formwork, as well as joint and galvanized mesh reinforcement and steel bars. The average cost per square meter built on floor was calculated as £26.75.

Table 6-7 shows the cost per square meter of the surface housing prototype designed for this study, which resulted in £ 88.22m², it can also be observed the total cost is £3,396.58, which corresponds to 38.5m²; this price includes material, labour, equipment and tools. The concrete slab is prefabricated and includes transport and placement.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Amount</th>
<th>Unit</th>
<th>Unit price</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminaries</td>
<td>38.50</td>
<td>m²</td>
<td>£4.26</td>
<td>£164.01</td>
</tr>
<tr>
<td>Foundation</td>
<td>38.50</td>
<td>m²</td>
<td>£16.50</td>
<td>£635.25</td>
</tr>
<tr>
<td>Walls</td>
<td>83.45</td>
<td>m²</td>
<td>£16.80</td>
<td>£1,401.96</td>
</tr>
<tr>
<td>Flat roof slab</td>
<td>38.50</td>
<td>m²</td>
<td>£26.75</td>
<td>£1,029.88</td>
</tr>
<tr>
<td>Parapet walls</td>
<td>9.85</td>
<td>m²</td>
<td>£16.80</td>
<td>£165.48</td>
</tr>
</tbody>
</table>

|                  |        |      |            | **£ 3,396.58** |

172
\[(TC) = S \times P\]

**Where:**
- **TC** (total cost) = £ 3,396.58
- **S** (surface) = 38.5 m² and
- **P** = average cost per square meter built

\[
P = \frac{\text{TC}}{S} = \frac{\text{£ 3,396.58}}{38.5} = \text{£ 88.22}
\]

Breakdown of the economic analysis can be found in Appendix 5. This includes the stages of preliminary, foundation slab, walls, flat roof slab and parapets of the housing prototype.

### 6.6.2 Economic analysis with the traditional construction system

This section explains the total cost of the housing prototype with a traditional construction system based on bricks and a structure of reinforced concrete to compare the total cost estimate of the unfinished housing prototype with 3D-LPs construction system against a traditional system. Technical directors interviewed in this study affirmed that structures built with the 3D-LPs are cheaper than structures built with traditional materials.

The simulator from the Mexican Institute of Cost Engineering (MICE) was used to estimate the total cost of a housing unit built with the traditional system. However, another comparison can be carried out with other construction materials such as wood or other methods.

According to Gonzalez, (1978) MICE is an institute that has developed a National Catalogue of cost that includes the breakdown of the concepts to build buildings. The breakdowns are composed of construction materials prices and the cost of labour, tools and equipment. Gonzalez, (1978) also indicates that the MICE provides a database which is linked to a simulator to calculate the direct and indirect cost of a building. The data are reliable because the institute researches and keeps updated the costs of materials, labour, tools and equipment. MICE is an institute affiliated to the International Costs Engineering Institute (ICEI) and companies in the Construction Industry in Mexico use this resource to participate in bids and to elaborate economic
proposals to public and private customers. Databases and certification in estimating unit costs are provided by the MICE through membership and workshops.

A basic dwelling called “social housing” made of bricks and structural elements (columns and beams) which is commonly used to resist accidental actions and to reduce hazards in Mexico was used to estimate the total cost of a building with a traditional system (World Habitat, 2008).

The total cost corresponds to a basic unit of 5.50m x 7.00m, namely 38.5m$^2$ in similar conditions to the housing prototype. Table 6-6 shows the concepts of the stages to build a structure similar to the housing prototype with traditional Mexican construction materials. It should be clarified that the five construction stages of the housing prototype were reduced to three because the MICE simulator grouped the activities of each stage in a different order.

- Foundation concept includes the activities of preliminaries and foundation slab,
- Structure concept grouped the activities to build walls, parapet and roof slab,
- Masonry and finished concept consists of placing of a plaster layer on internal walls and ceiling.

**Foundation concept**
The foundation breakdown to build housing of one level is composed of the activities of cleaning, terrain tracing and levelling. It also involved excavation and preparation of ditches to place the foundation. The foundation consists of a 10 centimetre thick slab of reinforced concrete $f'c$ 200 kg/cm$^2$ with the appearance of a finished floor. This includes formwork, steel, concrete placement, vibration and compaction, grading and finishing, curing and demoulding. The average cost per square meter built on floor area obtained from the simulator was £ 21.04 including materials, labour equipment and tools. This concept does not integrate a heavy foundation slab as the housing prototype because it was considered that the housing will be of one storey for the whole of its life cycle.

**Structure concept**
Structure concept for a level of social housing consists of:
• Walls made of medium size concrete bricks of 10 x 20 x 10 cm joined with mortar and concrete columns embedded on walls made of bricks with 2 steel bars.

• Concrete tie beams made of reinforced concrete of 20 x 15 cm the f’c 200 and steel bars of 1.905cm with formwork and steel fy = 4200 kg/cm\(^2\).

• The linking beams on walls of 15 x 15 cm are made of 4 steel bars of 0.79cm with stirrups of steel 0.635cm placed @ 30 cm and concrete f’c =150 kg/cm\(^2\).

• The flat slab roof is made of concrete of 10 cm with formwork and concrete of f’c 200=kg/cm\(^2\) and steel bars of 1.905cm.

The structure concept includes materials, equipment and labour as well as wall parapets of 40 cm with brick. The average cost per square meter built on floor area obtained from the simulator was £ 49.12 including materials, labour equipment and tools.

**Masonry and finishes**

The concept of the masonry and finishes consists of placing a layer of plaster on walls and ceiling interior. Masonry and finishes include the preparation of square openings to place door and windows and floor with finishes. The average cost per square meter built on floor area obtained from the simulator was £ 34.05 including materials, labour equipment and tools.

Table 6-8 shows the cost per meter of the surface housing prototype with concrete structure made of brick, columns, beams, slabs on floor and roof. This totalled £5,542.63 which corresponds to 38.5 m\(^2\). This cost includes material, labour, equipment and tools.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Amount</th>
<th>Unit</th>
<th>Unit price</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation</td>
<td>38.5</td>
<td>m(^2)</td>
<td>£21.04</td>
<td>£810.04</td>
</tr>
<tr>
<td>Structure</td>
<td>38.5</td>
<td>m(^2)</td>
<td>£49.12</td>
<td>£1,891.12</td>
</tr>
<tr>
<td>Masonry and finishes</td>
<td>83.45</td>
<td>m(^2)</td>
<td>£34.05</td>
<td>£2,841.47</td>
</tr>
</tbody>
</table>

(TC) = S x P

175
Where: TC (total cost) = £5,542.63
S (surface) = 38.5 m² and
P = average cost per square meter built

\[
P = \frac{TC}{S} = \frac{5,542.63}{38.5} = £143.96
\]

The comparison between the total cost of the prototype with bricks and a reinforced concrete structure allows observing an increase of £55.74 per square metre. This indicates that the cost of the production of the housing prototype with a traditional construction material is 36.82% more expensive than with the 3D-LPs construction system.

6.6.3 Summary and discussion

In terms of the research aim, it is possible to confirm that a housing unit built by means of the 3D-LPs construction materials is 36.82% cheaper than a housing unit built with traditional materials based on bricks and reinforced elements.

The quantification of areas obtained from the architectural model and the construction stages modelled on the BIM system allowed the total cost of the unfinished housing prototype to be estimated. The cost of production of the housing prototype with the 3D-LPs construction system resulted in £88.22 and by means of a traditional construction system based on bricks and structure of reinforced concrete in £143.96. This indicates that the production of housing with 3D-LPs allows savings of £55.74 per square metre.

Regarding the building of the housing prototype on a large scale, the BIM system showed that the prototype can be repeated as many times as necessary to manage a project after a disaster. BIM is able to update schedules time/stage/materials/costs, takeoff materials after modifying any element which contributes to saving design time and helps to manage a project in a single system.

The modelling cannot show the construction time of the housing prototype, because this was limited by the use of humans. The modelling was found as a means to develop a guidelines directed at unskilled people and also at Non-Governmental Organizations.
(NGOs). The architectural-structural modelling in BIM as part of the computer modelling showed the construction stages of the housing prototype with the 3D-LPs construction system, which could be used to explain how build a dwelling with panels, the 3D views are a tool that allows better understanding, since these show an approximation to real construction.

An advantage of using the BIM during the economic estimation was the verification of the amounts in the same design since the designs are connected to the list of materials of takeoff, therefore, the human errors can be reduced. As mentioned previously, the BIM system is more than a platform for drawing, BIM was found useful to show that new construction materials can be modelled by modifying the existent templates, and it was also found that an architectural design can be modified by adding new areas or changing measurements. The 3D views are a useful resource to verify that the models work as expected without the need to wait until seeing the real construction. Another advantage found in the BIM was that the quantities generated in the system can be exported into other programmes to estimate the price unit by means of the breakdown of the concepts.

6.7 Summary and conclusion of the chapter

The design and modelling of a basic housing prototype with 3D-LPs construction system was conducted to answer the research question (3) Can the BIM model show the cost-benefit in building housing with the 3D-LPs construction system and displaced people’s own labour? Chapter 6 has summaries at the end of sections 6.4.2, 6.5.4 and 6.6.3. The findings of this chapter enable the design of the guidelines directed to construction professionals to train unskilled people from communities affected by disasters in housing construction with the 3D-LPs construction system which are presented in Appendix 6. The guidelines include technical support to construction professionals provided by manufacturers and the guidelines to provide training to unskilled people by construction professionals.
7 Conclusions

7.1 Introduction
This chapter presents the results and analysis of the online questionnaire, semi-structured interview and the computer modelling; these have been summarised and discussed in relation to each other and holistically. The findings of this study have been compared with previous research and their implications for academic and industrial perspectives have been highlighted. Furthermore, the limitations of this study have been set out and recommendations have been made for further research.

7.2 Summary - Research questions and objectives
In order to understand and explore the housing reconstruction problem, three research questions were developed and four objectives were set up to meet the research aim. Table 7-1 shows the research questions and their relationships with the research strategy to address the problem.

<table>
<thead>
<tr>
<th>Research questions</th>
<th>Online questionnaire and semi-structured interview</th>
<th>Modelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How can displaced people use their own labour to save money and time?</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>2. How does the 3D-LPs construction system contribute to housing recovery after natural disasters?</td>
<td>✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>3. Can the BIM model show the cost-benefit in building housing with the 3D-LPs construction system and displaced people’s own labour?</td>
<td>✓ ✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Table 7-2 shows the resume of the conclusions by objectives and the place each of the objectives fulfilled, which will be explained in the next section.

<table>
<thead>
<tr>
<th>Research objectives</th>
<th>Objectives achievement</th>
<th>Exploratory study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Literature Review</td>
<td>Exploratory study</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Online questionnaire</td>
<td>interviews</td>
</tr>
<tr>
<td></td>
<td>Chapter 2</td>
<td>Chapter 4</td>
</tr>
</tbody>
</table>

1. To evaluate the problems associated with housing reconstruction following natural disasters to offer an early solution for housing recovery.

- Competition among NGOs for economic resources and participation.
- The shortage of transport and construction materials.
- The inability of builders to meet the standards.
- The lack of community involvement.
- Political problems.
- Appropriate housing designs to fulfill the needs of the affected people.
- Increases of construction materials costs.

2. To evaluate and to analyse a suitable panel to build housing after a disaster and to design and to model a housing prototype model with the suitable panel to investigate, the cost-benefit in building housing.

- Structure built by means of the 3D-LPs construction system could be ready in 50% less time than structures built using traditional systems.
- An architectural-structural-mechanical model of the 38.5 m² was modelled on the BIM system with the 3D-LPs construction system, which resulted 36.82% cheaper in comparison with traditional materials.

3. To analyse and to investigate how displaced people should participate in housing reconstruction after a disaster to create a novel approach to address the housing reconstruction problem.

- Participation in housing reconstruction is limited to skills of affected people and nature of construction process stages.
- People can be trained in the 3D-LPs construction system.
- To implement the guidelines to train unskilled people.

4. To recognize and analyse key actions to manage the housing reconstruction problem after a disaster.

- To provide training for unskilled people.
- To design appropriate housing that fits the needs of those affected.
- To allow collaboration level.
- To adapt new construction materials.
- To establish relationships between International agencies and manufacturers of the construction materials.
- To implement the guidelines to train unskilled people.
- To use the BIM system in the management of housing reconstruction on a large scale.
7.3 Answer to the research objectives

**Objective 1**

The first research objective of this study to evaluate the problems associated with housing reconstruction following natural disasters to offer an early solution for housing recovery.

In order to achieve this objective one of the largest disasters that occurred in recent decades (The Indian Ocean Tsunami, 2004) was chosen due to the fact there were many problems after the disaster in housing recovery. The problems identified have been described widely in chapter 2 and are shown as follows:

1. Competition among NGOs for economic resources and participation.
2. The shortage of transport and construction materials.
3. The inability of builders to meet the standards.
4. The lack of community involvement.
5. Political problems.
6. Appropriate housing designs to fulfil the needs of the affected people.
7. Increases of construction materials costs.
8. The lack of experience in management of disaster on a large scale
9. The lack of experience of some NGOs in housing construction and reconstruction.

**Objective 2**

The second objective was to evaluate and to analyse a suitable panel to build housing after a disaster and to design and to model a housing prototype model with the suitable panel to investigate, the cost-benefit in building housing. This was achieved through semi-structured interviews and computer modelling.

- The following conclusions are from semi-structured interviews:

Data from semi-structured interviews presented in chapter 5 regarding the physical and mechanical properties described by technical directors of 3D-LPs in section 5.3 and
corroborated in section 2.9 indicate that there is sufficient evidence to conclude that the main benefit in building housing with the 3D-LPs construction system is the capacity to withstand natural disasters, especially earthquakes and hurricanes. The 3D-LPs of 10.16cm width are able to bear up to 11,000 kg of load and 2200 kg on lateral bending stress and perform well under dynamic loads due to the 3D-LPs behaviour as a monolithic structure of reinforced concrete.

As a result of the findings shown in sections 5.3, 5.4, 5.5 and 5.6, it can be concluded that there were additional benefits in building housing with the 3D-LPs, such as:

a) Availability of a lightweight system throughout the world.
b) Reduction of construction time (up to 50%).
c) Creation of livelihoods (Due to the possibility to place a manufacturing plant).
d) Technical support provides by manufacturers in the area affected.

• The following conclusion is from the computer modelling:

From the computer modelling, it is possible to conclude that another benefit in building housing with the 3D-LPs is the possibility to design and to model dwellings that can be adaptable to needs of displaced people, since the 3D-LPs have shown easy adaptability to customised designs. To measure the benefit from building housing with the 3D-LPs, a computer modelling of a housing prototype of 38.5 m2 was carried out on the BIM Revit 2013 with the 3D-LPs construction system. The results indicated that there were no significant differences between the modelling of buildings based on reinforced elements and the 3D-LPs construction system. Furthermore, the modelling process described in section 6.2 and architectural design shown in section 6.3 remained constant.

• The following conclusion is from the semi-structured interviews and computer modelling:

To measure the cost on building housing with the 3D-LPs an economic comparison was carried out between the 3D-LPs construction system and the traditional construction system based on bricks and reinforced concrete elements by using the
housing prototype modelled in the BIM system. The results of the economic estimation indicate a significant difference of 36.82% in the total cost of the unfinished housing prototype, which permits the conclusion that housing units built by means of the 3D-LPs are cheaper than those built with bricks and reinforced concrete, which brings a positive benefit in building housing with 3D-LPs.

**Objective 3**
The third objective was to analyse and to investigate how displaced people should participate in housing reconstruction after a disaster to create a novel approach to address the housing reconstruction problem. The conclusions were achieved through rich qualitative data collected from housing experts. The viewpoints of 22 housing experts from 11 countries were examined on four themes. The results of these themes were analysed by pattern matching for generalization of the findings. The conclusions are presented in terms of community participation levels shown in section 2.5.4 and approaches used for housing reconstruction described in section 2.5.

**Conclusions in terms of community participation levels**

- **Architectural design**
  Based on the results of section 4.6, it can be concluded that the people affected by a disaster should participate in architectural design by means of a “consult” level to express their opinions and feeling to designers so that they can build appropriate houses, but they should not be included in the technical stages of the architectural design because they lack technical knowledge.

- **Choice of building materials**
  In terms of choosing building materials, the results in section 4.7 indicated that there was a strong agreement between housing experts which permits to conclude that the affected people by a disaster should participate in an “inform” level after a disaster in matter of choosing building materials.

- **Management of financial resources**
The perceptions of housing experts summarized in section 4.8 permit the conclusion that in terms of choice of building materials, the affected people should participate up to “inform” level.

- **Unskilled people**

From the viewpoints of housing experts shown in section 4.9, it can be concluded that displaced people should participate in level ‘empower’ in housing reconstruction in order that they can be given a sense of belonging and ownership. However, the findings of this section show that there is a strong agreement to limit the participation of unskilled people in technical stages and a positive willingness to provide training to unskilled people in order that they can achieve that level.

**Conclusion in terms of housing reconstruction programmes**

- **Cash approach**

In terms of the cash approach programme, people affected by disasters should participate under strict guidelines and frequent monitoring in management of financial resources. However, it can be concluded that in the opinion of experts, people should not manage financial resources because purchase of materials and hiring of builders and contractors require technical skills.

- **Owner Driven Reconstruction programme**

Opinions of housing experts were generally in favour of this approach; however, lack of experience was a factor frequently mentioned when considering whether to allow the participation of affected people in architectural design, management of the financial resources, or choice of building materials. So the conclusion is that affected people should participate in approaches similar to Owner Driven Reconstruction only when they have been trained or have skills to develop activities concerning architectural design, management of the financial resources and choice of the building materials.

- **Donor Driver Reconstruction programme**

This programme was clearly and strongly supported by housing experts; people should have little or no participation in matters of architectural design and choice of building materials because they lack the technical skills. The conclusion is that people should
be trained and informed to participate in this programme; otherwise people should only be spectators.

**Objective 4**

To recognize and analyse key actions to manage the housing reconstruction problem after a disaster. As a result of the findings shown in Chapters 5, 6 and 7, it can be concluded that there were identified key actions to manage the housing reconstruction problem after a disaster, such as:

1. To design appropriate housing that fits the needs of those affected.
2. To establish community participation levels with realistic expectations.
3. To use new construction materials that contribute to improving mechanical behaviour of housing in disasters
4. To establish a system to foster technical support from manufacturers in order that NGOs can overcome the lack of experience in construction.
5. To train unskilled people in building housing with realistic expectations.
6. To implement the use of the BIM system in the management of disasters on a large scale.

**7.4 Answer to the research questions**

By fulfilling the research objectives, the research sought to answer the research questions.

1. How can displaced people use their own labour to save money and time?
2. How does the 3D-LPs construction system contribute to housing recovery after natural disasters?
3. Can the BIM model show the cost-benefit in building housing with the 3D-LPs construction system and displaced people’s own labour?

**7.4.1 Answer to research question 1**

Can displaced people use their own labour to save money and time?

The study indicates that there is an alternative to involving displaced people in housing reconstruction to save money and time. This option gives the possibility of training unskilled people in construction activities that do not involve technical knowledge. The study maintains that unskilled people can be trained in the 3D-LPs construction
system by manufacturers in the affected place in 10 days in order that they can use their labour to save money and time. As a result, the reconstruction of dwellings could be ready in 90 days.

In response to this research question, the study provides guidelines directed at unskilled people and also Non-Governmental Organizations (NGOs), to help to solve the housing reconstruction problem and engage the displaced people in the housing reconstruction. Furthermore, the guidelines reveal that a pyramidal training could be implemented to train up to 100 people in the 3D-LPs construction system in the first session. 10 facilitators could train 10 groups of people at the same time in the different construction phases and thus a full group could be ready to begin rebuilding in a short time, which could also act as facilitator to train more people.

7.4.2 Answer to research question 2
How does the 3D-LPs construction system contribute to housing recovery after natural disasters?

Grounded in the data, this study argues that the 3D-LPs construction system contributes in different manners to housing recovery after a disaster. First, the system offers a robust possibility to build sustainable, resistant, affordable permanent houses in 50% less time in comparison to houses built with bricks and reinforced concrete elements which are also 36.82% more expensive. Second, the system can be acquired from three continents to fill the shortage of construction materials suffered post-the Indian Ocean tsunami. Third, manufactures of the system can provide training to unskilled people and technical support to NGOs to fill the lack of experience in housing construction. Fourth, the system enables the possibility to involve the community in housing reconstruction, since the study confirms that unskilled people can be trained in the system.

7.4.3 Answer to research question 3
Can the BIM model show the cost-benefit in building housing with the 3D-LPs construction system and displaced people’s own labour?

In response to this research question, the study provides a computer modelling of a housing prototype modelled on the BIM system with the 3D-LPs construction system.
This study revealed that the housing prototype modelled on the BIM system with the 3D-LPs construction system, and data collected from research question (2) is able to show the cost-benefit in building housing with the 3D-LPs construction system. However, the computer modelling does not show the cost-benefit in building housing with displaced people’s own labour, because the modelling was limited to no participation of Humans. Nevertheless, the computer modelling set up the basis to elaborate guidelines directed at unskilled people, since 3D views facilitate the explanation of the construction process of housing.

7.5 Answer the research aim

This research aims to reduce the construction time and cost of housing affected by natural disasters, through the evaluation of the use of lightweight panels type 3D-LPs in order to produce both affordable and sustainable housing in the shortest possible time on a large scale by the displaced or homeless people.

The results of the study show that through a BIM analysis of a housing prototype, an economic comparison between two construction systems, and an explorative study on participation of displaced people and the 3D-LPs construction system, the research aim have been achieved. However, there are limitations and further work to be done, which are explored in the following section.

7.6 Limitations of the research

A first limitation of this study was related to the physical construction of the housing prototype. This limitation restricted the ability to show the cost-benefit in building housing with the labour of displaced people.

A second limitation of this study was related to the information resources in this study. Most of the researchers invited to participate in the online questionnaire declined the invitation, arguing that they had experience in management of disasters or housing construction but no experience in housing reconstruction after a disaster.

7.7 Bias and errors

Qualitative analysis often admits more than one interpretation, so to reduce the bias, the data were triangulated with the literature review, findings from semi-structured interviews, personal emails, and websites and the computer modelling. The research
kept a neutral criterion and reported the findings, such as emerged from the qualitative analysis. According to Diebel, (2008) “In research, the term neutrality implies that an inquiry is free of bias or is separated from the researcher’s perspectives, background, position, or conditioning circumstances. When a researcher or the research is said to be neutral, the inquiry is also implied to be trustworthy and legitimate” “Neutrality is a term that is often attached to research to demonstrate that it provides an objective and unbiased view of the object under study. “

In order to reduce the bias and errors in data collected by semi-structured interviews the research several times corroborated the information with manufacturers during and after the interviews.

The reduction of errors in the computer modelling was addressed by more than once consulting manufacturers of the system and by sending the modelling to W Panel Company for validation. The suggestions of the technical director helped to prevent errors.

7.8 Contribution to Knowledge and theoretical implications

The theoretical background and the research methods are current and contribute to a growing body of academic research. The study is supported by the findings from three research questions that lay the foundation for future studies and enable the following contributions. An integral philosophy for a better understanding of the problem outlined in Chapter 2, since the study not only highlighted the use of BIM and 3D-LPs system, but also community participation. A wide analysis that takes into account the opinion of housing experts worldwide, the new construction systems based in the consultation of manufacturers of 3D-LPs in three continents and a modelling of a housing prototype in BIM (see Chapter 5, 6 and 7). Consequently, the contributions of this study are related to increase the knowledge in terms of housing reconstruction after a disaster and the spreading the opinion and knowledge of construction professionals in charge of housing reconstruction that offer the opportunity to learn from their suggestions to overcome future problems caused by disasters.

The study explored and offers wide knowledge in four areas that were consulted with the experts: architectural design, choosing of building materials, management of financial resources and unskilled people. Detailed knowledge in five topics was
explored with construction material manufacturers: features of the system, availability in the market, and international prices of the lightweight panels along with capacity to supply construction materials and technical support in areas hit by natural disasters. Further contribution to knowledge is also related with the modelling performed in this study which highlights the use of advanced technologies to the manager of construction projects that contribute to overcome the problem outlined in Chapter 2, since that BIM Revit 2013 allowed the representation of a basic housing prototype with new construction materials. In consequence the body of knowledge, community members affected by disaster, NGOs, manufactures of new construction system and governments all benefit from this study.

The originality and relevance of this study is demonstrated by the findings that allowed all of the stakeholders to determine what is significant and should be taken in account to find an appropriate solution in each place that has been affected by a disaster. Further originality is demonstrated; no previous studies have been conducted into the opinion of practitioners and researchers of housing constructions and manufacturers of lightweight panels around the world.

### 7.9 Implications for professionals and policy makers

The guidelines to enable trained skilled labour to train unskilled labour in order to produce the prototype anywhere affected by disasters attempt to involve NGOs, governments, construction professionals of the AEC industry and manufacturers of the 3D-LPs construction system to save money-time and empower those affected. There are indicators from the findings enabling the guidelines to be adopted by stakeholders for housing reconstruction in a short time in order to save money: such as the economic estimation and the computer modelling that show an unfinished housing prototype built with panels in a low cost. Furthermore, the training of unskilled people in the 3D-LPs construction system could create a cooperation level between the private and public sector to save money and construction time.

The results indicate how vital community participation is in housing reconstruction post-disaster and confirm that housing recovery programmes have been successful because people have participated in the housing process. However, there are no
policies to recognize community participation, nor to empower them. A legal frame could be created to include displaced people after a disaster and thus empower them.

7.10 Recommendations for further research

There are opportunities for further research to improve the results obtained for this research study.

It is proposed to carry out another study by means of physical construction of the housing prototype, which will allow accurate statistical. The study should specify clearly that the housing prototype must be built with the 3D-LPs construction system by unskilled people with management through the BIM system Revit, given that, otherwise, the result of such a study would not be comparable with this study.

It is recommended that, in future studies, NGOs should be interviewed by means of in-depth interviews to appreciate the possibility of implementing the guidelines and taking appropriate decisions to ensure housing construction in the shortest time possible by the displaced people.

Another recommendation is to carry the housing prototype as far as the finished stage using a sustainable approach to increase the qualities of the 3D-LPs construction system under realistic technologies which can be adapted to affordable designs.

Additionally, the proposals for future research focus on giving continuity to the computer modelling, including the possibility to research how the 3D-LPs construction system behaves under live and dead loads in the BIM. However, this area should be investigated by structural engineers. This recommendation is a challenge, because the use of the 3D-LPs construction system is limited to the BIM system, by which should be found an adequate way to simulate the prototype and to show how the system works under loads. It is suggested that the system is treated as reinforced concrete walls rather than structural panels to have a point of comparison.

Finally, beyond the possibilities that arise from continuing this study, it is important to note that a disaster is an opportunity to improve quality of housing to bear future disasters; but more important is to keep in mind that a disaster is a challenge to improve the lives of those who have been affected and that every effort should be made in order than they can be included in housing reconstruction.
7.11 Summary and conclusion of the Chapter

A detailed summary of findings for each chapter 5, 6 and 7 is provided in the text. The research aim and objectives were answered by means of answering three research questions. The main conclusion is that a BIM model can show the use of lightweight panels and enable the possibility to train construction professionals and unskilled people for housing recovery after a disaster as well involving NGOs and government in that process. The findings from the survey, semi-structured interviews and housing prototype model in BIM support the involvement of community members, appropriate housing and materials could contribute to produce both affordable and sustainable housing in a short time on a large scale.
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Appendix “1” Ethical Approval Letter

Secretary to Research Ethics Committees
Room 2.004 John Owens Building
Tel: 0161 275 2206/2046
Fax: 0161 275 5697
Email: timothy.stibbs@manchester.ac.uk

Compliance and Risk Office
University of Manchester
Oxford Road
Manchester, M13 9PL

ref: ethics/12433

Ms Alicia Flores Salas,
Research Student,
School of Mechanical, Aerospace and Civil Engineering
Pariser Building, Floor D

30th May 2013

Dear Alicia,

Research Ethics Committee 2
Salas, Fenn: BIM modelling and the use of WSIPs and unskilled labour in housing recovery post-natural disaster. (12433)

I write to thank you and Peter for attending the meeting on 29th April and to confirm that the amendments and additional information sent in your email of 16th May satisfies the concerns of the Committee and that the project has been given a favourable ethical opinion.

This approval is effective for a period of five years and if the project continues beyond that period it must be submitted for review. It is the Committee’s practice to warn investigators that they should not depart from the agreed protocol without seeking the approval of the Committee, as any significant deviation could invalidate the insurance arrangements and constitute research misconduct.

I would be grateful if you could complete and return the attached form at the end of the project or by the end of May 2014.

Yours sincerely

[Signature]

Dr T P C Stibbs
Secretary to the University Research Ethics Committee
Appendix “1 (a)” Ethical Approval Form

SECTION A – Administrative information
Title of the research: Evaluation of the use of lightweight concrete panels for post disaster house reconstruction using Building Information Modelling

2. Investigator(s) (nb. In the case of postgraduate student applications the supervisor is always the joint investigator):

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<tr>
<th></th>
<th>Student</th>
<th>Supervisor/Staff</th>
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</thead>
<tbody>
<tr>
<td>Title</td>
<td>Ms.</td>
<td>Dr.</td>
</tr>
<tr>
<td>Surname</td>
<td>Alicia</td>
<td>Peter</td>
</tr>
<tr>
<td>First name</td>
<td>Flores</td>
<td>Fenn</td>
</tr>
<tr>
<td>Post</td>
<td>Research student</td>
<td></td>
</tr>
<tr>
<td>Qualifications</td>
<td>BSc Civil Engineering MSc Construction</td>
<td>BSc, Dip Arp, PhD, FRICS, FCIArb</td>
</tr>
<tr>
<td>School/Unit</td>
<td>School of Mechanical, Aerospace and Civil Engineering. The University of Manchester</td>
<td>School of Mechanical, Aerospace and Civil Engineering. The University of Manchester</td>
</tr>
<tr>
<td>Contact Address</td>
<td>The University of Manchester Manchester M139PL</td>
<td>The University of Manchester Manchester M139PL</td>
</tr>
<tr>
<td>Email address</td>
<td><a href="mailto:alicia.salas@postgrad.manchester.ac.uk">alicia.salas@postgrad.manchester.ac.uk</a> <a href="mailto:Peter.fenn@manchester.ac.uk">Peter.fenn@manchester.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Telephone</td>
<td>+44 (0) 161 306 2353 +44 (0) 161 306 4233</td>
<td></td>
</tr>
</tbody>
</table>

3. School contact (if applicable): If the School wishes to have a copy of the outcome of the ethical review, the relevant School officer should enter the appropriate details here.
Name: 
Post: 
Email address: 

4. Is this study, or any part of this study a student project? Yes/No
If Yes what degree is it for?
A PhD degree

5. Please provide the names and email addresses of any academic staff or students involved, other than those named at 2 above:

SECTION B – Details of Project
6. When will the data collection take place?
Start date: 15/April/2013
End date: 01/April/2015

7. Where will the data collection take place?
The data collection will take place in The University of Manchester

8. What is the principal research question?
How can displaced people use their own labour to save money and time? This will be answered by questionnaire.
How do the 3D-LPs construction system contributes to housing recovery after natural disasters? This will be answered by interview.

9. What is the academic justification for the research? (Must be in language comprehensible to a lay person)
This research is strongly focused on identifying solutions for housing recovery following a natural disaster, given that people need to regain their properties as soon as possible. Therefore, to achieve this it is important to create housing prototypes that can anticipate future disasters and so be ready for implementation immediately after the completion of the emergency phase. Motivated by the need to give housing to the displaced people, and considering that those affected spend much time in shelters unemployed until the civil engineers are able to contribute to the solution of the dwelling recovery problem, this research has designed a housing prototype...
in which the displaced or homeless people are the main builders, given that housing costs are likely to be reduced if skilled paid labour is replaced by the labour of disaster victims.

To support this process, a modelling of the prototype will be carried out on the BIM software (Building Information Modelling), given that it was considered the best alternative to achieve this research, since the physical construction of the prototype planned in the first instance would require economic funds and protocols. The modelling of the prototype has as objective to identify critical activities in the construction process, the economic estimation and production of housing by displaced people, as well as the development of a self-build manual.

Integral to the modelling of the prototype proposed in this research is the use of structural insulated panels (SIPs), from Panel W which will be employed to replace the traditional construction materials, since SIPs have been shown to have good physical and mechanical behaviour in response to natural disasters and are inexpensive, lightweight and easy to use.

In addition, the literature review carried out about the housing problem caused by natural disasters showed that community participation has contributed to housing recovery (Ophiyandri, 2011, Jha, 2010, Davidson et al., 2007). The owner-driven reconstruction (ODR) programme launched by the World Bank in Indonesia, Sri Lanka, India and China was successful, which was mainly due to help from the homeless people, who were able to help with their labour after natural disasters occurred in their countries (The World Bank, 2005). However the lack of guides, manuals and precise instructions has contributed to extending the time and cost of housing recuperation post disaster (Davidson et al., 2007). This research seeks to answer the following questions:

How can displaced people use their own labour to save money and time? This will be answered by questionnaire.

How do the 3D-LPs construction system contributes to housing recovery after natural disasters? This will be answered by interview

Can the BIM model show the cost-benefit in building housing with Panels W type SIPs and displaced people’s own labour? This will be answered by a computer modelling.

10. Give a summary of the design and methodology of the planned research, including a brief explanation of the theoretical framework that informs it. It should be clear exactly what will happen to the research participant, how many times and in what order. Describe any involvement of research participants, patient groups or communities in the design of the research. (This section must be completed in language comprehensible to the lay person and should be no longer than half a page. If there is a full research proposal or protocol it can be appended to the application, but it does not replace the information given in this section)

Purpose:

An exploratory-descriptive research study will be conducted to examine the community participation (unskilled people) and housing construction with traditional building materials and Panel W type Structural Isolation Panels (3D-LPs) after a natural disaster, to develop a theory that involves those affected in the construction process for housing and to develop a systematic framework that facilitates the implementation of the 3D-LPs in zones affected by natural disasters immediately after the emergency phase in order to build affordable, resistant and cheap housing on a large scale in the shortest possible time.

Design and Methodology

A questionnaire will be used with researchers or construction professionals, with the purpose of collecting their viewpoints on community participation (unskilled people) after natural disasters in construction activities such as: architectural design, choice of building materials, management of financial resources and labour to answer research question 1, how can displaced people use their own labour to save money and time. An interview will also be conducted with manufacturers of traditional construction materials and 3D-LPs with the purpose of examining features, availability, prices of traditional construction materials and 3D-LPs as well as capacity and technical support in areas affected by natural disasters, to answer research question 2, how do the 3D-LPs construction system contribute to housing recovery after natural disasters. The data collected from questionnaire and interview will be loaded and organized into themes and categories in a database created in Nvivo. Therefore, qualitative and quantitative methods will be used to analyse data. Finally, data validation will be conducted using triangulation.

Participants in questionnaire

Research participant in questionnaire are people who have working experience in the Construction Industry.
Procedure:
An advertisement will be placed in the Yahoo group called Co-operative Network Building Researcher (CNBR) and other similar (See Appendix C).
If the participants agree to participate in this study after receiving the email they must read the Participation Information Sheet (PIS) and consent form attachment in the email before answering the online survey questionnaire (See Appendix A and Appendix B).
The participants must electronically sign the Participation Information Sheet and submit this to the researcher in order to receive a link to answer the online survey questionnaire (See Appendix E).
The participants must fill in and submit at one attempt the online survey questionnaire (See Appendix D).
The collected data will be automatically recovered in a database in SelectSurvey and translated to Nvivo to facilitate interpretation and the development of models, maps and graphs to allow visualizing and sharing findings.
To validate the results obtained by questionnaire a triangulation will be conducted; the process might be done between the literature, results collected and the Guideline from the World Bank to train people for Housing Recovery after natural disasters.

Participants in interview:
Research participants in interview are people who supply construction materials to the construction industry.

Procedure:
Research participants will be contacted by email, telephone or letter (See Appendix I) and given the participant information sheet and consent forms. (See Appendix F and G) and their own website. (See Appendix H)
If the research participants agree to take part, a telephone call will be arranged at a time suitable for the participants and the researcher.
The interviews will be recorded if the participants agree. (See Appendix G) The interview will be arranged in open-ended questions to explore and describe features of the construction materials. Anonymity will be maintained at all times in semi-structured individual interviews.
The data recorded will be introduced in a database created Nvivo software to facilitate interpretation and the development of models, maps and graphs to allow visualizing and sharing findings.
To validate the results obtained by interview a triangulation will be conducted between the literature, results collected and the platform Construction 21 from the World Bank.

11. How has the scientific quality of the research been assessed? (Tick all that apply)

☐ Internal review (e.g. involving colleagues, academic supervisor)
☐ Review within a multi-centre research group
☐ Independent external review
☐ Review within a commercial company
☐ None external to the investigator
☐ Other, e.g. in relation to methodological guidelines (give details below)

If relevant, describe the review process and outcome. If the review has been undertaken but not seen by the researcher, give details of the body which has undertaken the review:

12.1 Does the research involve the administration of any physically invasive procedures, or physical or psychological testing?
☐ Yes ☐ No

If No, proceed to 12.2
If Yes, please ensure you complete Section F

12.2 Does the research involve interviewing participants or focus groups?
☐ Yes ☐ No

If No, proceed to 12.3
If Yes, please describe briefly how they will be conducted
The interview will be conducted by telephone/Skype

12.3 Does the research involve the administration of questionnaires?
☐ Yes ☐ No

If No, proceed to 12.4
If Yes, please describe the process of delivery and collection
The questionnaire will be delivered electronically by email (see appendix E); the collection will be done automatically in a database created in SelectSurvey.

12.4 Is statistical sampling relevant to this research?
☐ Yes ☑ No
If No, proceed to 12.5
If Yes, please answer the following questions:

12.4.1 Has the protocol submitted with this application been the subject of review by a statistician independent of the research team? Select one of the following:
☐ Yes – copy of review enclosed
☐ Yes - details of review available from the following individual or organisation (give contact details)
☐ No – justify below

12.4.2 If relevant, specify the statistical experimental design and why it was chosen.

12.5 If you are not using statistical sampling how was the number of participants decided upon?
No formal sample size calculation was used for the qualitative data. The maximum number of participants for questionnaire was decided 30 and 20 for interview, as this research is looking for qualitative answers which can expand the knowledge in the construction field. However, the number of research participants will depend on the response rate and how useful is the data collected. The number of participants was decided based on the literature reporting similar research and on a reasonable number which will allow analysis. The research might be thought of as theory building rather than theory test and data will be analysed using qualitative techniques data saturation occurs.

12.6 Has the research methodology and/or the statistical basis been the subject of a review independent of the research team? (Select one of the following)
☐ Yes – copy of review enclosed
☐ Yes details of review available from the following individual or organisation (give contact details below)
☑ No – justify below

12.7 Describe the methods of analysis (statistical or other appropriate methods, e.g. for qualitative research) by which the data will be evaluated to meet the study objectives.
The data obtained from the questionnaire and interviews will be evaluated to meet the study objectives through a categorization of topics. The data collected will be categorized and introduced in a database created in Nvivo to facilitate interpretation and the development models, maps and graphs to allow visualizing and sharing findings.

13.1 What do you consider to be the main ethical issues which may arise with the proposed study?
The main ethical issues which may arise in the proposed study might be divulging confidential information and company information and which could be sensitive.

13.2 What steps will be taken to address the issues raised in question 13.1?
To address this, the consent form and PIS will be sent before the online questionnaire and interviews. It also will kept anonymity and confidentiality.

14. Has this or a similar application been previously considered by a Research Ethics Committee in the UK, the European Union or the European Economic Area?
☐ Yes
☐ No
If Yes give details of each application considered, including:
Name of Research Ethics Committee or regulatory authority:
Decision and date taken:
Research ethics committee reference number:

SECTION C – Details of participants

15. How many participants will be recruited? (If there is more than one group, state how many participants will be recruited in each group. For international studies, say how many participants will be recruited in the UK and in total. Please ensure you clearly state the total number of participants)
A maximum of 30 structured questionnaires and 20 semi-structured interviews are expected. The number depends on data saturation.

### 16. Age range of participants:

- **Age range:** > 18
- **Sex:** random

### 17. What are the principal inclusion criteria for participants? *(Please justify)*

The main inclusion criteria for participants in the questionnaire for this study will be experience in housing construction and for interview will be that the suppliers should be manufacturers or wholesale suppliers of construction materials. This due to that this research is looking for expert opinion to expand knowledge in the construction field and provide an early solution to the housing problem.

### 18. What are the principal exclusion criteria for participants? *(Please justify)*

For the questionnaire people who have no working experience whatsoever and for interview retail suppliers of construction materials will be excluded from this study.

#### 19.1 Will the participants be from any of the following groups? *(Tick all that apply)*

- [x] Adult healthy volunteers (i.e. not under medical care for a condition which is directly relevant to the application)
- [ ] Children under 16
- [ ] Adults with learning difficulties
- [ ] Adults who have a terminal illness
- [ ] Adults with mental illness (particularly if detained under mental health legislation)
- [ ] Adults with dementia
- [ ] Adults in care homes
- [ ] Adults or children in emergency situations
- [ ] Prisoners
- [ ] Young offenders
- [ ] Those who could be considered to have a particularly dependent relationship with the researcher, e.g. students taught or examined by the researcher.
- [ ] Other vulnerable groups

*Please note: If an adult participant is not able to give informed consent (eg through mental capacity or is unconscious) or if a prisoner or young offender is involved in health related research ethical review should be undertaken by an appropriate NHS Research Ethics Committee.*

#### 19.2 If you will be using participants other than healthy volunteers please justify their inclusion:

N/A

### 20.1 How will the potential participants be identified?

Potential research participants in the questionnaire to this study will be identified on Co-operative Network Building Researcher (CNBR) and other similar database of researchers and builders and potential research participants in the interview will be identified on the website pages of main construction materials suppliers over the world. A list of manufacturers is in appendix L. This includes three databases of manufacturers in Asia, China and America, which will be used as many times as required to collect data, because these have more than 1000 manufacturers and wholesale of construction materials.

### 20.2 How will they be approached and by whom?

Potential research participants for the questionnaire and interviews will be contacted by the research student via letter, telephone or email explaining the research purpose and procedure briefly. (See Appendix C and I) The manufacturers will be also approached using the option contact in their website by filling their forms, where they will be invited to participate and they will be asked for name of company representatives in order to send the invitation by email or letter. (See appendix H)

### 20.3 How will they be recruited? *(Where research participants will be recruited via advertisement, please append a copy to this application)*

Potential participants expressing interest in the study will be given the participant information sheet and consent form as well as time and opportunities to ask questions about the study. Once the participants agree to take part in the research and send the consent form back, the recruitment is over.
21. Will any research participants be recruited who are involved in existing research or have recently been involved in any research prior to recruitment?

☐ Yes  ☐ No  ☑ Not known

(If yes, give details and justify their inclusion. If Not known, please state what steps will you take to find out)

I will ask the participants if they are involved in existing research or have recently been involved in any research before the research start.

22. Will individual research participants receive reimbursement of expenses or any other incentives or benefits for taking part in this research?

☐ Yes  ☑ No

(If yes, indicate how much and on what basis this has been decided)

23. What is the expected total duration of participation in the study for each participant? For ethnographic research focusing on one or more groups rather than individual participants, indicate the approximate period of time over which research will focus on particular groups

For questionnaire, it is expected the research participants will take 25 minutes to complete their participation and for interview, the total duration of participation in the study for each participant will be around 30 minutes to one hour.

24. What is the potential benefit to research participants?

The research participants can benefit from this study when the document is published. They may consult the findings to understand more about the housing problem after natural disasters and possible solutions.

25. Will any benefit or assistance, which the participant would normally have access to, be withheld as part of the research?

☐ Yes  ☑ No

(If yes, give details and justification)
SECTION D – Consent

26.1 Will informed consent be obtained from the research participants?
☑ Yes ☐ No
If Yes, give details of how consent will be obtained. Give details of your experience in taking consent and of any particular steps to provide information to participants before the study takes place eg information sheet, videos, interactive material.
Once the participants have decided to take part in the study, they must sign and send the consent form back to the researcher. The consent and Participant Information Sheet forms will be sent promptly, and time and opportunities to ask questions about the study before the questionnaire or interview will be conducted.
If participants are recruited from any of the potentially vulnerable groups listed in Question 19.1, give details of extra steps taken to assure their protection. Describe any arrangements to be made for obtaining consent from a legal representative.
If consent is not to be obtained, please explain why not.

26.2 Will a signed record of consent be obtained?
☑ Yes ☐ No
If not, please explain why not. Please append any consent forms to this application.

27. How long will the participant have to decide whether to take part in the research? (If less than 24 hours please justify)
Up to one month

28. What arrangements have been made for participants who might not adequately understand verbal explanations or written information given in English, or who have special communication needs? (e.g. translation, use of interpreters etc.)
All participants are expected to have commercial English competence. The researcher is a fluent Spanish speaker, and if it is convenient to participants, the questionnaires may be conducted in Spanish and then translated into English.

SECTION E – RISKS AND SAFEGUARDS

29. Activities to be undertaken (This should be in the form of a brief list, such as answering a questionnaire, being interviewed)
For questionnaire
If the participants agree to participate in this study when receiving the email they must read the Participation Information Sheet (PIS) and consent form attachment in the email before answering the online survey questionnaire (See Appendix A and Appendix B).
The participants must electronically sign the Participation Information Sheet and submit this to the researcher in order to receive a link to answer the online survey questionnaire (See Appendix E).
The participants must fill in and submit at one attempt the online survey questionnaire (See Appendix D).

For interview
1. To read the Participant Information Sheet (PIS) (See appendix F).
2. To approve the consent form (See appendix G).
3. To answer the telephone at the time agreed mutually.
4. The interview will take 30 minutes to one hour. However, interview duration will depend on the willingness of the participants to share the information.

30.1 What are the potential adverse effects, risks or hazards for research participants, including potential for pain, discomfort, distress, inconvenience or changes to lifestyle for research participants? Are they any greater than those that would arise from normal social interaction?
No potential adverse effects are anticipated.

30.2 Could individual or group interviews/questionnaires raise any topics or issues that might be sensitive, embarrassing or upsetting, or is it possible that criminal or other disclosures requiring action could take place during the study (e.g. in the application of screening tests for drugs)?
☐ Yes ☑ No
If yes, provide your distress policy/give details of procedures in place to deal with these issues:
30.3 What precautions have been taken to minimise or mitigate the risks identified above? 
N/A 
31.1 What is the potential for adverse effects, risks or hazards, pain, discomfort, distress, or inconvenience to the researchers themselves? (If any) 
N/A 
31.2 Where will the research take place? 
In The University of Manchester 
31.3 What precautions have been taken to minimise or mitigate the risks identified above? (If the research means working alone in a location which is not public, semi-public or otherwise risk-free, please describe your lone worker policy or append a copy) 
N/A 
32. The University will automatically provide indemnity and/or compensation for most approved studies, but you should complete the appended Ethics Insurance Assessment form and consult the University Procurement Office if necessary. If another body or institution is providing insurance or indemnity please provide details below. 
N/A 
33. Please confirm that any adverse event requiring a radical change of method or design, or even abandonment of the research, will be reported to the Committee. 
I confirm that if any adverse event happens I will report it to the Committee. 

SECTION F – MEDICAL INTERVENTION 
This section need only be completed by applicants whose project involves any form of medical, psychological or therapeutic intervention (ie you answered ‘Yes’ to question 12.1) 
34. Drugs and other substances to be administered (if applicable) 
Indicate status, eg full product licence, CTC, CTX. Attach: evidence of status of any unlicensed product; and Martindales Pharmacopoeia details for licensed products 

<table>
<thead>
<tr>
<th>DRUG</th>
<th>STATUS</th>
<th>DOSAGE/FREQUENCY/ROUTE</th>
</tr>
</thead>
</table>

35. Procedures to be undertaken 
Details of any invasive procedures, and any samples or measurements to be taken, and/or any psychological tests etc. What is the experience of those administering the procedures? 
N/A 
36. Will any procedures which are normally undertaken be withheld? 
N/A 
37.1 Will the research participants’ General Practitioner be informed that they are taking part in the study? 
☐ Yes ☑ No 
If No, explain why not 
This study will not involve any mentally or physically issue of participants and there is no drugs, risks, hazards, pain, discomfort or distress involved in this research. 
37.2 If you answered yes to question 37.1, will permission be sought from the research participants to inform their GP before this is done? 
☐ Yes ☐ No 
If No, explain why not 
N/A 
38. What are the criteria for electively stopping research prematurely? 
N/A 

SECTION G – Data protection and confidentiality 
39. Will the research involve any of the following activities at any stage (including identification of potential research participants)? (Tick all that apply) 
Storage of personal data on any of the following: 
☐ Storage of personal data on manual files 
☑ Storage of personal data on laptops or other personal computers 
☑ Storage of personal data on University computers
40. What measures have been put in place to ensure confidentiality of personal data? Give details of what encryption or other anonymisation procedures will be used and at what stage? Note: the University requires all personal data stored electronically to be held on wholly managed University servers or to be encrypted.

Data will be anonymised by removing any identifying information from all collected data. Personal data will only appear on the printed consent form and will be stored in a locked university file and destroyed via shredding after 5 years. The database will be stored using password protected files. Data protection and confidentiality will comply with the university protocol.


41. Where will the analysis of the data from the study take place and by whom will it be undertaken?

It will take place in The University of Manchester and be undertaken by the researcher

42.1 Who will control and act as the custodian for the data? Note: for a student project this must be a supervisor or a permanent member of staff

My supervisor: Dr. Peter Fenn

42.2 Who will have access to the data?

My supervisor and me

42.3 Will the data be stored for use in future studies? If yes, has this been addressed in the consent process?

No

43. For how long will the data from the study be stored?

5 Years

Note: the University requires non-medical data to be held for a minimum of 5 years and medical data to be held for a minimum of 10 years after the completion of the research. Some funding bodies require storage for longer periods.

44. What arrangements are in place to ensure participants receive any information that becomes available during the course of the research that may be relevant to their continued participation?

N/A

45. What arrangements are in place for monitoring the conduct of the research by parties other than the researcher?

N/A

□ Yes
☑ Not relevant

SECTION H – Conflict of Interest

46.1 Will individual researchers receive any personal payment over and above normal salary and reimbursement of expenses for undertaking this research?

□ Yes ☑ No

If Yes, indicate how much and on what basis this has been decided:
46.2 Does the principal researcher or any other investigator/collaborator have any direct personal involvement (e.g. financial, share-holding, personal relationship etc.) in the organisation sponsoring or funding the research that may give rise to a possible conflict of interest?
☐ Yes ☒ No
If Yes, give details:

47. Will the host organisation or the researcher’s department(s) or institution(s) receive any payment of benefits in excess of the costs of undertaking the research?
☐ Yes ☒ No
If Yes, give details:
SECTION I - Reporting Arrangements

48. How is it intended the results of the study will be reported and disseminated? *(Tick as appropriate)*

- [ ] Peer reviewed academic journals
- [ ] Book or contribution to a book
- [ ] Other published outlets e.g. ESRC or Cochrane Review,
- [ ] Thesis/dissertation
- [ ] Conference presentation
- [ ] Internal report
- [ ] Other e.g. deposition in University Library

49. How will the results of research be made available to research participants and communities from which they are drawn?

- [ ] Presentation to participants or relevant community groups
- [ ] Written feedback to research participants
- [ ] Other e.g. videos, interactive website

50. Will dissemination allow identification of individual participants?

- [ ] Yes  [x] No

If No, proceed to 51
If Yes, indicate how these individuals’ consent will be obtained:

50.2 Will dissemination involve publication of extended direct quotations from identified participants and/or distribution of audiovisual media in which identified participants play leading roles?

- [ ] Yes  [x] No

If No, proceed to 52
If Yes, indicate how the participants’ possible Intellectual Property or Performance Rights in these outputs will be negotiated. Where relevant, attach a model of the release form that will be used.

50.3 Are special arrangements needed to provide indemnity and/or compensation in the event of a claim by, or on behalf of, participants on grounds such as libel, breach of confidence and infringement of Intellectual Property or Performance Rights?

N/A

SECTION J – Funding and sponsorship

51. Has external funding for the research been secured?

- [ ] Yes  [x] No

If Yes, give details of funding organisation(s) and amount secured and duration:

- Organisation:
- UK contact:
- Amount (£):
- Duration:  Months

52. Name of organisation which will act as Sponsor for the research, if other than the University:

*Note: the University will normally act as Sponsor (ie responsible for the design, management and conduct of the research project by University staff and/or students), but in some cases of externally commissioned research the funder will be the Sponsor. If this is the case please provide details)*

*Note: Appendices mentioned in the Ethical Approval Form were omitted from this appendix due to their extent. These were adapted from the University Forms.*
SECTION K — Confirmation of Application

Signature(s) of applicant(s):

[Signature]

15/04/2013

DATE

SIGNATURE

Alicia Flores Salas  PhD Student

NAME AND POST OF APPLICANT (PLEASE PRINT)

[Signature]

15/04/2013

DATE

SIGNATURE

Dr. Peter Fenn  Supervisor

NAME AND POST OF APPLICANT (PLEASE PRINT)

Signature by or on behalf of the Head of School

The Committee expects each School to have a pre-screening process for all applications for an ethical opinion on research projects. The purpose of this pre-screening is to ensure that projects are scientifically sound, have been assessed to see if they need ethics approval and, if so, go to the relevant ethics committee. It is not to undertake ethical review itself, which must be undertaken by a formal research ethics committee.

The form must therefore be counter-signed by or on behalf of the Head of School to signify that this pre-screening process has been undertaken.

I approve the submission of this application

[Signature]

15/04/2013

DATE

SIGNED BY OR ON BEHALF OF HEAD OF SCHOOL

Dr. Parthasarathi Mandal

NAME (PLEASE PRINT)
## Appendix “2” Online questionnaire

<table>
<thead>
<tr>
<th>Section</th>
<th>Questions</th>
</tr>
</thead>
</table>
| **Personal Data**              | 1. How long have you been working in housing construction?  
                                | 2. How do you evaluate your experience in housing construction?  
                                | 3. Have you ever participated in housing recovery after natural disasters?  
                                | 4. How did you participate in housing recovery after natural disasters?  
                                | 5. How do you evaluate your skills in teaching construction activities? |
| **Architectural design**       | 6. Should the affected people’s opinions be used in the architectural design of their homes post natural disasters? If so how  
                                | 7. Should the affected people’s feelings be considered regarding their needs in architectural spaces? If so how  
                                | 8. Should the people affected by natural disasters be included in the architectural design of their homes? If so how  
                                | 9. Should the people affected by natural disasters participate in the architectural design of their homes? If so how  
| **Choice of building materials** | 10. Should traditional housing construction be preserved after a natural disaster? If so how  
                                | 11. Should new construction materials for housing recovery be used after natural disasters? If so how  
                                | 12. Should the people affected by natural disasters be consulted in the choice of building materials to build their house after natural disaster? If so how  
                                | 13. Should the affected people participate in choosing building materials? If so how  
| **Management of financial resources** | 14. What do you think about giving cash to the affected people after natural disasters for housing recovery by themselves?  
                                | 15. What do you think about giving cash to the affected people after natural disasters for hiring contractors for housing recovery? |
| **Unskilled labour**           | 16. Do you feel that construction activities should be exclusive to professionals?  
                                |                      If yes, explain why? |
                                | 17. What do you think about training unskilled people from communities affected by natural disasters for housing recovery by themselves under supervision of professionals? |
### Appendix “3” Semi-structured interview

| Introduction | • Greet the interviewee and introduce myself.  
|              | • Ask participant’s permission for audio recording  
|              | • Briefly explain the background and purpose of the research  
|              | • Briefly explain the process of interview  
| Features of construction materials | 1. What is the physical and mechanical behaviour of your materials in earthquakes?  
|                               | 2. How is the quality control done on materials in your company before they are put on the international market?  
| Availability in the market | 3. Tell me please, are your materials available in the international market?  
|                               | 4. Tell me please, if your company has supplied materials in international markets?  
|                               | 5. How prepared is your company to supply building materials in areas affected by natural disasters?  
| International prices | 6. Could you tell me, please if there is a competitive market in prices for your product in the international market?  
|                               | 7. How willing is your company to negotiate new prices in order to be awarded a supply contract?  
|                               | 8. Is a price list of your products available?  
| Capacity to supply construction materials and technical support in areas hit by natural disasters | 9. How easily could your company supply construction materials in areas hit by natural disasters?  
|                               | 10. Are there extra charges for supplying construction materials in areas hit by natural disasters?  
|                               | 11. If yes, could you tell me which?  
|                               | 12. How long will it take for your company to provide building materials for the first time in areas affected by natural disasters?  
|                               | 13. Could you tell me, please? What is your monthly production of (cubic metre of concrete, square metre of the panels or ton of steel)?  
|                               | 14. How does your company give technical support in areas affected by natural disasters?  
| Summary and closure | • Do you have anything to add?  
|                               | • Is there anything I should have asked?  
|                               | • How did the interview feel for you?  
|                               | • Close the interview by thanking the participant for his/her time.  

Appendix “4” Data coding process

An alphanumeric systematic system clave was used to classify more than 15,000 words collected from the 22 online questionnaires conducted with 22 housing experts and 7 semi-structured interviews with 7 technical directors of 7 companies manufacturing construction materials in Nvivo 10 in themes, categories and patterns. The process was devised to group and identify similar data, so data were divided into themes, categories, and patterns. The coding process was achieved through establishing nodes in hierarchies to enable moving from themes at the top (the parent node) to more specific categories (nodes) by using patterns (child nodes) (Figure 1).

Thus, 10 themes (parent nodes), 31 categories (nodes) and 52 patterns (child nodes) were created to facilitate the analysis. The coding process to load data in nodes created in Nvivo 10 was composed of three steps.

First step:
The first step in the coding process was the creation of parent nodes (themes). Themes were determined previously during the design of the questionnaires based on the theoretical framework related to the post-disaster Housing Reconstruction Programmes and the 3D-LPs construction system. Five are related to the online questionnaire and the other five are related to the semi-structured interviews (see Table 1).
Appendix “4-b” Data coding process

Table 1 Themes of the online questionnaire and semi-structured interviews

<table>
<thead>
<tr>
<th>Online questionnaire themes</th>
<th>Semi-structured interviews themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Data</td>
<td>Features of the system</td>
</tr>
<tr>
<td>Architectural design</td>
<td>Availability in the market</td>
</tr>
<tr>
<td>Choice of building materials</td>
<td>International prices</td>
</tr>
<tr>
<td>Management of financial resources</td>
<td>Capacity to supply construction materials</td>
</tr>
<tr>
<td>Unskilled labour</td>
<td>Technical support in areas hit by natural disasters</td>
</tr>
</tbody>
</table>

The 10 themes were coded by assigning a letter and the name of the category as in the following example:

Figure 2 Alphanumeric clave for parent nodes

Thus the 10 themes (parent nodes) shown in Table 1 were coded in Nvivo 10 to enable the qualitative analysis. The first five parent nodes coded 374 responses from 22 housing experts totalling 10527 words. The second five parent nodes coded 98 responses from 7 manufacturers totalling 4892 words. Figure 3 shows the 10 themes coded in Nvivo 10.
Appendix “4-c” Data coding process

Second step
The second step in the coding process was to reduce the volume of data to enable the qualitative analysis and moving from the themes to categories to get specific information. To achieve this, nodes (categories) were created by dividing each parent node (theme) again. Then each parent node was composed of one to five categories. Figure 4 and 5 show the theme codes (nodes) belonging to the questionnaires applied online and semi-structured interviews created in Nvivo 10.
Appendix “4-d” Data coding process

Figure 7 shows the alphanumeric clave assigned to categories (nodes) ATCQ-1- category name to allow their identification where:

Third step

The third step was the building of child nodes (patterns). These come from the nodes (categories); the coding was carried through a manual process, which consisted of reading, highlighting and marking similar words (patterns) loaded in the theme codes as many times as was needed (Saldaña, 2009). In consequence, each child node contains specific and meaningful information regarding the category asked about in each theme. Subsequently, data coded were displayed alongside each node by colouring bars (coding stripes) to visualize and identify particular information related to the pattern under analysis for the building of thematic trends in Nvivo 10 (Figure 8).
Appendix “4-e” Data coding process

Figure 9 shows the alphanumeric clave assigned to patterns (child nodes) ATCQ-1-PT1 1-5 Years to allow their identification where:

Figure 8 shows the child nodes belonging to question 1 of the data personal category created in Nvivo 10. As can be seen, the personal data theme (parent node) is composed of 5 categories (nodes) and 16 patterns (child nodes). A similar process was conducted with each node created until all data was coded.

Figure 8 Patterns (Child nodes) created in Nvivo 10
Appendix “4-f” Data coding process

Some pattern names, such as participation, experience, yes, not, prices and supply among others, were used on more than one occasion due to the nature of the questions, since the same keywords were used by the respondents several times to express their opinions about the participation of the affected people, or for explaining their viewpoints. The coding process allowed the control of specific data to explain the objective of each question and to strengthen the theoretical propositions.

After the coding was ready the qualitative rich data were arranged in matrices to extract meaningful and significant patterns. Each matrix consisted of rows and columns with similar expressions (child nodes). Then, the process consisted of searching for similar wording in text previously coded at selected nodes (child nodes) as many times as was necessary to visualize findings and proceed to the interpretation. Patterns found were presented in a narrative manner to enable the conclusions after a numerical explanation to show the agreement and disagree of respondents in each theme.
## Appendix “4-g” Data coding process

<table>
<thead>
<tr>
<th>Parent nodes (Themes)</th>
<th>Nodes (categories)</th>
<th>Child nodes (patterns)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A Personal Data</strong></td>
<td>ATCQ-1 Years</td>
<td>ATCQ-1-PT1 1-5 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATCQ-1-PT2 6-10 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATCQ-1-PT3 11-15 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATCQ-1-PT4 16-20 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATCQ-1-PT5 21-25 years</td>
</tr>
<tr>
<td></td>
<td>ATCQ-2 Experience</td>
<td>ATCQ-2-PT1 Experienced</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATCQ-2-PT2 Inexperienced</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATCQ-2-PT3 Other</td>
</tr>
<tr>
<td></td>
<td>ATCQ-3 Participation</td>
<td>ATCQ-3-PT1 Activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATCQ-3-PT2 Field</td>
</tr>
<tr>
<td></td>
<td>ATCQ-4 Activities</td>
<td>ATCQ-4-PT1 Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATCQ-4-PT2 No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATCQ-4-PT3 Other</td>
</tr>
<tr>
<td></td>
<td>ATCQ-5 Teaching</td>
<td>ATCQ-5-PT1 Experienced</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATCQ-5-PT2 Inexperienced</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATCQ-5-PT3 Other</td>
</tr>
<tr>
<td><strong>B Architectural design</strong></td>
<td>BTCQ-6 Opinions</td>
<td>BTCQ-6-PT1 Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-6-PT2 No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-6-PT3 Other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-6-PT4 Participation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-6-PT5 Needs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-6-PT6 Experience</td>
</tr>
<tr>
<td></td>
<td>BTCQ-7 Feelings</td>
<td>BTCQ-7-PT1 Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-7-PT2 No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-7-PT3 Other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-7-PT4 Participation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-7-PT5 Needs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-7-PT6 Experience</td>
</tr>
<tr>
<td></td>
<td>BTCQ-8 Inclusion</td>
<td>BTCQ-8-PT1 Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-8-PT2 No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-8-PT3 Other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-8-PT4 Participation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-8-PT5 Needs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-8-PT6 Experience</td>
</tr>
<tr>
<td></td>
<td>BTCQ-9 Participation</td>
<td>BTCQ-9-PT1 Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-9-PT2 No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-9-PT3 Other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-9-PT4 Participation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-9-PT5 Needs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTCQ-9-PT6 Experience</td>
</tr>
<tr>
<td><strong>C Chose of building materials</strong></td>
<td>CTCQ-10 Preservation</td>
<td>CTCQ-10-PT1 Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CTCQ-10-PT2 No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CTCQ-10-PT3 Other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CTCQ-10-PT4 Workability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CTCQ-10-PT5 Improvement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CTCQ-10-PT6 Heritage</td>
</tr>
<tr>
<td></td>
<td>CTCQ-11 New</td>
<td>CTCQ-11-PT1 Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CTCQ-11-PT2 No</td>
</tr>
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<td></td>
<td></td>
<td>CTCQ-11-PT3 Other</td>
</tr>
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<td></td>
<td></td>
<td>CTCQ-11-PT4 Workability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CTCQ-11-PT5 Improvement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CTCQ-11-PT6 Use</td>
</tr>
<tr>
<td></td>
<td>CTCQ-12 Involvement</td>
<td>CTCQ-12-PT1 Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CTCQ-12-PT2 No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CTCQ-12-PT3 Other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CTCQ-12-PT4 Workability</td>
</tr>
<tr>
<td>Parent nodes (Theme categories)</td>
<td>Nodes (theme codes)</td>
<td>Child nodes (patterns)</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td><strong>Questionnaire via semi-structured interview</strong></td>
<td>FTCQ-1 Structural Behaviour</td>
<td>FTCQ-1-PT1 System FTCQ-1-PT2 Structure FTCQ-1-PT2 Workability</td>
</tr>
<tr>
<td>F Features of the construction materials</td>
<td>FTCQ-2 Quality control</td>
<td>FTCQ-2-PT1 Product FTCQ-2-PT2 Raw material</td>
</tr>
<tr>
<td>G Availability in the market</td>
<td>GTCQ-3 Availability</td>
<td>GTCQ-3-PT1 National</td>
</tr>
<tr>
<td></td>
<td>GTCQ-4 Customers</td>
<td>GTCQ-4-PT1 International</td>
</tr>
<tr>
<td></td>
<td>GTCQ-5 Supply</td>
<td>GTCQ-5-PT1 Immediately GTCQ-5-PT2 Schedule</td>
</tr>
<tr>
<td>H International prices</td>
<td>HTCQ-6 Competitive market</td>
<td>HTCQ-6-PT1 Yes HTCQ-6-PT2 Unsure</td>
</tr>
<tr>
<td></td>
<td>HTCQ-7 Negotiation of prices</td>
<td>HTCQ-7-PT1 Discounts</td>
</tr>
<tr>
<td></td>
<td>HTCQ-8 List of prices</td>
<td>HTCQ-8-PT1 Yes HTCQ-8-PT2 No</td>
</tr>
<tr>
<td>I Capacity to supply construction materials</td>
<td>FTCQ-9 Supply</td>
<td>FTCQ-9-PT1 Easily FTCQ-9-PT2 Via</td>
</tr>
<tr>
<td></td>
<td>FTCQ-10 Charge and type of charge</td>
<td>FTCQ-10-PT1 Yes FTCQ-10-PT2 No FTCQ-10-PT2 Export</td>
</tr>
<tr>
<td></td>
<td>FTCQ-11 Time</td>
<td>FTCQ-11-PT1 Days FTCQ-11-PT2 Transport</td>
</tr>
<tr>
<td></td>
<td>FTCQ-12 Supply</td>
<td>FTCQ-12-PT1 month</td>
</tr>
<tr>
<td></td>
<td>FTCQ-13 Production</td>
<td>FTCQ-13-PT1 month</td>
</tr>
</tbody>
</table>
| J Technical support | JTCQ-14 Technical department | JTCQ-13-PT1 Technical department
|---------------------|-----------------------------|-----------------------------
|                     | JTCQ-13-PT2 Worksite        |
|                     | JTCQ-13-PT3 Unskilled people |
Appendix “5” Economic analysis of the housing prototype

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminaries and plot</td>
<td>m²</td>
<td>April, 2012</td>
</tr>
<tr>
<td>preparation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cleaning up of plot includes manual removal of bushes, roots, rubbish and a layer of 20 cm of organic soil. Trace and topographic levelling of the plot is carried out with metrical tape and hose. Compaction and levelling of plot is carried out manual in layers of 5 cm wet and compacted with hand tools. Excavation with shovel to up 40 cm includes cuts and filling and preparation of ditches to place the foundation.

<table>
<thead>
<tr>
<th>CONCEPT</th>
<th>UNIT</th>
<th>AMOUNT</th>
<th>UNIT PRICE</th>
<th>SUBTOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrated lime</td>
<td>ton</td>
<td>0.0002</td>
<td>49.60</td>
<td>0.010</td>
</tr>
<tr>
<td>Timber re-used ¾” x 2” x 8”</td>
<td>piece</td>
<td>0.1556</td>
<td>0.43</td>
<td>0.067</td>
</tr>
<tr>
<td>nails to timber 2 ½”</td>
<td>Kg</td>
<td>0.0044</td>
<td>0.68</td>
<td>0.003</td>
</tr>
<tr>
<td>wire annealed gage 18</td>
<td>kg</td>
<td>0.0112</td>
<td>0.64</td>
<td>0.007</td>
</tr>
<tr>
<td>Water</td>
<td>litre</td>
<td>34.1084</td>
<td>0.005</td>
<td>0.156</td>
</tr>
<tr>
<td>diesel</td>
<td>litre</td>
<td>0.1778</td>
<td>0.37</td>
<td>0.067</td>
</tr>
<tr>
<td>Helper bricklayer</td>
<td>time basis</td>
<td>0.2833</td>
<td>10.94</td>
<td>3.100</td>
</tr>
<tr>
<td>Bricklayer</td>
<td>time basis</td>
<td>0.025</td>
<td>23.10</td>
<td>0.577</td>
</tr>
<tr>
<td>General auxiliary</td>
<td>time basis</td>
<td>0.025</td>
<td>10.94</td>
<td>0.274</td>
</tr>
</tbody>
</table>

Unit price total £ 4.26
Appendix “5-b” Economic analysis of the housing prototype

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation: Slab with beams</td>
<td>m²</td>
<td>April, 2012</td>
</tr>
</tbody>
</table>

Foundation consists of a 10 centimetre thick slab of reinforced concrete $f'c$ 200 kg/cm² elaborated in situ. Structured slab grade 20 x 20 cm with the appearance of a finished floor. Reinforcement with mesh of $6'' \times 6'' \times 1/4'' \times 1/4''$ on top and the sides of the structure. Includes formwork, steel, concrete placement, vibration and compaction, grading and finishing, curing and demoulding.

<table>
<thead>
<tr>
<th>CONCEPT</th>
<th>UNIT</th>
<th>AMOUNT</th>
<th>UNIT PRICE</th>
<th>SUBTOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland cement type 1</td>
<td>ton</td>
<td>0.0439</td>
<td>83.98</td>
<td>3.69</td>
</tr>
<tr>
<td>Grave 3/4&quot;</td>
<td>m³</td>
<td>0.0944</td>
<td>8.86</td>
<td>0.84</td>
</tr>
<tr>
<td>Sand from river</td>
<td>m³</td>
<td>0.0676</td>
<td>5.47</td>
<td>0.37</td>
</tr>
<tr>
<td>Water</td>
<td>litre</td>
<td>26.667</td>
<td>0.00</td>
<td>0.13</td>
</tr>
<tr>
<td>Timber re-used ¾&quot; x 2&quot; x 8&quot;</td>
<td>piece</td>
<td>0.1317</td>
<td>0.47</td>
<td>0.06</td>
</tr>
<tr>
<td>Timber re-used ¾&quot; x 4&quot; x 8&quot;</td>
<td>piece</td>
<td>0.3075</td>
<td>0.93</td>
<td>0.29</td>
</tr>
<tr>
<td>nails to timber 2 ½&quot;</td>
<td>Kg</td>
<td>0.0191</td>
<td>0.74</td>
<td>0.01</td>
</tr>
<tr>
<td>wire annealed gage 18</td>
<td>kg</td>
<td>0.051</td>
<td>0.69</td>
<td>0.04</td>
</tr>
<tr>
<td>Structure to beam 15cm x 20 cm x 4</td>
<td>piece</td>
<td>0.2552</td>
<td>4.51</td>
<td>1.15</td>
</tr>
<tr>
<td>Steel bars x 6 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electro welded mesh 6&quot; x 6&quot;</td>
<td>m</td>
<td>0.7018</td>
<td>4.08</td>
<td>2.86</td>
</tr>
<tr>
<td>x ¼&quot; x ¼&quot; of 2.5 m wide</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel bar Ø 5/16&quot; long 6 m</td>
<td>piece</td>
<td>0.0638</td>
<td>1.78</td>
<td>0.11</td>
</tr>
<tr>
<td>Black plastic roll of 2 m</td>
<td>m</td>
<td>0.7018</td>
<td>0.44</td>
<td>0.31</td>
</tr>
<tr>
<td>Diesel</td>
<td>litre</td>
<td>0.0797</td>
<td>0.40</td>
<td>0.03</td>
</tr>
<tr>
<td>Bricklayer</td>
<td>time basis</td>
<td>0.18</td>
<td>24.89</td>
<td>4.48</td>
</tr>
<tr>
<td>Helper bricklayer</td>
<td>time basis</td>
<td>0.18</td>
<td>11.79</td>
<td>2.12</td>
</tr>
<tr>
<td>Cement mix portable</td>
<td>rent per day</td>
<td>0.0138</td>
<td>6.39</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Unit price total £ 16.50
Appendix “5-c” Economic analysis of the housing prototype

The concept of the walls consists of supply and construction of structural walls with SIPs panels 2” wide and 5 x 5 galvanized steel meshes; this includes the placement of a structural layer of mortar on both sides up to a maximum wall thickness of 3.5”. Union and anchoring of panels is accomplished with steel bars and mesh tied with annealed wire and placing reinforcing mesh on the windows and doors.

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Data</th>
<th>CONCEPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls of Panel W 2” # 5 x 5 with mortar</td>
<td>m²</td>
<td>April, 2012</td>
<td></td>
</tr>
<tr>
<td>The concept of the walls consists of supply and construction of structural walls with SIPs panels 2” wide and 5 x 5 galvanized steel meshes; this includes the placement of a structural layer of mortar on both sides up to a maximum wall thickness of 3.5”. Union and anchoring of panels is accomplished with steel bars and mesh tied with annealed wire and placing reinforcing mesh on the windows and doors.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CONCEPT</th>
<th>UNIT</th>
<th>AMOUNT</th>
<th>UNIT PRICE</th>
<th>SUBTOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel W of 2” # 5x5 x 1.22m x 2.44 m</td>
<td>piece</td>
<td>0.3549</td>
<td>16.23</td>
<td>5.76</td>
</tr>
<tr>
<td>Flat mesh of 2.44 m.</td>
<td>piece</td>
<td>0.8892</td>
<td>0.96</td>
<td>0.86</td>
</tr>
<tr>
<td>Flat mesh of 2.44 m.</td>
<td>piece</td>
<td>0.5460</td>
<td>0.96</td>
<td>0.53</td>
</tr>
<tr>
<td>Wire annealed gage 18.</td>
<td>kg</td>
<td>0.0754</td>
<td>0.69</td>
<td>0.05</td>
</tr>
<tr>
<td>Steel bar AR-42 of ¼” x 12 m</td>
<td>piece</td>
<td>0.0623</td>
<td>4.04</td>
<td>0.25</td>
</tr>
<tr>
<td>Portland cement type 1</td>
<td>ton</td>
<td>0.0206</td>
<td>83.98</td>
<td>1.73</td>
</tr>
<tr>
<td>Sand from river</td>
<td>m³</td>
<td>0.0627</td>
<td>5.47</td>
<td>0.34</td>
</tr>
<tr>
<td>Water</td>
<td>litre</td>
<td>18.81</td>
<td>0.005</td>
<td>0.09</td>
</tr>
<tr>
<td>Polypropylene fibre</td>
<td>piece</td>
<td>0.055</td>
<td>2.76</td>
<td>0.15</td>
</tr>
<tr>
<td>Helper</td>
<td>time basis</td>
<td>0.0138</td>
<td>11.79</td>
<td>0.16</td>
</tr>
<tr>
<td>Official installer panels</td>
<td>time basis</td>
<td>0.0622</td>
<td>24.89</td>
<td>1.55</td>
</tr>
<tr>
<td>helper of official installer panels</td>
<td>time basis</td>
<td>0.0622</td>
<td>11.79</td>
<td>0.73</td>
</tr>
<tr>
<td>Bricklayer</td>
<td>time basis</td>
<td>0.1119</td>
<td>24.89</td>
<td>2.79</td>
</tr>
<tr>
<td>Helper bricklayer</td>
<td>time basis</td>
<td>0.1119</td>
<td>11.79</td>
<td>1.32</td>
</tr>
<tr>
<td>cement mix portable</td>
<td>rent per day</td>
<td>0.0138</td>
<td>6.39</td>
<td>0.09</td>
</tr>
<tr>
<td>Scaffold</td>
<td>rent per day</td>
<td>0.0884</td>
<td>0.40</td>
<td>0.04</td>
</tr>
<tr>
<td>pneumatic mortar launcher</td>
<td>hour</td>
<td>0.7333</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>compressor 5 hp</td>
<td>hour</td>
<td>0.7333</td>
<td>0.42</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Unit price total £ 16.80
Appendix “5-d” Economic analysis of the housing prototype

The concept of the slabs consisted of supply and construction of structural slabs with SIP panels 4” wide. This includes the placement of a concrete structural layer of 1½” with resistance of f'c 200 kg/cm². The concept includes equipment and tools, labour and the activities of placement and removal of formwork, as well as union and galvanized mesh reinforcement and steel bars.

<table>
<thead>
<tr>
<th>CONCEPT</th>
<th>UNIT</th>
<th>AMOUNT</th>
<th>UNIT PRICE</th>
<th>SUBTOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel W of 4” 1.02 m x 2.44 m</td>
<td>piece</td>
<td>0.4139</td>
<td>22.90</td>
<td>9.48</td>
</tr>
<tr>
<td>Flat mesh of 2.44 m.</td>
<td>piece</td>
<td>0.65</td>
<td>0.96</td>
<td>0.63</td>
</tr>
<tr>
<td>Flat mesh of 2.44 m.</td>
<td>piece</td>
<td>0.5211</td>
<td>0.96</td>
<td>0.50</td>
</tr>
<tr>
<td>Wire annealed gage 18.</td>
<td>kg</td>
<td>0.1282</td>
<td>0.69</td>
<td>0.09</td>
</tr>
<tr>
<td>Steel bar AR-42 of ¾” x 12 m</td>
<td>piece</td>
<td>0.0949</td>
<td>4.04</td>
<td>0.38</td>
</tr>
<tr>
<td>Steel bar AR-42 of ½” x 12 m</td>
<td>piece</td>
<td>0.1797</td>
<td>4.04</td>
<td>0.73</td>
</tr>
<tr>
<td>Premix concrete f2c 200 kg/cm² with grave ½ and pumping</td>
<td>m³</td>
<td>0.061</td>
<td>59.03</td>
<td>3.60</td>
</tr>
<tr>
<td>Portland cement type 1</td>
<td>ton</td>
<td>0.0083</td>
<td>83.98</td>
<td>0.70</td>
</tr>
<tr>
<td>Sand from river</td>
<td>m³</td>
<td>0.0251</td>
<td>5.47</td>
<td>0.14</td>
</tr>
<tr>
<td>Water</td>
<td>litre</td>
<td>7.524</td>
<td>0.005</td>
<td>0.04</td>
</tr>
<tr>
<td>Polypropylene fibre</td>
<td>piece</td>
<td>0.022</td>
<td>2.76</td>
<td>0.06</td>
</tr>
<tr>
<td>Timber re-used¾” x 2” x 8”</td>
<td>piece</td>
<td>0.1282</td>
<td>0.93</td>
<td>0.12</td>
</tr>
<tr>
<td>diesel</td>
<td>litre</td>
<td>0.0385</td>
<td>0.40</td>
<td>0.02</td>
</tr>
<tr>
<td>Helper</td>
<td>time basis</td>
<td>0.0055</td>
<td>11.79</td>
<td>0.06</td>
</tr>
<tr>
<td>Official installer panels</td>
<td>time basis</td>
<td>0.0542</td>
<td>24.89</td>
<td>1.35</td>
</tr>
<tr>
<td>Helper of official installer panels</td>
<td>time basis</td>
<td>0.0542</td>
<td>11.79</td>
<td>0.64</td>
</tr>
<tr>
<td>Bricklayer</td>
<td>time basis</td>
<td>0.1451</td>
<td>24.89</td>
<td>3.61</td>
</tr>
<tr>
<td>Helper bricklayer</td>
<td>time basis</td>
<td>0.1964</td>
<td>11.79</td>
<td>2.32</td>
</tr>
<tr>
<td>Steel prop formwork 2.44 m</td>
<td>rent per day</td>
<td>0.0055</td>
<td>6.39</td>
<td>0.04</td>
</tr>
<tr>
<td>Adjustable steel push-pull prop</td>
<td>rent per day</td>
<td>0.19</td>
<td>0.40</td>
<td>0.08</td>
</tr>
<tr>
<td>Cement mix portable</td>
<td>rent per day</td>
<td>2.3077</td>
<td>0.06</td>
<td>0.14</td>
</tr>
<tr>
<td>Scaffold</td>
<td>rent per day</td>
<td>6.9231</td>
<td>0.06</td>
<td>0.42</td>
</tr>
<tr>
<td>Pneumatic mortar launcher</td>
<td>hour</td>
<td>0.444</td>
<td>0.08</td>
<td>0.04</td>
</tr>
<tr>
<td>Compressor 5 hp</td>
<td>hour</td>
<td>0.444</td>
<td>0.42</td>
<td>0.19</td>
</tr>
<tr>
<td>Petrol concrete vibrator</td>
<td>hour</td>
<td>0.2048</td>
<td>0.60</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Unit price total £26.75
Appendix “6” Guidelines

Introduction

This appendix presents the guidelines directed to construction professionals to train unskilled people from communities affected by disasters in housing construction with the 3D-LPs construction system. The guidelines include technical support to construction professionals provided by manufacturers and the guidelines to provide training to unskilled people by construction professionals.

Guidelines objective

To provide a systematic process to construction professionals and Non-Governmental Organizations, in order that they can train people affected by disasters in the 3D-LPs construction system for housing recovery in the shortest time possible.

Justification

The guidelines were motivated by the need to provide technical skills to people affected by natural disasters. In this way, they could be included in the reconstruction process of permanent housing after overcoming the emergency phase. The results obtained from online questionnaire, semi-structured interview and computer modelling have shown that the displaced people should participate in housing reconstruction after having been trained, and the 3D-LP construction system has shown to be an option to build robust, affordable and sustainable housing. In addition to that the BIM system has shown the 3D views of the housing prototype which enable the understanding of the construction process of the housing prototype. The guidelines aim to provide a feasible alternative to solve the housing recovery problem; in addition, the design and development of the guidelines were also motivated by the willingness of manufacturers to offer training in the place affected by a disaster.

General considerations

The following guidelines were elaborated based on the findings of the online questionnaire, semi-structured interviews and computer modelling and the answers obtained from the research questions. A pyramidal training scheme is proposed to recover the damaged housing on a large scale in order to provide International
Agencies (IA) and NGOs of a systematic process to implement housing reconstruction process. It is important to clarify the following points to enable the implementation of these guidelines:

1. The guidelines will frequently identify construction professionals of the architecture, engineering and construction (AEC) industry as the construction professionals who will provide the training to unskilled people, but other professionals such as designers and surveyors are encouraged to participate in the implementation of these guidelines, as a multidisciplinary team would strengthen the training of displaced people.

2. These guidelines should be implemented on the assumption that there will be a technical team composed of 10 professionals in the affected place hired by IA and NGOs, and people willing to participate in self-construction of their homes. The number has been determined based on the number of the construction stages and the need to quickly multiply the number of skilled people. It has also been determined based on “Typical training program staffing” from the Handbook for Reconstructing after Natural Disasters “A “four eyes” principle is strongly recommended, which implies that no field team should have fewer than two people. The number of field staff on each team may be as many as five, depending on such factors as the accessibility of the sites.”(Jha et al., 2010).

3. The guidelines should be implemented immediately after the emergency phase has been overcome and the assessment of the number of houses to be built has been made. In order that the displaced or homeless people do not remain in shelters for long periods until their new houses become available. Additionally, the guidelines should be implemented as soon as necessary arrangements of land ownership and the collaboration of the government to provide urban services in the area affected have been made.

4. Manufacturers should be contacted by International agencies or NGOs, who should make all of the arrangements to acquire construction materials for
housing recovery and provide them with the facilities to give technical support, in the understanding that the training will involve theoretical-practical sections.

5. IA and NGOs should introduce construction professionals to manufacturers in order that they can have direct contact. However, it is advisable that IA and NGOs made all administrative and logistics arrangements.

6. IA and NGOs should act as intermediaries between manufacturers and construction professionals for all management issues.

7. Manufacturers will be responsible for providing technical support to construction professionals and they will have contact with unskilled people only during the training stage as construction professionals will be responsible to implement the housing recovery process and monitor unskilled people after training.

8. Construction professionals will be responsible for providing technical training to unskilled people from the communities affected by the disaster in the affected place with technical support of manufacturers. Next, trained people will have to act as facilitators to train unskilled people. Construction professionals as monitors.

9. It is assumed that the housing prototype was designed under building regulations that satisfy the design of appropriate housing and measurements and construction materials required for its construction. The practical training should make use of the housing prototype designed in this study (see chapter 6). In consequence two types of guidelines are proposed:

- Guidelines for the provision of technical support to construction professionals by manufacturers of the 3D-LPs construction system and,
- Guidelines for the provision of training to unskilled people by construction professionals.
Appendix “6” Guidelines

Guidelines for the provision of technical support to construction professionals by manufacturers of the 3D-LPs construction system

➤ Introduction
These guidelines aim to strengthen the technical skills of construction professionals and provide the technical knowledge to build housing with the 3D-LPs construction system, in order that they can train and monitor unskilled people from communities affected during the construction of new dwelling units built with such a system.

➤ Objective
To provide effective and constant technical support to construction professionals in the construction of housing with the 3D-LPs construction system.

Process to implement the technical support

The following activities should be carried out to implement the technical support directed to construction professionals by manufacturers of the 3D-LPs construction system, in order to guarantee the appropriate technical support in the place affected by a disaster on the basis mentioned in general considerations (see Table 1).

<table>
<thead>
<tr>
<th>Activities</th>
<th>Responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Determination of the scope of the technical support</td>
<td>International agency and NGOs base on section 8.5.2</td>
</tr>
<tr>
<td>2. Determination of the persons responsible for providing technical support</td>
<td>International agency and NGOs and manufacturers</td>
</tr>
<tr>
<td>3. Determination of the means to receive technical support</td>
<td>International agency and NGOs and construction professionals</td>
</tr>
<tr>
<td>4. Planning of the stages of the technical support</td>
<td>Construction professionals</td>
</tr>
<tr>
<td>5. Elaboration of the technical support schedule</td>
<td>Manufacturers and construction professionals</td>
</tr>
<tr>
<td>6. Evaluation of the technical support</td>
<td>Manufacturers</td>
</tr>
<tr>
<td>7. Documentation of the technical support</td>
<td>Construction professionals and manufacturers</td>
</tr>
</tbody>
</table>

Determination of the scope of the technical support

This activity is to establish the scope of the technical support which involves three stages: before training unskilled people, during training unskilled people and other
after training unskilled people. Hence, in this activity the construction professionals have to establish three types of technical support as follow.

A. Construction professionals have to ask for a three days workshop before training unskilled people which includes the following themes:

- Description of the 3D-LPs construction system.
- Description of physical and mechanical properties of 3D-LPs.
- Description of the construction process used to build housing of one storey through the 3D-LPs construction system.
- Physical demonstration of the use of panels by means of the construction of a structural wall with panels.
- Session of questions and answers and clarification of doubts.

B. Construction professionals have to ask for technical support while training unskilled people to show the construction process to unskilled people.

C. Construction professionals have to ask for visits after training unskilled people to obtain the viewpoint of the technical team on the following points:

- Assembling of the panels on foundation.
- Connecting of panels to build walls and roofs.
- Mortar layers on both panel faces.
- Concrete layer on the roof.
- Placing of pipes to allow electrical-hydraulic and sanitary installations.

Technical support after training unskilled people in the worksite assumes the presence of the technical team in the affected place. Construction professionals have to ask for technical visits in the affected place, especially in the initial phase of implementation of the construction process where trained people (from communities affected) will participate. Subsequently, construction professionals may consult technical teams to clarify doubts or problem regarding the construction process in order to guarantee the correct performance of the system in terms of building codes.
Determination of the persons responsible for providing technical support

In this activity construction professionals have to be informed, who responsible for providing the technical support will be. Construction professionals have to make a list (see Table 2) with all details of those responsible and keep it updated in order that they can have direct contact with the technical support team as follows:

Table 2 Details of those responsible for providing technical support to manufacturers

<table>
<thead>
<tr>
<th>Item</th>
<th>Details of those responsible for providing technical support</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Name of main person responsible for technical support</td>
</tr>
<tr>
<td>2.</td>
<td>Names of technical team members in charge of providing technical support</td>
</tr>
<tr>
<td>3.</td>
<td>Company address</td>
</tr>
<tr>
<td>4.</td>
<td>Company telephone numbers</td>
</tr>
<tr>
<td>5.</td>
<td>Telephone numbers of technical team members and main person responsible</td>
</tr>
<tr>
<td>6.</td>
<td>Mobile phone numbers of technical team and main person responsible</td>
</tr>
<tr>
<td>7.</td>
<td>email addresses of technical team and main person responsible</td>
</tr>
<tr>
<td>8.</td>
<td>Websites, Skype names and any other social network available</td>
</tr>
<tr>
<td>9.</td>
<td>Working hours at the office</td>
</tr>
</tbody>
</table>

Determination of the means to receive technical support

This activity includes the determination of the means for receiving additional support. Construction professionals have to make sure where they can obtain such support, as they will be responsible for training and monitoring the work of affected people (see Table 3). Hence, construction professionals have to ask the technical director by means of International Agencies and NGOs the following:

Table 3 Extra-technical support

<table>
<thead>
<tr>
<th>Item</th>
<th>Means</th>
<th>Availability (e.g. Online, printed, etc.)</th>
<th>Frequency (e.g. open and closed times, daily or weekly)</th>
<th>Details of access (e.g. WebPages, location, meetings or appointments)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Manuals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Guidelines</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Webinar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Mobile or satellite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Blogs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Face to face</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Planning of the stages of the technical support
Construction professionals have to prepare a plan to guarantee technical support, which involves two stages: one before training unskilled people and other after training unskilled people.

- The first stage is to be familiar with the construction process using the 3D-LPs construction system. In order that they can implement the guidelines for the provision of training to unskilled people developed in this study.

- The second stage is to obtain technical support in the worksite; this plan will be elaborated for the starting phase of the reconstruction process, since construction professionals will need to verify that the first dwellings meet the specification required by manufacturers of the system and the building regulations. Subsequently, construction professionals have to act as monitors, as unskilled people will be trained, they will need to supervise the work of trained people.

Evaluation of the technical support received
Construction professionals have to evaluate the quality of the technical support received, in order to give feedback to manufacturers and improve technical support (see Table 4). Manufacturers have to evaluate the skills achieved by construction professionals in order to make sure that the 3D-LPs construction system was understood correctly.

<table>
<thead>
<tr>
<th>Item</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Technical support regarding the construction process with the 3D-LPs construction system</td>
</tr>
<tr>
<td>2.</td>
<td>Advice in the worksite</td>
</tr>
<tr>
<td>3.</td>
<td>Technical support to meet the specification of the 3D-LPs construction system</td>
</tr>
<tr>
<td>4.</td>
<td>Technical support to verify housing in terms of construction regulations</td>
</tr>
</tbody>
</table>

It is advisable that construction professionals prepare a written technical report of the technical support received to be delivered to NGOs.
It is advisable that manufacturers prepare a brief exam to evaluate the skills achieved by construction professionals.

**Documentation and report of technical support**
Construction professionals and manufacturers have to prepare a report regarding the technical support received and provided to be sent to NGOs in order to make the process of receiving and providing technical support transparent.
Appendix “6” Guidelines

Guidelines for the provision of training to unskilled people by construction professionals

➢ Introduction
These guidelines aim to strengthen the technical skills of community members affected by disasters and provide the basic knowledge to build housing with the 3D-LPs construction system. The guidelines provide the process to implement the training for unskilled people in the place affected by a disaster.

➢ Objective
To provide effective training to unskilled people in order that they can participate in housing reconstruction after a disaster, and to give them a sense of belonging and ownership in addition to reducing the time and cost of their housing.

Process to implement the training for unskilled people after a disaster

The following activities are to implement the training for unskilled people in the affected place post-disasters by construction professionals in the 3D-LPs construction system on the basis mentioned in general conditions (see Table 5).

<table>
<thead>
<tr>
<th>Activities</th>
<th>Responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Determine profile of unskilled people to participate in the training</td>
<td>International agencies and NGOs</td>
</tr>
<tr>
<td>2. Determine the stages in which unskilled people will participate</td>
<td>Construction professionals</td>
</tr>
<tr>
<td>3. Formation of construction professional groups in charge of providing the training</td>
<td>International agencies and NGOs</td>
</tr>
<tr>
<td>4. Formation of unskilled people for stages of the construction process</td>
<td>Construction professionals</td>
</tr>
<tr>
<td>5. Evaluation of the result obtained</td>
<td>Manufacturers and Construction professionals</td>
</tr>
<tr>
<td>6. Report of the training provided to unskilled people</td>
<td>Manufacturers and Construction professionals</td>
</tr>
</tbody>
</table>

Determine profile of unskilled people to participate in the training
Construction professionals have to ask NGOs for men and women over 18 years. However, where men and women under 16 years are available, construction professionals have to decide whether to allow their inclusion in the construction stages. The desired physical and mental health characteristics of the unskilled people should be determined by International agencies and NGOs with information provide by construction professionals.

**Determine the stages in which unskilled people will participate**

The construction process of the housing prototype involves five stages (see Table 6):

<table>
<thead>
<tr>
<th>Stages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Preliminaries and plot preparation</td>
</tr>
<tr>
<td>2. Foundation slab with beams</td>
</tr>
<tr>
<td>3. Structural walls made of 3D-LPs and</td>
</tr>
<tr>
<td>mortar layer</td>
</tr>
<tr>
<td>4. Roof slab made of 3D-LP and concrete</td>
</tr>
<tr>
<td>5. Parapet made of 3D-LPs and mortar layer</td>
</tr>
</tbody>
</table>

**Formation of construction professional groups in charge of providing the training**

Assuming that the 10 construction professionals are familiar with the 3D-LPs construction system, and they have received and will receive technical support by manufacturers during the implementation of the housing recovery, the group of 10 construction professionals have to divide into 2 groups of five people each.

Each group has to be in charge of providing training to unskilled people in the five stages required to build the housing prototype and specified in Table 6. Hence, each construction professional from each group has to be in charge of training up to 10 unskilled people in each stage of construction of the prototype (Figure 1). This means that each unskilled person will be trained only in one stage of the construction process.
Thus in 10 days there will be 100 skilled people ready to start the construction of the housing prototype (Figure 2).

The number of unskilled people to be trained was chosen in order to quickly multiply the number of skilled people to build the housing prototype. In consequence, after assigning 10 unskilled people to each construction professional, they have to teach all activities concerning each construction stage, this gives the possibility to have a complete team to build the housing prototype after the first training course. In this stage is advisable that International Agencies and NGOs implement the “Four eyes” principle in order that each construction professional can work with one member of the technical team provide by manufacturers to provide the training to unskilled people. It can be achieved by asking manufacturers for their technical support.

**Formation of unskilled people for stages of the construction process**

The training has to be provided in 10 days or less by a practical method in order that unskilled people can acquire practical experience. Construction professionals have to provide a brief theoretical introduction to the 3D-LPs construction system using 3D
digital views obtained from the BIM system. Construction professionals have to provide also didactical material provided by manufacturers to enable understanding regarding the type of housing that is intended to be achieved.

The training has to be carried out as follows: each professional has to focus on a unique stage of the construction process and ask NGOs for all materials necessary to carry out the theoretical and practical training. The activities marked ‘to be carried out in the worksite’ have to be performed firstly by construction professionals helped by manufacturers in order to show the process. Subsequently, unskilled people must carry out the activities by themselves under supervision of construction professionals. Below is a list of the themes that construction professionals have to teach to unskilled people.

In this stage construction professionals in groups “A” and “B” have to teach the same activities in order to achieve 20 skilled people in preliminaries and plot preparation (see Table 7).

<table>
<thead>
<tr>
<th>Stage 1 Preliminaries and plot preparation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
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<td>5</td>
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<tr>
<td>6</td>
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<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
</tbody>
</table>

In this stage, construction professionals in groups “A” and “B” have to teach the same activities in order to achieve 20 people skilled in laying foundations (see Table 8).
Table 8 Activities of foundation

<table>
<thead>
<tr>
<th>Stage 2 Foundation</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day</strong></td>
<td><strong>Activity</strong></td>
<td><strong>Avenue</strong></td>
</tr>
<tr>
<td>1</td>
<td>Provide a general introduction to the project and the construction stage</td>
<td>Room</td>
</tr>
<tr>
<td>2</td>
<td>Teach how to place the black plastic and formwork on the ditches</td>
<td>Room</td>
</tr>
<tr>
<td>3</td>
<td>Teach how to enable the steel structure of foundation beams and to cut and bend to 90° the steel bars that will be anchored to the foundation beam to place the walls</td>
<td>Room and worksite</td>
</tr>
<tr>
<td>4</td>
<td>Teach how to install pipes for hydraulic and sanitary installations</td>
<td>Room and worksite</td>
</tr>
<tr>
<td>5</td>
<td>Teach how to place the steel structure of the beams on the ditches and anchor the steel bars to the structure of the foundation beams to place the walls.</td>
<td>Room and worksite</td>
</tr>
<tr>
<td>6</td>
<td>Teach how to spread the concrete on the foundation beams and remove the formwork</td>
<td>Room and worksite</td>
</tr>
<tr>
<td>7</td>
<td>Teach how to place the electro welded mesh on the top and the sides of the structure to enable the construction of the slab foundation and place and remove the formwork</td>
<td>Room and worksite</td>
</tr>
<tr>
<td>8</td>
<td>Teach how to spread, vibrate, compact and level the concrete on the slab foundation</td>
<td>Room and worksite</td>
</tr>
<tr>
<td>9</td>
<td>Teach how to do the curing</td>
<td>Room and worksite</td>
</tr>
<tr>
<td>10</td>
<td>Teach how to give the appearance of a finished floor</td>
<td>Room and worksite</td>
</tr>
</tbody>
</table>

**Note:** the concrete is pre-mixed. If the slab foundation does not require foundation beams because of good soil conditions, the construction professionals should omit these steps.

In this stage, construction professionals in groups “A” and “B” have to teach the same activities to achieve 20 people skilled in the construction of structural panels (see Table 9).

Table 9 Activities of structural walls

<table>
<thead>
<tr>
<th>Stage 3 Structural walls made of 3D-LPs</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day</strong></td>
<td><strong>Activity</strong></td>
<td><strong>Avenue</strong></td>
</tr>
<tr>
<td>1</td>
<td>Provide a general introduction to the project and the construction stage</td>
<td>Room</td>
</tr>
<tr>
<td>2</td>
<td>Teach how to place structural 3D-LPs on the steel bars of the slab foundation</td>
<td>Room</td>
</tr>
<tr>
<td>3</td>
<td>Teach how to connect the panels to each other with mesh made of galvanized steel and tie them with annealed wires or staples</td>
<td>Room and worksite</td>
</tr>
<tr>
<td>4</td>
<td>Teach how to cut the steel bars, and to bend them to 90° and “U” shapes</td>
<td>Room and worksite</td>
</tr>
<tr>
<td>5</td>
<td>Teach how to connect the panels to each other with steel bars at the corners and when three panels coincide</td>
<td>Room and worksite</td>
</tr>
<tr>
<td>6</td>
<td>Teach how to place meshes in square opened windows and doors and place and remove shoring</td>
<td>Room and worksite</td>
</tr>
<tr>
<td>7</td>
<td>Teach how to install pipes to enable the placing of electrical-hydraulic and sanitary installations</td>
<td>Room and worksite</td>
</tr>
<tr>
<td>8</td>
<td>Teach how to spread the mortar layer on both sides in accordance with the manufacturer’s specifications</td>
<td>Room and worksite</td>
</tr>
</tbody>
</table>
In this stage, construction professionals in groups “A” and “B” have to teach the same activities to achieve 20 people skilled in the construction of a structural roof (see Table 10).

### Table 10 Activities of roof slab

<table>
<thead>
<tr>
<th>Stage 4 Room slab walls made of 3D-LPs</th>
<th>Avenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>Provide a general introduction to the project and the construction stage</td>
</tr>
<tr>
<td>Day 2</td>
<td>Teach how to place shoring and formwork to place the roof panels</td>
</tr>
<tr>
<td>Day 3</td>
<td>Teach how to place the 3D-LPs structural panels on the shoring and formwork</td>
</tr>
<tr>
<td>Day 4</td>
<td>Teach how to connect roof panels to structural wall panels with mesh made of galvanized steel and tie them with annealed wires or staples</td>
</tr>
<tr>
<td>Day 5</td>
<td>Teach how to cut steel bars to connect roof panels to structural wall panels</td>
</tr>
<tr>
<td>Day 6</td>
<td>Teach how to connect roof panels to structural wall panels with steel bars tie them with annealed wires or staples</td>
</tr>
<tr>
<td>Day 7</td>
<td>Teach how to install pipes to enable the placing of electrical and sanitary installations</td>
</tr>
<tr>
<td>Day 8</td>
<td>Teach how to spread a concrete layer on the top sides of the roof panels and to spread a mortar layer on the internal faces of the roof panels, in accordance with the manufacturer’s specifications</td>
</tr>
<tr>
<td>Day 9</td>
<td>Teach how to do the curing</td>
</tr>
<tr>
<td>Day 10</td>
<td>Teach how to give the appearance of finished walls</td>
</tr>
</tbody>
</table>

In this stage, construction professionals in groups “A” and “B” have to teach the same activities to achieve 20 people skilled in the construction of structural parapets (see Table 11).

### Table 11 Activities of wall parapets

<table>
<thead>
<tr>
<th>Stage 5 Structural wall parapets made of 3D-LPs</th>
<th>Avenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>Provide a general introduction to the project and the construction stage</td>
</tr>
<tr>
<td>Day 2</td>
<td>Teach how to place structural 3D-LPs on the roof to build the parapet (this activity must be done before placing the concrete layer on the roof to give continuity to the structure)</td>
</tr>
<tr>
<td>Day 3</td>
<td>Teach how to connect the panels to each other with mesh made of galvanized steel and tie them with annealed wires or staples</td>
</tr>
<tr>
<td>Day 4</td>
<td>Teach how to cut the steel bars and to bend them to 90° and “U” shapes</td>
</tr>
<tr>
<td>Day 5</td>
<td>Teach how to connect the panels to each other with steel bars at the corners</td>
</tr>
<tr>
<td>Day 6</td>
<td>Teach how to place meshes internally and externally to connect the parapet to the roof slab</td>
</tr>
<tr>
<td></td>
<td>Teach how to spread the mortar layer on both sides in accordance with the manufacturer’s specifications</td>
</tr>
<tr>
<td>---</td>
<td>----------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>8</td>
<td>Teach how to do the curing</td>
</tr>
<tr>
<td>9</td>
<td>Teach how to give the appearance of finished walls</td>
</tr>
</tbody>
</table>

**Evaluation of the result obtained**

Construction professionals have to evaluate the skills and work achieved by the unskilled people after carrying out each stage, in order to make sure that each stage meets the building regulations and construction specifications of the manufacturers. At this stage the construction professionals have to evaluate the weaknesses of the training in order to amend it so that the training can easily multiply the labour numbers in the affected place, to involve as many people as possible in housing reconstruction on a large scale. The evaluation has to enable the continuity of the pyramidal training, so that there will be 100 skilled people to provide training to more affected people. In this phase construction professionals will have 20 persons able to carry out the construction of the five stages of the housing prototype (Figure 3).

Figure-3 Initial phase of the pyramidal training
Construction professionals therefore have to act as trainers and monitors by dividing again. Group “A” and one half of the newly skilled people can start the actual construction of the housing prototype with the technical support of the manufacturers, as was established in the guidelines for the provision of technical support to construction professionals by manufacturers. Group “B” and the other half of the newly skilled people can provide training to more unskilled people from the community affected (Figure 4). Thus by repeating the process several times, hundreds of people can be trained to build the housing prototype leading to housing recovery. Construction professionals have to make sure that all skilled people participate at least once in the actual construction of the housing prototype and once as facilitator (providing training).

![Figure 4 Results of the second training](image)

**Documentation of the training provided to unskilled people**

Construction professionals should prepare documentation of the training provided and deliver this to NGOs, in order to make the training provided transparent.