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Multi-criteria decision-making method for assessing the sustainability of post-disaster temporary housing units technologies: A case study in Bam, 2003

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ABSTRACT

Temporary housing units (THUs) have been used for displaced population (DP) in the aftermath of natural disasters to serve as an alternative residence while the permanent housing process is completed. A THU is often provided as a prefabricated system, which has been criticized due to the economic, environmental, and social aspects of THUs. However, this model has been widely used in previous recovery programs. Additionally, it should be highlighted that the lack of potential of certain areas persuades decision-makers to implement the THUs. This paper presents a new model for choosing optimized THUs based on the sustainability concept. This model supports decision-makers in selecting a more adequate type of THU, to reduce the negative impact of temporary housing (TH) when there is no other possibility.

The Integrated Value Model for Sustainable Assessment (MIVES), a Multi-Criteria Decision Making (MCDM) model that includes the value function concept, is used to evaluate the sustainability value of each THU alternative.

THU technologies that had been suggested for the Bam earthquake recovery program by a semi-public organization have been analysed by this method to achieve two aims: (1) to determine the most sustainable technology to use and (2) to test the designed model.

1. Introduction

According to Yonetani (2014), twenty-two million people worldwide lost their homes to natural disasters in 2013. Additionally, in 2050, the population of areas highly prone to natural disasters is expected to be double that of 2009 for the same area (Lall & Deichmann, 2009). Furthermore the urban population will reach 66% of the world population by 2050 (UN, 2014). Meanwhile, UN-Habitat (2014) reported that in developing countries, one-third of the urban population lives in slums that are highly vulnerable in terms of temporary housing (TH) provision (Johnson, Lizarralde, & Davidson, 2006).

DP need somewhere to live in secure and sanitary conditions, and to return to normal life as before the disaster while their permanent houses are reconstructed; this is called TH (Collins, Corsellis, & Vitale, 2010; Davis, 1978; United Nations Disaster Relief Organization (UNDRO), 1982). TH has generally been criticized due to the lack of sensibility towards an integrated view of sustainability, especially regarding the THUs.

THUs which need to be constructed after natural disasters are often categorized as a camp (United Nations High Commissioner for Refugees (UNHCR), 1999), grouped in planned camps (Corsellis & Vitale, 2005), organized in a top-down approach (Johnson, 2007a). According to Félix, Branco, and Feio (2013), THUs consist of (1) ready-made units and (2) supply kits. Although a THU is often conceived as a precast system (Johnson, 2009), on-site masonry construction was used in previous TH programs.

The problems of the THU as a commonly used type of TH can be: (1) delays, (2) lack of fit with the culture of the DP, (3) the need for large public expenditures, (4) consumption of resources and investment assigned to permanent buildings, (5) permanent building reconstruction delays, (6) discordant durability of used

Abbreviations: THU, temporary housing unit; 3D, 3D sandwich panels; DCv, decrease concavely; TH, temporary housing; Smax, maximum satisfaction; DCx, decrease convexly; DP, displaced population; Smin, minimum satisfaction; ICx, increase convexly; HFIR, Housing Foundation of Islamic Republic of Iran; *I*, sustainability index; IS, increase S-shape; AAC, autoclaved aerated concrete blocks; V_{R_k}, requirement value; IRR, Iranian Rial (Iranian currency); CMU, concrete masonry units; V_{C_k}, criterion value; pts, points; PR, pressed reeds; V_{I_k}, indicator value.

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Table 1
The use of THUs in previous TH programs.

Natural disaster	Method Prefabricated		References
	Kit approach	Ready-made	
Mexico-1985	X		Johnson, 2007b
Japan-1995	X	X	Johnson, 2007b; UNISDR, 2010
Turkey-1999	X	X	Arslan, 2007; Arslan & Cosgun, 2008; Johnson, 2007a, 2007b; Johnson et al., 2006
Iran-2003	X	X	Fayazi & Lizarralde, 2013; HFIR, 2013; Mahdi & Mahdi, 2013; Rafieian & Asgary, 2013
USA-2005	X	X	McIntosh, Gray, & Fraser, 2013; Sobel and Leeson, 2006; UNISDR, 2010
China-2008	X		UN, 2009
New Zealand-2011	X	X	Giovinazzi, Stevenson, Mason, & Mitchell, 2012; Siembieda, 2012
Turkey-2011	X	X	Erdik, Kamer, Demircioglu, & Sesetyan, 2012; IFRC, 2012
Japan-2011	X	X	EERI Special Earthquake Report, 2011; Murao, 2015; Shiozaki, Tanaka, Hokugo, & Bettencourt, 2012
Iran-2012	X		HFIR, 2012

materials and usage time, (7) site development process requirements, (8) site pollution, (9) infrastructure needs, (10) inflexibility, and (11) top-down approaches (Arslan, 2007; Arslan & Cosgun, 2008; Barakat, 2003; Chandler, 2007; El-Anwar, El-Rayes, & Elnashai, 2009a; Hadafi & Fallahi, 2010; Johnson et al., 2006; Johnson, 2007a).

In this sense, most significant research studies and guidelines acknowledge that THUs have discordant characteristics and have focused on solving the aforementioned issues. However, according to El-Anwar et al. (2009a) and Yi and Yang (2014), there are few studies that have considered THU optimization and sustainable construction such as: Johnson (2007a), El-Anwar et al. (2009a), El-Anwar, El-Rayes, and Elnashai (2009b, 2009c), El-Anwar (2010, 2013), Chen (2012), and Karatas and El-Rayes (2014). Meanwhile, the use of THUs has been widespread in previous TH, as shown in Table 1.

Despite the weakness of the THU, the use of this TH model illustrates why decision-makers have chosen this model for DP. The factors in THU choice can be: (1) immediacy, (2) high demand, (3) DP pressure on the government, (4) lack of other options, and (5) avoiding the mass exodus of DP (Hadafi & Fallahi, 2010; Quarantelli, 1995). Therefore, for the aforementioned reasons, sometimes there are no suitable TH alternatives (e.g., apartment rental) besides THUs. Although this type of building, with its short life span, has generally been criticized in terms of sustainability, it is possible to determine a more adequate alternative within this category.

The *objective* of this paper is to present a model for selecting the optimized THU by considering local characteristics and sustainability for regions using exclusively THUs, either because it is the only choice or because THUs are part of the region's TH program. The model is capable of identifying the optimized THU based on the satisfaction function of the involved stakeholders.

To that end, the Integrated Value Model for Sustainable Assessment (MIVES) from the Spain has been used in this paper. The MIVES model, which is a multi-criteria decision-making method which incorporates the concept of a value function (Alarcon, Aguado, Manga, & Josa, 2011), assesses the main sustainability requirements of different alternatives which answer the same housing requirements. MIVES can also be calibrated to a certain time period and applied for different areas with varied local living standards and characteristics by adapting the indicators and weights defined in the requirements tree. MIVES has been used to evaluate sustainability and to make decisions in the fields of (1) university professors (Viñolas, Aguado, Josa, Villegas, & Prada, 2009), (2) infrastructure (Ormazabal, Viñolas, & Aguado, 2008), (3) industrial buildings (Aguado, Caño, Cruz, Gómez, & Josa, 2012; del Caño & Gómez, 2012; de la Fuente, Armengou, Pons, & Aguado, 2015; Lombera & Rojo, 2010; Pons & Aguado, 2012; Pons & Fuente, 2013), and (4) TH.

As a case study, four technologies suggested for THUs after the Bam earthquake are assessed. This paper aims to reconsider these technologies to determine suitable options and to evaluate the sustainability of each technology. This study also assesses the THUs for a total usage period of 50 years: 5 years of temporary use and the rest as permanent use in the same location. This assumption has been made based on THUs of Bam, especially those which have been erected in private properties.

2. Methodology

The decision-making process proposed in this paper was organized in three choice phases: (1) initial, (2) middle, and (3) final choice, as shown in Fig. 1. In the *initial choice phase*, decision-makers consider the local potential based on TH features. In the *middle choice phase*, a requirements tree comprises criteria and indicators. The tree is designed with three varying levels (economic, environmental, and social) based on local characteristics (geographic and stakeholder requirements). In the *final choice phase*, a suitable decision-making model is used to determine sustainable THUs. Finally, the weights of the indexes have been determined by a group of experts using the Analytical Hierarchy Process (AHP) (Saaty, 1990).

Certain indexes, such as material availability, plan, storey, and second life of THUs can have considerable effects on the design tree and weights. Meanwhile, in this paper, only the second and third phases of the method have been applied in the case study to determine a suitable alternative, as shown in Fig. 1. Eight technologies had already been suggested by decision-makers as initial alternatives after the Bam earthquake, based on local potential.

3. Technologies suggested for constructing THUs in Bam

An earthquake that was estimated at Mw = 6.6 by the USGS (United States Geological Survey) (Kuwata, Takada, & Bastami, 2005) occurred on September 26th, 2003, in Bam, which is located in southeastern Iran, approximately 1000 km southeast of Tehran (Anafpour, 2008). The population of Bam was approximately 100,000 before the disaster (Ahmadizadeh & Shakib, 2004). In the aftermath of the earthquake, 80% of buildings were completely destroyed (Havaii & Hosseini, 2004), approximately 30% of Bam's population was killed (Kuwata et al., 2005), and approximately 75,000 people were left homeless (Khazai, Eeri, & Hausler, 2005).

In general, the Bam THU provision was based on two approaches: (1) THU provision in public camps and (2) THU provision on private properties. A total of 35,905 THUs were built: 26,900 units on private properties and 9005 in 23 camps (Ghafory-Ashtiany & Hosseini, 2008; Rafieian & Asgary, 2013). THUs that were provided at camp sites had considerable problems. Khatam (2006) states the TH cost reached $60 million, while 10–20% of THUs have never been occupied.

In April 2004, most of the DP received THUs with an area of 18–20 m^2 (Fallahi, 2007; Havaii & Hosseini, 2004) that were built