Multicriteria Decision-Making Method for Sustainable Site Location of Post-Disaster Temporary Housing in Urban Areas

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Abstract: Many people lose their homes around the world every year because of natural disasters, such as earthquakes, tsunamis, and hurricanes. In the aftermath of a natural disaster, the displaced people (DP) have to move to temporary housing (TH) and do not have the ability to choose the settlement dimensions, distributions, neighborhood, or other characteristics of their TH. Additionally, post-disaster settlement construction causes neighborhood changes, environmental degradation, and large-scale public expenditures. This paper presents a new model to support decision makers in choosing site locations for TH. The model is capable of determining the optimal site location based on the integration of economic, social, and environmental aspects into the whole life cycle of these houses. The integrated value model for sustainable assessment (MIVES), a multicriteria decision making (MCDM) model, is used to assess the sustainability of the aforementioned aspects, and MIVES includes the value function concept, which permits indicator homogenization by taking into account the satisfaction of the involved stakeholders. **DOI: 10.1061/(ASCE)CO.1943-7862.0001137.**

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Introduction

Over the last decade, 200 million people have been affected by natural disasters and hazards; 98% of these people lived in developing countries where climate change causes extreme temperatures, increased flooding, intense heat waves, and droughts (Aquilino 2011). Those who lost their homes to natural disasters needed somewhere to live while their houses were rebuilt or needed to find alternative accommodations (Collins et al. 2010; Davis 1982). The years between living in emergency accommodations and permanent houses present a time gap that needs to be bridged by temporary housing (TH) (Johnson et al. 2006). However, these temporary houses have, to date, been criticized for their inability to meet the expectations of displaced people (DP) (Chen 2012).

In general, according to most relevant studies (Arslan 2007; Chandler 2007; El-Anwar et al. 2009a, b; Félix et al. 2013; Johnson 2007a), TH programs have been criticized on several issues: (1) TH delivery time; (2) social and welfare quality; (3) TH locations; (4) cost of the TH implementation process; and (5) impact on the environment.

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Improper site selection is a major problem that has caused dissatisfaction with regard to the DP of previous natural disasters, such as Istanbul, Turkey, in 1999 (Johnson 2007b, c); Bam, Iran, in 2003 (Ghafory-Ashtiany and Hosseini 2008; Khazai and Hausler 2005); L'Aquila, Italy, in 2009 (Rossetto et al. 2014); and the Great Eastern Japan Earthquake in 2011 (Shiozaki et al. 2013). In general, according to most relevant studies, the site location factors that cause DP to be dissatisfied are: (1) losing previous social communities; (2) not fitting in new communities; (3) inadequate access to urban facilities, such as shopping centers, recreation centers, and so on; (4) large distance from the new location to previous activities (job, university, and previous private property); and (5) concern about private property. For instance, Khazai and Hausler (2005) declared that some of the Bam TH units remained vacant because of their site location.

Additionally, according to El-Anwar et al. (2009a) and Johnson (2002), finding a suitable TH location is the main reason for delaying the provision of TH. Furthermore, according to Johnson (2007a), the site location for TH can have a substantial impact on public expenditures. Johnson (2007a) stated that TH sites located on the outskirts of cities needed further development because of their distance to basic necessities, such as schools, clinics, and so on. Therefore, the site location of TH has considerable effects on the provision of TH as well as public expenditure, in addition to the aforementioned social impacts.

Numerous TH studies have considered the importance of selecting an appropriate location for a DP temporary settlement. Some have assessed site selection exclusively, covering topics such as guidelines for shelter location (UNHCR 2000), site selection indicators (Corsellis and Vitale 2005; Davis and Lambert 2002; Soltani et al. 2014), strategies of site selection (Kelly 2010), selection of fixed seismic shelters by the technique for order preference by similarity to ideal solution (TOPSIS) (Chua and Su 2012), urban shelter locations based on covering models (Wei et al. 2012), hierarchical location models for earthquake-shelter planning (Chen et al. 2013), site selection and decision-making methods

(Omidvar et al. 2013), and optimizing TH assignments to minimize displacement distance (El-Anwar and Chen 2012).

All of these research studies have contributed to the development of TH, but only a few have considered TH optimization (El-Anwar et al. 2009b) and sustainable construction (El-Anwar et al. 2009c). The number of studies in which urban areas have been considered is also small compared to those dealing with rural areas.

However, it is necessary to assess urban areas and to do so individually because of their own characteristics, such as concentration of population, homes and other buildings, transportation infrastructure, and industries (IFRC 2010).

Additionally, as different cities have various local living standards and characteristics, the weight of these model indicators, criteria, and requirements are different from one metropolitan area to another (Davis 1982; Johnson 2007a). Therefore, because site selection for TH is a process that involves various criteria (Kelly 2010; Omidvar et al. 2013) and different stakeholders, decision makers need help dealing with the selection of the most suitable options by considering multiple criteria with respect to the requirements and characteristics of all of the involved stakeholders.

The objective of this paper is to present a new model that is capable of selecting an optimized location for TH by assessing economic, social, cultural, and environmental aspects. To obtain the optimal satisfaction of the involved stakeholders, this model was designed to (1) maximize the well-being of DP, (2) minimize the negative impact on neighborhood life, (3) minimize TH public expenses, (4) minimize the negative impact on the environment, and (5) maximize the well-being of people involved in the TH construction process (e.g., engineers, workers). The site chosen in the present model specifically embraces the TH phase based on Quarantelli's definition of phases (Quarantelli 1995), even though the site can be used for the emergency shelter and temporary shelter phases as well. Additionally, the paper provides a method meant to choose and prepare TH locations during the normal situation (predisaster).

To this end, the integrated value model for sustainable assessment (MIVES), which consists of a multicriteria decision-making method that incorporates the concept of the value function (Alarcon et al. 2011), has been used. The MIVES model defined in this research project relies on seminars given by international multidisciplinary experts. MIVES has already been used to assess sustainability and to make decisions in the fields of (1) the Spanish Structural Concrete Code (Aguado et al. 2012); (2) sewerage concrete pipes (Viñolas et al. 2011); (3) school edifices (Pons and Aguado 2012); (4) probabilistic method (MIVES–EHEm–Monte Carlo) development for large and complex edifices (del Caño and Gómez 2012); (5) structural concrete columns (Pons and de la Fuente 2013); (6) wind-turbine supports (de la Fuente et al. 2015); and (7) TH (Hosseini et al. 2016).

This new model has been applied to find the best site location for TH in the case of a probabilistic earthquake of Mosha's fault in Tehran, Iran. This case is based on reports from the Japan International Cooperation Agency (JICA), which has assisted the Iranian government in providing a disaster management master plan for Tehran since 1999 (JICA 2000).

Methodology

A holistic approach was used in this paper to present a TH process that used site selection as one of the significant components of TH implementation. This methodology has four phases: (1) data collection; (2) data analysis; (3) model design; and (4) model application, as shown in Fig. 1. In the *data collection phase*, the

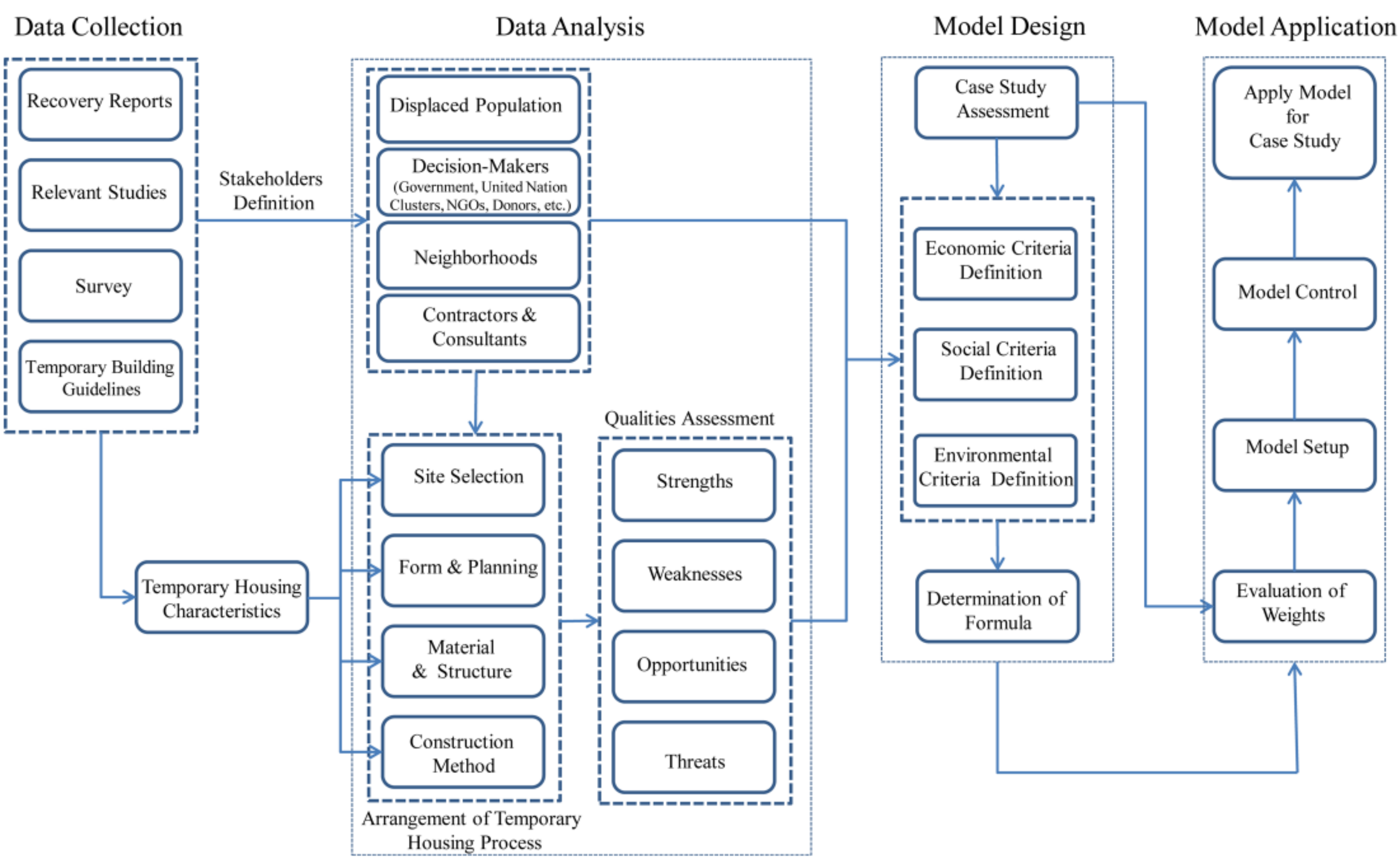

Fig. 1. Methodology for considering the whole TH process and the sustainability assessment method based on MIVES

necessary information on TH is obtained through comprehensive literature reviews, recovery reports, surveys, and TH guidelines. In the *data analysis phase*, the stakeholders and characteristics of TH are defined. Then, the defined characteristics are assessed to distinguish the negative and positive points according to their strengths, weaknesses, opportunities, and threats mode (SWOT). In the *model design phase*, the requirements tree is based on the local characteristics of the case study and its demands.

As the objective of this paper includes site selection exclusively, the estimation of DP is considered to determine the demand area of the TH site, as shown in Fig. 2, before defining the requirements tree. The designed tree must contain minimum indicators, which are independent from each other and calculable in formula.

In the *model application phase*, the weights of the indices are evaluated by a group of multidisciplinary experts who use the analytical hierarchy process (AHP) (Saaty 1990) based on previous studies and local characteristics. Decision makers also define alternative sites that have the ability to be used as locations of post-disaster TH with regard to the determined requirements and the relative weights of these requirements. The decision maker can decide to have some small distributed sites in the city or a unique large site, which is usually located on the outskirts.

Because the data collection and analysis phases of site selection for TH have already been considered in the introduction of the paper, the following section defines the model design for site selection.

Sustainability Assessment of Post-Disaster Temporary Housing

According to MIVES, a specific tree, which is shown in Fig. 3, was developed to assess the sustainability of site selection for post-disaster TH based on data collected from extensive technical literature and seminars that have been given by multidisciplinary engineers who are expert in this subject.

The first level of the tree includes the economic, environmental, and social requirements; the second hierarchical level includes the five criteria; and the last level includes the nine indicators. Unlike

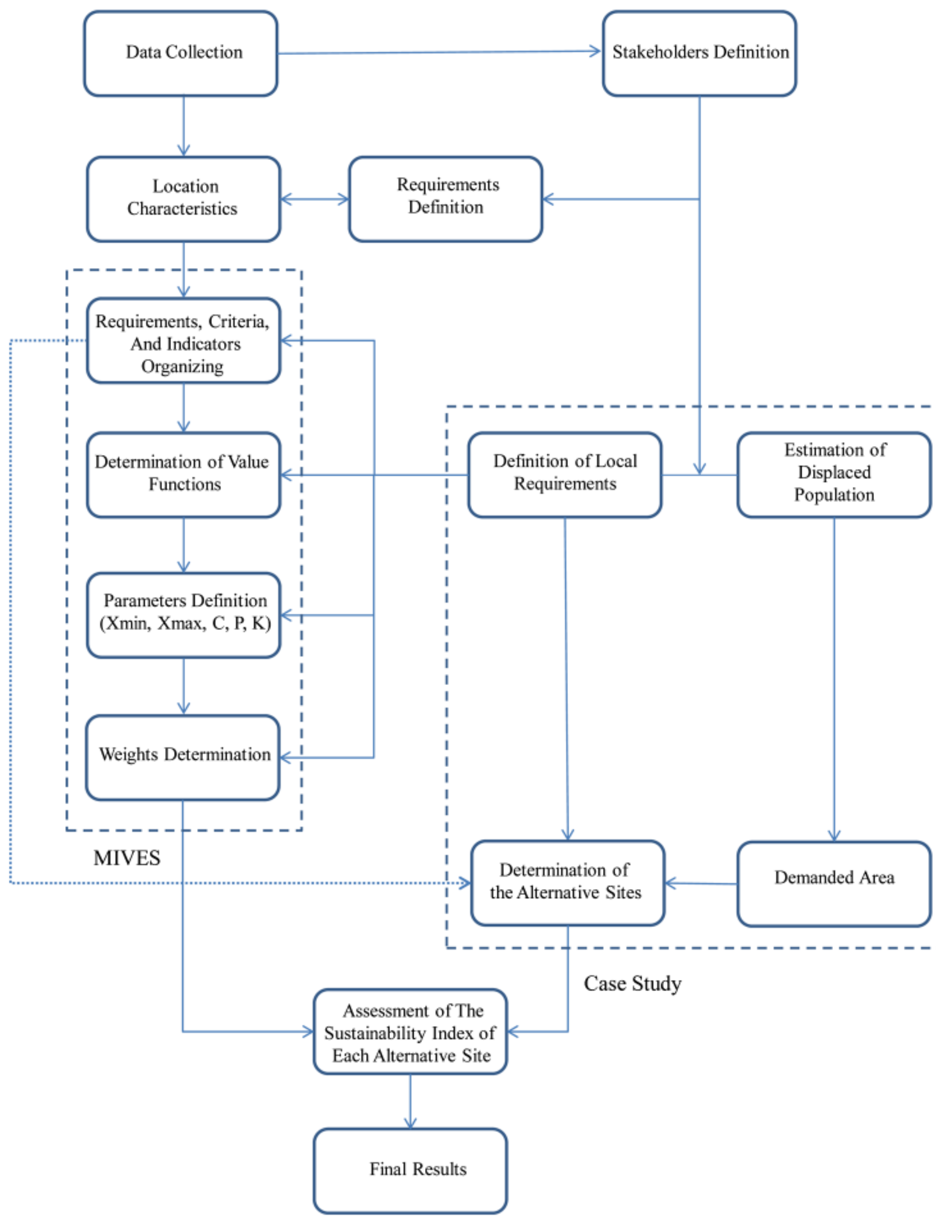

Fig. 2. Model implementation for site selection

the requirements and criteria, the indicators are measurable variables to quantify each alternative site.

The *economic requirement* (R_1) assesses the investment of each proposed site that could be a location for TH. The *social requirement* (R_2) takes the impact of each alternative site, in terms of the social aspects on DP as users of temporary houses and third parties who are involved in TH, into account. The *environmental requirement* (R_3) assesses the environmental effects of all of the processes related to the site location throughout all of the phases of the life cycle.

Definitions of Indicators

Land price indicator (I_1) evaluates the cost of land per square meter (cost/m^2). As already mentioned, it is possible to have sets of several sites whose total area is equal to or close to the required area.

Cost of site preparation (I_2) assesses the amount of expenditure during the site preparation process; I_2 locates the site that requires the minimum investment for preparation activities. Cost of site preparation is related to the following site characteristics: (1) slope, (2) topography, (3) type of soil, (4) type of plants, (5) level of groundwater, (6) access, (7) mobilization, and (8) utilities and utility vulnerability after a disaster. The experts have estimated the cost of site preparation for each alternative in cost/m^2.

Because the selected site may be located in a district where the urban facilities (water pipes, power cables, etc.) would be damaged by natural disasters, the δ factor prevents choosing a site in a district where the urban facilities will need to be repaired in the aftermath of a natural disaster. The δ factor presents the quality of the utilities after the disaster based on professional prediction. The system assigning points has been employed for this factor.

The *efficient use of investment* indicator ensures that the chosen alternative site(s) has an area equal to or close to the required area. This indicator has been eliminated because most alternative sites are owned by the government, one of the main investors; it is possible to use a portion of each site to avoid extra expenses.

The dimensions of the site are defined by the prediction of DP multiplied by the required area per person. Handbook for Emergencies (2000) suggests a figure of 30 m^2 per person, which includes the necessary area for roads, foot paths, educational facilities, and so on. Davis and Lambert (2002) stated that 45 m^2 per person is necessary for temporary settlements according to the sphere project. Aside from the number of DP, other factors, such as building design varying from flat houses to multilevel houses, average number of people in households, and local characteristics, impact the area of site location.

Access (I_3) considers the quality and time of access for DP, third parties, and emergency services from the beginning of the TH process to its end; I_3 takes into account the access for a period of time that contains the (1) construction phase, (2) operation phase in normal situations (predisaster), and (3) operation phase as a TH location (post-disaster).

During the construction phase, the access for people involved in construction (employees, workers, engineers, etc.) is assessed. During the operation phase in post-disaster periods, two issues are assessed: (1) the quality of DP access to other parts of the city, and (2) the quality and time of access for emergency services (medical, fire fighter, police, etc.) to the site. Because the access in the predisaster construction and operation phases is the same as the access for DP, only the accessibility for the operation phase during the post-disaster period is considered. Thus, I_3 takes into account the accessibility of DP and emergency services.

Therefore, the quality of access for DP is determined by using the following point assigning system for the access coefficient (α).

The access of emergency services takes into account two factors: (1) access time for emergency services in minutes; and (2) quality of emergency services, which embraces (a) the quantity and quality of equipment, and (b) the number of emergency services that cover the location of the TH with the same function that is considered by the coefficient β. This coefficient is measured by assigning points. Additionally, this paper assumes that the weights of emergency services are equal.

As the accessibility for emergency services is vitally more important than access for DP, the coefficient for the accessibility of emergency services is 70%, and the coefficient for the accessibility of DP is 30%. These coefficients can change according to each situation.

Population covering indicator (I_4) analyses alternatives to (1) maximize the coverage of DP, (2) distribute chosen sites throughout the city (decentralization of temporary sites), and (3) distribute facilities based on the distribution of the displaced population.

In other words, I_4 helps decision makers obtain two goals: (1) there is no region where the DP have problems because of area deficiency; and (2) no selected site remains empty or forces DP to move to another site that is far from the previous local zone of the DP. Thus, the population coverage is evaluated by Eq. (1)

$$PC_i = \sum_{1}^{m} \left(\frac{D_{a_i \to R_m}}{P_{R_m}} \right) \tag{1}$$

The *distance from the sources of danger indicator* (I_5) has been designed because the chosen site should be located far from the sources of dangers, such as secondary hazards that could risk the integrity of the DP.

In addition to the previous distance from the hazardous zone, the danger level of the source should be considered. Therefore, a system assigning points has been used to assess the danger level of the source that is defined with the γ-coefficient.

The *user safety criterion* (C_2) could also include an additional indicator, *preparation activities time*, which is vital for DP. However, this model does not consider the time of site preparation because the assumption of this paper is to choose and prepare locations of TH during the normal situation (predisaster).

Property and land use zoning indicator (I_6) considers site conditions in terms of land use, land property, and legal restrictions based on a comprehensive master plan. A system assigning points has also been used.

Neighborhood accessibility indicator (I_7) takes into account the impact of TH on the neighborhood environment. This paper has assessed the following items as subindicators: (1) density, (2) quality of medical care services, (3) green area, and (4) school capacity. Additionally, the weights of the previously mentioned subindicators are assumed to be equal.

Landscape respect indicator (I_8) takes into account the impact of TH on ecosystem changes, such as isolated district or access limitation, damage from sewage, excavation, acidification, and other negative influences. The system assigning points has also been employed for this indicator.

Building construction causes high energy consumption and CO_2 emissions during the life cycle stages of construction, usage, and demolition (Pons and Wadel 2011). Thus, indicators should be designed to assess the impact of the TH site on the environment in terms of CO_2 emissions and energy consumption based on the life cycle assessment (LCA). The environmental impacts of the site location embrace only the construction and demolition phases:

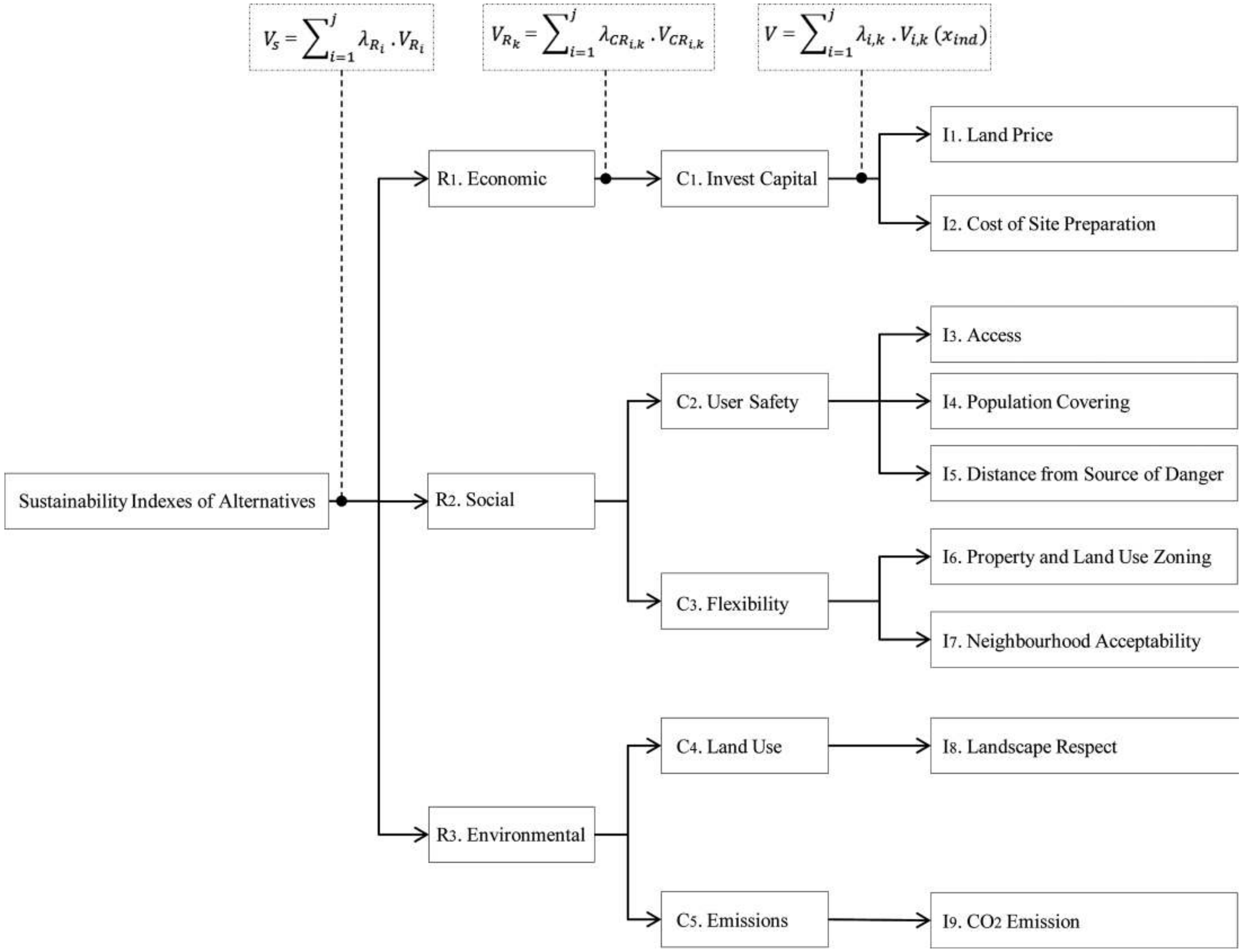

Fig. 3. Requirements tree designed for this model

(1) construction phase, considering only transportation and site preparation activities; and (2) demolition phase, considering only transportation.

Therefore, CO_2 *emission indicator* (I_9) was designed to measure the amount of CO_2 emissions according to two aspects: (1) preparation activities for each site during the construction phase, and (2) required transportation for each site during the construction and demolition phases.

Because the value of preparation activities has already been calculated for the economic requirement, according to the MIVES concept, this indicator should be independent, and the consequent amount of CO_2 emissions due to preparation activities is not considered. Therefore, only the CO_2 emissions from transportation for each alternative are assessed by using the formulas proposed in the 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories destructive gas emissions and energy consumption (Houghton et al. 1996).

The values of the model parameters suggested by *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (Houghton et al. 1996) are the same for all of the alternative sites, except for the activity parameter that includes the fuel consumed or distance traveled. Thus, the amount of CO_2 emissions from transportation depends on the activity parameter. Consequently, I_9 calculates the total distance traveled for each alternative site, which includes the distances from the material resources center and the landfill site to the alternative site.

Other polluting emissions and energy consumption have values proportional to the indicator CO_2 emissions (Pons and Aguado 2012) for each of the studied alternatives. Thus, instead of assessing all polluting emissions and energy consumption, only the CO_2 emissions are assessed. Additionally, TH water consumption is not considered because it is negligible during most phases, such as construction and demolition.

Application Example

An application example illustrates all of the phases of the sustainability decision-making model to choose an adequate site location for post-disaster TH in Tehran based on the Mosha fault scenario. The example includes four of the 22 Tehran districts. The population of these districts is almost 1,200,000, as shown in Table 1. The assessed scenario is based on reports from the Japan International Cooperation Agency (JICA) (JICA 2000). This agency, together with the Center for Earthquake and Environmental Studies of Tehran (CEST), assessed potential earthquakes in Tehran in 2000 (Omidvar et al. 2013). This study evaluated damaged buildings and casualties in the aftermath of probabilistic earthquakes based on four different scenarios: the Rey fault model, the north of Tehran

Table 1. Relevant Information of the Case Study Districts

Properties	Case study districts				Other districts (where the alternative sites have been located)				References
	District 2	District 3	District 6	District 7	District 1	District 4	District 5	District 22	
Area (km^2)	48.2	29.4	21.5	15.4	64	61.4	54.5	61.1	Implementation of the 2011 Iranian Population and Housing Census (2011); Iran: Tehran City (2014), JICA (2000), and Zayyari et al. (2012)
Census 1996 population	458,089	259,019	220,331	300,212	249,676	663,166	427,995	56,020	Implementation of the 2011 Iranian Population and Housing Census (2011) and JICA (2000)
Census 2011 population	632,917	314,112	229,980	309,745	439,467	861,280	793,750	128,985	
Green area (km^2)	6.8	3.9	2.8	0.8	3.8	7.7	7.6	1.8	Atlas of Teheran Metropolis (2014), Implementation of the 2011 Iranian Population and Housing Census (2011), JICA (2000), Mohammadzade Asl et al. (2010), and Zayyari et al. (2012)
Medical service	418	368	577	254	232	277	328	36	Implementation of the 2011 Iranian Population and Housing Census (2011) and JICA (2000)
Police station	35	39	78	52	75	67	5	41	JICA (2000) and Mohammadzade Asl et al. (2010)
Fire station	4	4	2	2	2	5	5	2	Alavi et al. (2013), JICA (2000), and Mohammadzade Asl et al. (2010)
Educational centre	735	586	795	431	572	627	586	63	Mohammadzade Asl et al. (2010),
Urban development level (%)	77.94	89.96	9.91	72.48	100	59.79	51.49	52.56	Atlas of Teheran Metropolis (2014), and Mohammadzade Asl et al. (2010)
Damaged building proportion (%)	11.1	16.4	12.7	12.8	17.9	13.8	8.6	6.8	JICA (2000)
Causalities proportion (%)	0.1	0.2	0.2	0.2	0.3	0.2	0.00	0.00	JICA (2000)

fault model, the Mosha fault model, and the floating model (Omidvar et al. 2013). This paper considers a model for choosing an adequate site location for post-disaster TH in Tehran based on the JICA and CEST results for the Mosha fault model.

According to the JICA and CEST study (JICA 2000), if a probabilistic earthquake occurs during the day, it will cause almost 18,000 casualties, more than 610,000 DP, and 90,000 damaged residential buildings in total. The statistics for damaged buildings evaluated only residential buildings as blocks without considering the number of total residential units in one block. The estimated displaced populations of the four districts considered add up to approximately 160,000 people. Because it is assumed that one-third of the DP will be settled in multilevel houses in the camp, the total area demanded is nearly 1 km^2 (100 ha), corresponding to 20 square meters per person. According to UNHCR (2000) and the sphere project, the area demanded in the camp ranges between 30 and 45 m^2/person. However, based on the assumptions of this paper and the land scarcity in Tehran, two-story and three-story TH units have been designed. Thus, a demanded area of almost 20 m^2/person has generally been obtained.

Based on the required area [1 km^2 (100 ha)] for this case, alternative sites with the required initial features have been selected. There are six alternatives, which include 23 sites in or around the zones of this application example. There are four individual sites and two sets. The areas of these four alternative sites ($A_1 - A_4$) are approximately equal to or larger than the area demanded. The last two alternative sets include divisions: Set B includes five sites ($B_1 - B_5$) with a total area of 100 ha, and Set C includes seventeen sites ($C_1 - C_{14}$, B_2, B_4, and B_5), including three sites of Set C in common with Set B, as shown in Fig. 4. All of these sites are open spaces that need site preparation, except for C_{12} (parking lot) and C_{14} (barracks). Eighteen sites are located in the four chosen districts, and five sites (A_1, A_2, A_4, B_4, and B_5) are located outside of these four districts. Sites A_1 and A_2 are located outside the city center, close to entry roads.

Analysis

By determining a value function for each indicator according to the MIVES equations, it is possible to quantify each attribute. According to Alarcon et al. (2011), for the determination of the satisfaction value for an indicator, there are four stages: (1) determine the tendency (increasing or decreasing) of the value function, (2) determine the points to find $S_{\min}$ and $S_{\max}$, (3) determine the shape of the value function (linear, concave, convex, S-shaped), and (4) determine the mathematical expression of the value function.

According to Alarcon et al. (2011), when satisfaction increases rapidly or decreases slightly, a *concave-shaped* function is the most suitable. The *convex* function is used when the satisfaction tendency is contrary to the concave curve case. If satisfaction increases/decreases steadily, a *linear* function is presented. An *S-shaped* function is used when the satisfaction tendency contains a combination of concave and convex functions, as shown in Fig. 5. There is complete information about the MIVES methodology in previous studies, such as Alarcon et al. (2011), Aguado et al. (2012), and Cuadrado et al. (2015).

The value function implemented in MIVES is based upon the general exponential Eq. (2). This function permits the simulation of a wide range of responses by properly modifying the constitutive parameters (Pons and de la Fuente 2013)

$$V_i = A + B \cdot [1 - e^{-k_i \cdot (|X_{\text{ind}} - X_{\min}|/C_i)^{P_i}}] \tag{2}$$

This last equation permits the generation of sets of indicator values $[V_i(x_i)]$ that are between 0 and 1, according to the satisfaction range

$$B = [1 - e^{k_i \cdot (|X_{\max} - X_{\min}|/C_i)^{P_i}}]^{-1} \tag{3}$$

Because the related value function for each indicator has been matched, this method proceeds with the assessment of the sustainability index for each alternative site. Having previously determined each indicator value (V_i) and weight (λ_i), the formula that is presented in Eq. (4) should be applied to each tree level. $[V_i(x_i)]$ is a value function that presents the preferences that are assigned by the decision makers to each value obtained by parameter (x_i). For the multicriteria case, the additive formula corresponding to Eq. (4) is introduced

$$V = \sum \lambda_i \cdot V_i(x_i) \tag{4}$$

The values of $X_{\min}$ and $X_{\max}$, and the function shapes have been derived from international guidelines, the scientific literature, Iranian principles, and the background of experts who participated in seminars, as shown in Table 2. These functions have the following shapes: four decrease, of which two decrease in a concave fashion

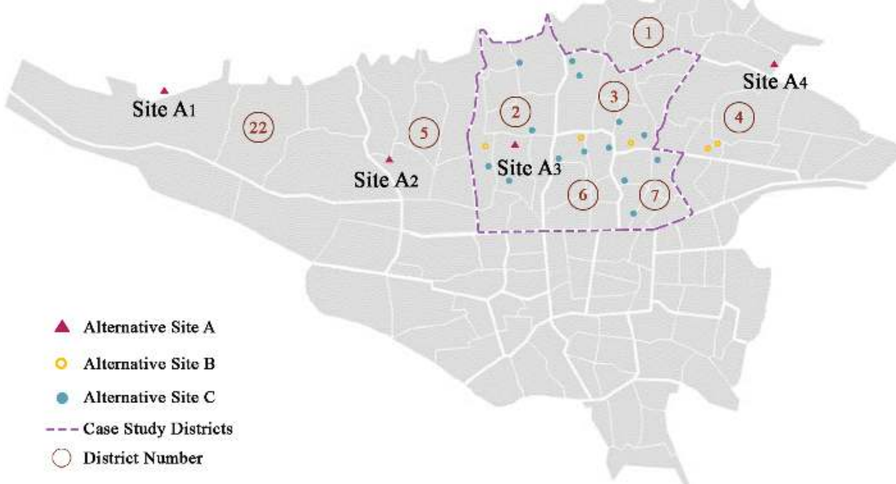

Fig. 4. Tehran map (including the case study districts and alternative sites)

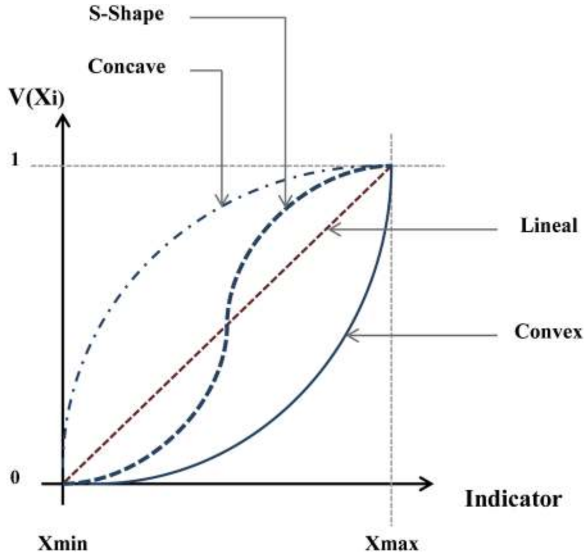

Fig. 5. Value function types

(DCv) and two decrease in a convex fashion (DCx); and five increase, of which three are S-shaped (IS) and two increase in a convex fashion (ICx). The values of X_{min} and X_{max} are defined for each indicator, as shown in Table 2.

Like I_5, S-shaped functions have a minimum satisfaction that drops to zero for values that are smaller than a defined lower indicator value, a maximum satisfaction that reaches 1 for values greater than a defined upper indicator value, and an increasing satisfaction from almost 0 to 1 for values between the defined lower and upper indicator values. Concave functions represent indicators in which the maximum value (such as population covering, I_4) is demanded (Alarcon et al. 2011). The convex I_1 function aims to promote the reduction of land price. The minimum X_{min} is the lowest land price per each square meter in Tehran's regions [2.4×10^7 Iran Rial rates (IRR)]. Additionally, satisfaction decreases rapidly when the building cost increases; a decreasing convex (DCx) curve is assigned for the tendency of this indicator value function, as shown in Fig. 6.

Four indicators (I_3, I_6, I_7, and I_8) have been measured by points. The maximum X_{max} has a maximum value of 1, corresponding to the geometric mean value of the subindicators for each indicator for I_3 and I_7. These subindicators have five parameters that are similar to the indicators shown in Table 3. Finally, by defining a value function according to Eq. (2) for each indicator, it is possible to assess each attribute.

Weight Assignment

In this step, the weights of the requirements, criteria, and indicators are assigned by using the analytical hierarchy process (AHP) based on previous studies, local characteristics, and the knowledge of the experts involved in seminars. Several individual meetings and seminars were organized and held by professors of the Universitat Politècnica de Catalunya, Universitat Internacional de Catalunya, and the experts of the Tehran Disaster Mitigation and Management Organization to determine the weights (λ_i). Regarding the weight distribution obtained for each of the elements constituting the requirements tree (Table 4), it should be emphasized that the coefficients of variation (CVs) of each λ_i did not exceed 10%, except the outliers that were initially rejected. Thus, the mean values of λ_i were used throughout the sustainability analysis

Table 2. Parameters and Coefficients for Each Indicator Value Function

Indicator	Unit	X_{max}	X_{min}	C	K	P	Shape	References
I_1	IRR/m^2	1.2×10^8	2.4×10^7	1.2×10^7	0.001	2	DCx	JICA (2000) and Prices of Housing Market in Tehran (2010)
I_2	IRR/m^2	40,000	0	3.2×10^4	0.2	2.5	DCx	Pricing Schedule of Buildings in Iran (2012)
I_3	pts.	1	0	0.35	0.2	3	IS	Alavi et al. (2013), Atlas of Teheran Metropolis (2014), It's About Time: Why emergency response times matter to firefighters and the public (2010)
I_4	m/pop	3.00	0.3	0.3	0.3	0.9	DCv	Amiri et al. (2013), JICA (2000), and Mohammadzade Asl et al. (2010)
I_5	m	2,000	0	750	0.2	4.5	IS	Chua and Su (2012), and Nojavan and Omidvar (2013)
I_6	pts.	1	0	1.5	1	5	ICx	JICA (2000)
I_7	pts.	1	0	0.3	0.2	3	IS	JICA (2000) and Mohammadzade Asl et al. (2010)
I_8	pts.	1	0	1.2	1	3.5	ICx	JICA (2000) and Zayyari et al. (2012)
I_9	km	27	0	15	2	0.9	DCv	JICA (2000)

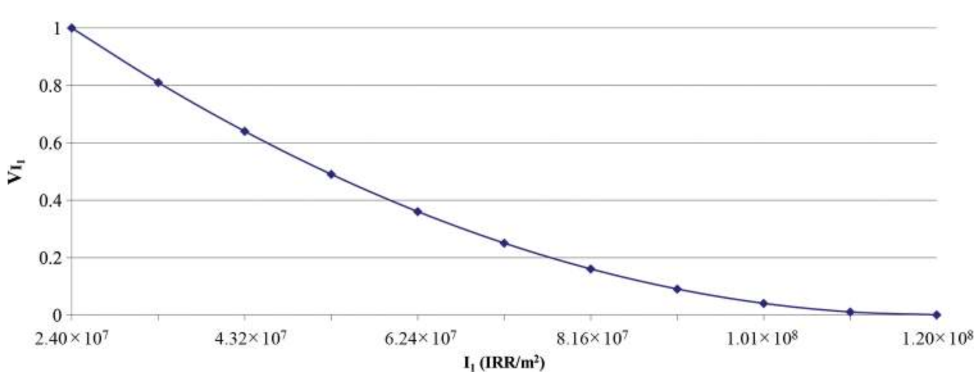

Fig. 6. Value function of the land price indicator (I_1)

Table 3. Parameters and Coefficients for Each Sub-Indicator Value Function

I_x	Sub-indicator	Unit	X_{max}	X_{min}	C	K	P	Shape	References
I_3	Access of DP	Pts	1	0	0.3	0.2	3	IS	Atlas of Teheran Metropolis (2014)
	Access to emergency services	min	20	4	9.2	0.8	3.4	DS	Alavi et al. (2013), It's About Time: Why Emergency Response Times Matter to Firefighters and the Public (2010), and Lee (2012)
I_7	Density	pers./Ha	349	9	360	0.05	2.5	DCx	Atlas of Teheran Metropolis (2014), JICA (2000), and Mohammadzade Asl et al. (2010)
	Hospital	pop./N Hosp.	180,000	50,000	220,000	0.5	4	DCx	Atlas of Teheran Metropolis (2014), JICA (2000), and Mohammadzade Asl et al. (2010)
	School	pop./N Sch.	2,100	200	2,150	0.05	3	DCx	Atlas of Teheran Metropolis (2014), JICA (2000), and Mohammadzade Asl et al. (2010)
	Green area	m^2/pop	20	2	13	0.15	6	ICx	Atlas of Teheran Metropolis (2014), JICA (2000), Mohammadzade Asl et al. (2010), and zayyari et al. (2012)
	Police	pop./N P.S.	14,000	1,300	15,000	1	3	DCx	Atlas of Teheran Metropolis (2014), JICA (2000), and Mohammadzade Asl et al. (2010)
	Fire station	pop./N F.S.	300,000	10,000	400,000	1	3	DCx	Atlas of Teheran Metropolis (2014), It's About Time: Why Emergency Response Times Matter to Firefighters and the Public (2010), Alavi et al. (2013), and Structure Fire Response Times (2006)

Table 4. Requirements Tree with Weight Assignments

Requirements	Criteria	Indicators
R_1. Economic (45%)	C_1. Invest capital (100%)	I_1. Land price (75%)
		I_2. Cost of site preparation (25%)
R_2. Social (25%)	C_2. User safety (80%)	I_3. Access (30%)
		I_4. Population covering (20%)
		I_5. Distance from source of danger (50%)
	C_3. Flexibility (20%)	I_6. Property and land use zoning (60%)
		I_7. Neighbourhood acceptability (40%)
R_3. Environmental (30%)	C_4. Land use (25%)	I_8. Landscape respect (100%)
	C_5. Emissions (75%)	I_9. CO_2 emission (100%)

[del Caño and Gómez (2012) for an uncertainty treatment approach]. Additionally, the alternative approach used herein to address the assessment of the weights is presented in the results and discussion section. This approach does not depend on the priorities of the experts. The assigned weights are based on choosing a site during a predisaster normal situation. These weights should be considered when this model is applied after the disaster.

Finally, by having each index value function (V_{x_k}) and its weight (λ_k), which have previously been explained, Eq. (4) can be applied for each level of the tree. Fig. 3 shows the mentioned process to obtain the sustainability index.

Results and Discussion

The results from this evaluation are the sustainability index (I), requirement values (V_{R_k}), criteria values (V_{C_k}), and indicator values (V_{I_k}) for each alternative, as shown in Table 5. The maximum sustainability index score I of the site location for TH is 0.61. Additionally, there are indicators and criteria that only change because of the site characteristics, irrespective of the site location, such as I_5, I_6, and I_8. For instance, I_6 is only related to land use and ownership.

Some indicators are influenced by the site location, such as I_2, I_3, I_4, I_7, and I_9. The sites that are located near the city center obtain high satisfaction values in accessibility (I_3) and population cover (I_4). The sites that are located on the outskirts of the city have an adequate density and green area, are usually close to resources and main roads, and usually have lower land prices. Thus, these sites have higher satisfaction values for the following indicators: land price (I_1), neighborhood acceptability (I_7), and emissions (I_9). Additionally, alternatives that consist of some sets, such as B and C, obtain maximum satisfaction according to access (I_3) and population cover (I_4) and minimum satisfaction from the cost of site preparation (I_2).

In general, Sets B and C have minimum values for economic requirements, and these sets and A_2 have high values for social requirements. Alternatives A_1 and A_4, which are located out of town, have maximum values for the environmental requirement.

Table 5. Sustainability Index (I), Requirements (V_{R_k}), Criteria (V_{C_k}), and Indicators (V_{I_k}) Values for the Six Alternative Sites

Alternative	I	V_{R1}	V_{R2}	V_{R3}	V_{C1}	V_{C2}	V_{C3}	V_{C4}	V_{C5}	V_{I1}	V_{I2}	V_{I3}	V_{I4}	V_{I5}	V_{I6}	V_{I7}	V_{I8}	V_{I9}
A_1	0.61	0.59	0.50	0.73	0.59	0.37	1.00	0.50	0.80	0.56	0.68	0.78	0.60	0.03	1.00	1.00	0.50	0.80
A_2	0.55	0.47	0.92	0.35	0.47	0.92	0.91	0.50	0.30	0.46	0.52	0.82	0.88	1.00	1.00	0.79	0.50	0.30
$\mathbf{A_3}$	0.37	0.18	0.46	0.58	0.18	0.41	0.68	0.50	0.61	0.02	0.67	0.59	0.98	0.07	1.00	0.19	0.50	0.61
A_4	0.52	0.28	0.49	0.91	0.28	0.41	0.82	0.75	0.96	0.13	0.72	0.72	0.88	0.03	1.00	0.54	0.75	0.96
B	0.43	0.13	0.78	0.60	0.13	0.79	0.75	0.58	0.61	0.05	0.36	0.99	0.98	0.59	1.00	0.36	0.58	0.61
C	0.47	0.09	0.93	0.65	0.09	0.99	0.72	0.73	0.62	0.11	0.02	0.98	0.98	0.99	1.00	0.31	0.73	0.62

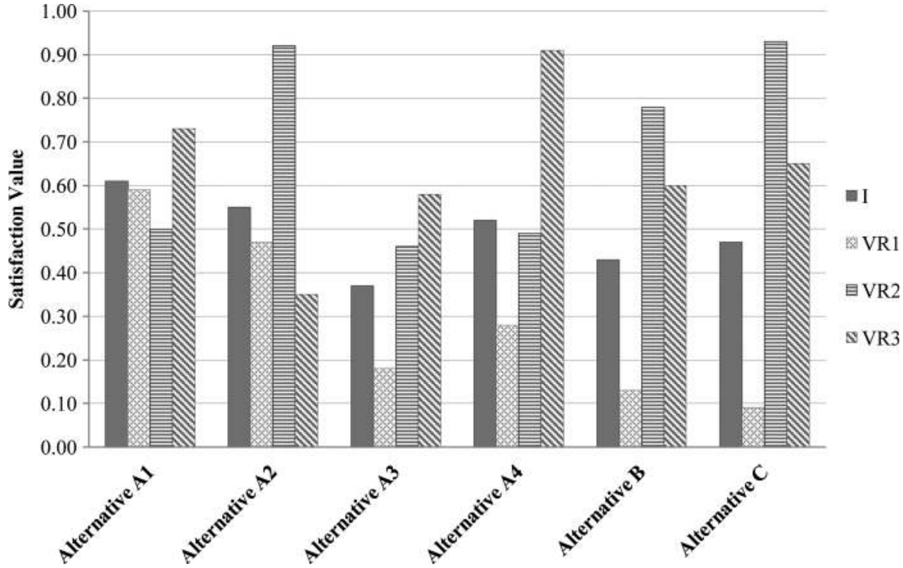

Fig. 7. Sustainability index (I) and requirement values (V_i) for the six alternatives

Alternative A_1 has the maximum value for economic requirements. A_1 is the most sustainable alternative site for post-disaster TH among the alternatives assessed, as shown in Table 5 and Fig. 7.

Moreover, the sites that have been provided for other functions and have facilities, such as C_{12} (parking lot) and C_{14} (barracks), obtain high sustainability values. Moreover, the sites that are located on the outskirts of the city obtained high environmental index values because they are close to resources and main roads; there are no landscape vulnerabilities greater than the other alternatives.

Sixteen different scenarios have been considered to determine the sustainability index trends for the alternatives when the requirement ratios were different, as shown in Fig. 8. The highlighted point on the horizontal axis (economic 45%, social 25%, and environmental 30%) shows the sustainability indexes of technologies based on suitable weights chosen by the experts. If the environmental weight increases compared to the social weight, such as the first point on the horizontal axis in Fig. 8 (economic 47%, social 18%, and environmental 35%), A_1 becomes a more sustainable alternative. If the economic weight increases, such as the fifth point on the horizontal axis in Fig. 8 (economic 50%, social 25%, and environmental 25%), A_1 becomes a more sustainable alternative again. If the social requirement weight increases, A_2, C, and A_1 will be suitable alternatives, although the economic and environmental requirement weights can qualify A_1 as a final result. Therefore, if the quality of life of DP was the first priority for decision makers, A_2 and C could be suitable alternatives. However, A_1 has a high sustainability value that is based on suitable weights chosen in the seminars and the economic requirement to a greater degree than the other alternatives. Additionally, the trend of the A_1 sustainability index did not change drastically when considering different requirement weights. A_3, A_4, and B obtain lower sustainability values compared to the other alternatives under all of the conditions assessed.

In the end, the results obtained by the MIVES method have been compared with several techniques to consider the validation of the model results. To this end, the technique for order preference by similarity to ideal solution (TOPSIS) (Hwang and Yoon 1981), elimination et choix traduisant la realité/elimination and choice expressing reality (ELECTRE) (Roy 1968), and simple additive

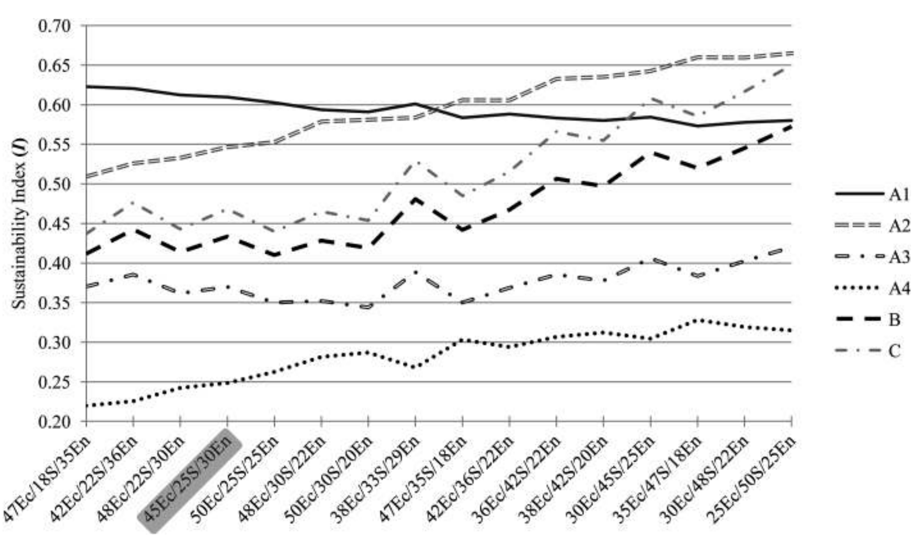

Fig. 8. Sustainability indexes of the six alternatives with different requirement weights [economic (Ec), social (S), and environmental (En)]

Table 6. Ranking of Alternatives Based on the Methods

Ranking	MIVES (AHP)	MIVES (SE/NW)	TOPSIS (SE/NW)	TOPSIS (SE/W)	ELECTRE (SE/NW)	ELECTRE (SE/W)	SAW (SE/NW)	SAW (SE/W)	Total result
	Method								
1	A_1	A_2	A_2	A_1	A_1	A_1	A_1	A_1	A_1
2	A_2	A_1	A_1	C	A_2	A_2	A_4	A_4	A_2
3	A_4	A_4	A_4	A_2	A_4	A_4	A_2	A_2	A_4
4	C	C	A_3	A_4	C	C	C	C	C
5	B	B	B	A_3	B	B	B	B	B
6	A_3	A_3	C	B	A_3	A_3	A_3	A_3	A_3

weighting (SAW) have been used. Additionally, Shannon's entropy (SE) has been applied to evaluate the weights of the indicators. The weights of the indicators have been obtained by Shannon's entropy based on two approaches: (1) with regard to the weights assigned to the indicators based on expert judgment (SE/W) and (2) without regard to the weights assigned to the indicators (SE/NW). Therefore, six models, including three techniques (TOPSIS, ELECTRE, and SAW) with two weight assignment techniques (SE/NW and SE/W), have been considered. Additionally, the MIVES method has been considered according to the weights of the indicators, which were obtained by Shannon's entropy without consideration of the indicator priorities (SE/NW), except the suitable weights chosen by the experts.

Table 6 presents the ranking of the alternatives obtained from the various methods. Obviously, different methods provide diverse results, although the results are almost the same for the ranking of four alternatives. Sites A_1, A_3, B, and C are ranked as the first, sixth, fifth, and fourth alternatives, respectively, based on the results of at least six techniques among eight. Although the four alternatives have been presented in the second rank by the methods, A_2 has been selected more than the other alternatives. Additionally, A_4 has been chosen more than A_2 for the third rank by the methods. Therefore, the results provided by the proposed techniques qualify the model presented by this paper. However, the differences between MIVES and the results of the other methods are understandable because this model incorporates the concept of the value function, which is necessary for TH consideration.

Conclusions

In this research paper, a new sustainability assessment model, which has been specifically configured to analyze alternative sites for temporary post-disaster settlements in urban areas, has been presented. For the application example, a total of six different alternatives for temporary housing have been assessed, which include 23 different sites in Tehran. This model takes into account the following aspects: maximizing the well-being of the DP, minimizing the negative impacts on neighborhood life, minimizing the public expenditures on TH, minimizing the negative environmental impacts, and maximizing the well-being of the people involved in the TH process. The following conclusions can be derived from this research:

- This study defines an assessment model based on the MIVES methodology, which has been demonstrated to be a suitable strategy to conduct multicriteria decision processes for an integral sustainability analysis of each alternative.
- This model is capable of comparing alternatives without being limited by present conjuncture. As a consequence, this tool is capable of adapting its parameters (cost, methods, access, etc.), which change from one period of time to another. Additionally, this model has the ability to be used for distinct cities by reconsidering the requirement tree weights.
- During the site selection process, this model assists decision makers in observing and comparing the index values of all alternatives. Sometimes, decision makers choose alternatives that have weaknesses caused by limitations; based on the aforementioned feature of this model, decision makers can detect the weak parts of a specific site and then overcome these weaknesses with proper actions.
- Diffuse sites located in different districts have the best social index value. Indeed, these sites can give higher satisfaction to DP, involving labor and neighbors. However, these sites have lower economic and environmental index values. Moreover, these disperse sets can cause increased transportation and individual mobilization, and they are usually located at greater distances from resources. Consequently, they cause increases in expenses and environmental damages.
- Sites that had other functions prior to selection and already had facilities have higher sustainability indices.

The model and the requirements tree proposed in this study are generic for any site location of post-disaster TH. However, some indicators and weights should be adjusted according to the specific analysis of site selection for other public functions, such as public facilities, educational services, health services, and so on.

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Notation

The following symbols are used in this paper:

A = response value of $X_{\min}$ (indicator abscissa), generally $A = 0$;
B = factor that prevents the function from leaving the range (0.00, 1.00);
C_k = criterion k;
$D_{a_i \rightarrow R_m}$ = distance from the gravity center of the alternative site i to the gravity center of the region m;
DCv = decrease concavely;
DCx = decrease convexly;
DS = decrease S-shape;

Ec = economic;
En = environmental;
I = sustainability index;
ICx = increase convexly;
I_k = indicator k;
IS = increase S-shape;
K_i = factor that defines the response value to C_i;
m = number of assessed regions;
min = minute(s);
N F.S. = number of fire station(s);
N Hosp. = number of hospital(s);
N P.S. = number of police station(s);
N Sch. = number of school(s);
NW = without considering the weights assigned to the indicators;
PC_i = population covering parameter for alternative site i;
P_i = shape factor that determines whether the curve is concave or convex or whether is linear or S-shaped;
P_{R_m} = predicted displaced population in the region m;
pts. = points;
R_k = requirement k;
S = social;
SE = Shannon's entropy;
$S_{\max}$ = maximum satisfaction;
$S_{\min}$ = minimum satisfaction;
V = value;
X_{ind} = considered indicator abscissa that generates a value V_i;
$X_{\max}$ = maximum value indicator;
$X_{\min}$ = minimum value indicator;
W = considering the weights assigned to the indicators; and
λ_i = weight of the indicator or criterion considered.

References

Aguado, A., Caño, A. D., Cruz, M. P., Gómez, D., and Josa, A. (2012). "Sustainability assessment of concrete structures within the Spanish structural concrete code." *Constr. Eng. Manage.*, 138(2), 268–276.

Alarcon, B., Aguado, A., Manga, R., and Josa, A. (2011). "A value function for assessing sustainability: Application to industrial buildings." *Sustainability*, 3(1), 35–50.

Alavi, A., Salarvand, E., Ahmadabadi, A., Sis, S. F., and Bosshaq, M. R. (2013). "Spatial analysis of fire stations based on crisis management by the combination of MCDM and network analysis case study: Tehran, district 6." *Disaster Manage.*, 1(2), 57–65.

Amiri, G. G., Khoshnevis, N., and Amrei, S. R. (2013). "Probabilistic assessment of earthquake damage and loss for the city of Tehran, Iran." *J. Rehabil. Civ. Eng.*, 1(2), 12–25.

Aquilino, M. J. (2011). *Beyond shelter architecture for crisis*, Thames and Hudson, London.

Arslan, H. (2007). "Re-design, re-use and recycle of temporary houses." *Build. Environ.*, 42(1), 400–406.

Atlas of Teheran Metropolis. (2014). ⟨http://atlas.tehran.ir/⟩ (May 12, 2014).

Chandler, P. J. (2007). "Environmental factors influencing the siting of temporary housing." Master thesis, Dept. of Environmental Studies, Louisiana State Univ., Baton Rouge, LA.

Chen, L. (2012). "A web-based system for optimizing post disaster temporary housing allocation." Master thesis, Dept. of Industrial Engineering, Univ. of Washington, Seattle.

Chen, Z., Chen, X., Li, Q., and Chen, J. (2013). "The temporal hierarchy of shelters: A hierarchical location model for earthquake-shelter planning." *Int. J. Geog. Inf. Sci.*, 27(8), 1612–1630.

Chua, J., and Su, Y. (2012). "The application of TOPSIS method in selecting fixed seismic shelter for evacuation in cities." *Syst. Eng. Procedia*, 3, 391–397.

Collins, S., Corsellis, T., and Vitale, A. (2010). "Transitional shelter: Understanding shelter from the emergency through reconstruction and beyond." ALNAP, ⟨http://www.alnap.org⟩ (Jan. 24, 2016).

Corsellis, T., and Vitale, A. (2005). *Transitional settlement displaced populations*, Univ. of Cambridge, Cambridge, U.K.

Cuadrado, J., Zubizarreta, M., Pelaz, B., and Marcos, I. (2015). "Methodology to assess the environmental sustainability of timber structures." *Constr. Build. Mater.*, 86(1), 149–158.

Davis, I. (1982). *Shelter after disaster*, Oxford Polytechnic Press, Oxford, U.K.

Davis, J., and Lambert, R. (2002). *Engineering in emergencies—A practical guide for relief workers*, 2nd Ed., ITDG, London.

de la Fuente, A., Armengou, J., Pons, O., and Aguado, A. (2015). "Multi-criteria decision-making model for assessing the sustainability index of wind-turbine support systems: Application to a new precast concrete alternative." *Civ. Eng. Manage.*, 1–10.

del Caño, A., and Gómez, D. (2012). "Uncertainty analysis in the sustainable design of concrete structures: A probabilistic method." *Constr. Build. Mater.*, 37, 865–873.

El-Anwar, O., and Chen, L. (2012). "Computing a displacement distance equivalent to optimize plans for postdisaster temporary housing projects." *J. Constr. Eng. Manage.*, 139(2), 174–184.

El-Anwar, O., El-Rayes, K., and Elnashai, A. (2009a). "An automated system for optimizing post-disaster temporary housing allocation." *Autom. Constr.*, 18(7), 983–993.

El-Anwar, O., El-Rayes, K., and Elnashai, A. (2009b). "Optimizing large-scale temporary housing arrangements after natural disasters." *Comput. Civ. Eng.*, 23(2), 110–118.

El-Anwar, O., El-Rayes, K., and Elnashai, A. S. (2009c). "Maximizing the sustainability of integrated housing recovery efforts." *Constr. Eng. Manage.*, 136(7), 794–802.

Félix, D., Branco, J. M., and Feio, A. (2013). "Temporary housing after disasters: A state of the art survey." *Habitat Int.*, 40, 136–141.

FEMA (Federal Emergency Management Agency). (2006). *Structure fire response times*. U.S. Dept. of Homeland Security, Emmitsburg, MD, ⟨http://nfa.usfa.dhs.gov/downloads/pdf/statistics/v5i7.pdf⟩ (Jan. 24, 2016).

Ghafory-Ashtiany, M., and Hosseini, M. (2008). "Post-Bam earthquake: recovery and reconstruction." *Nat. Hazards*, 44(2), 229–241.

Hosseini, S. M. A., de la Fuente, A., and Pons, O. (2016). "Multi-criteria decision-making method for assessing the sustainability of post-disaster temporary housing units technologies: A case study in Bam, 2003." *Sustainable Cities Soc.*, 20, 38–51.

Houghton, J. T., and et al. (1996). "Revised 1996 IPCC guidelines for national greenhouse gas inventories." IPCC/OECD/IEA, Paris.

Hwang, C. L., and Yoon, K. P. (1981). *Multiple attribute decision-making: Methods and applications*, Springer, New York.

IFRC (International Federation of Red Cross and Red Crescent Societies). (2010). "World disasters report 2010 focus on urban risk." International Federation of Red Cross and Red Crescent Societies, Geneva.

Implementation of the 2011 Iranian Population and Housing Census. (2011). "Statistical center of Iran." Tehran (in Persian).

Iran: Tehran City. (2014). "City population." ⟨http://www.citypopulation.de/php/iran-tehrancity.php⟩ (May 5, 2014) (in Persian).

It's about time: Why emergency response times matter to firefighters and the public. (2010). Fire Brigades Union, ⟨http://www.epsu.org/IMG/pdf/6367-Its-about-time-LOW-RES2.pdf⟩ (Jan. 24, 2016).

JICA (Japan International Cooperation Agency). (2000). "The study on seismic microzoning of the greater Tehran area in the Islamic Republic of Iran." *Rep.*, Center for Earthquake an Environmental Studies of Tehran (CEST) and Japan International Cooperation Agency (JICA), Tehran (in Persian).

Johnson, C. (2002). "What's the big deal about temporary housing? Types of temporary accommodation after disasters: An example of the 1999 Turkish earthquake." *Proc., TIEMS 2002 Int. Disaster Management Conf.*, Univ. of Waterloo, Canada, 14–17.

Johnson, C. (2007a). "Impacts of prefabricated temporary housing after disasters: 1999 earthquakes in Turkey." *Habitat Int.*, 31(1), 36–52.

Johnson, C. (2007b). "Strategic planning for post-disaster temporary housing." *Disasters*, 31(4), 435–458.

Johnson, C. (2007c). "Strategies for the reuse of temporary housing." *UrbanTransFormation Conf.*, Holcim Forum for Sustainable Construction, Shanghai, China.

Johnson, C., Lizarralde, G., and Davidson, C. H. (2006). "A systems view of temporary housing projects in post-disaster reconstruction." *Constr. Manage. Econ.*, 24(4), 367–378.

Kelly, C. (2010). *Strategic site selection and management*, World Wildlife Fund, American National Red Cross, San Francisco.

Khazai, B., and Hausler, E. (2005). "Intermediate shelters in Bam and permanent shelter reconstruction in villages following the 2003 Bam, Iran, earthquake." *Earthquake Spectra*, 21(S1), 487–511.

Lee, S. (2012). "The role of centrality in ambulance dispatching." *Decis. Support Syst.*, 54(1), 282–291.

Mohammadzade Asl, N., Emamverdi, Q., and Afraz, M. S. (2010). "Ranking urban prosperity index of Tehran's districts." *Res. Urban Plann.*, 1(1), 85–106 (in Persian).

Nojavan, M., Omidvar, B., and Salehi, E. (2013). "The selection of site for temporary sheltering using fuzzy algorithms: Case study: Tehran metropolitan after earthquake." *Urban Manage.*, 11(31), 205–221.

Omidvar, B., Baradaran-Shoraka, M., and Nojavan, M. (2013). "Temporary site selection and decision-making methods: A case study of Tehran, Iran." *Disasters*, 37(3), 536–553.

Pons, O., and Aguado, A. (2012). "Integrated value model for sustainable assessment applied to technologies used to build schools in Catalonia, Spain." *Build. Environ.*, 53, 49–58.

Pons, O., and Fuente, A. D. (2013). "Integrated sustainability assessment method applied to structural concrete columns." *Constr. Build. Mater.*, 49, 882–893.

Pons, O., and Wadel, G. (2011). "Environmental impacts of prefabricated school buildings in Catalonia." *Habitat Int.*, 35(4), 553–563.

Prices of Housing Market in Tehran. (2010). "The management information system of real estate." Statistical Center of Iran, Tehran, ⟨http://www.amar.org.ir⟩ (Mar. 10, 2014) (in Persian).

Pricing Schedule of Buildings in Iran. (2012). "Vice-president for strategic planning and supervision of Iran." Dept. of Technical, Tehran, ⟨http://www.mporg.ir⟩ (Mar. 10, 2014) (in Persian).

Quarantelli, E. L. (1995). "Patterns of shelter and housing in U.S. disasters." *Disaster Prev. Manage.: Int. J.*, 4(3), 43–53.

Rossetto, T., et al. (2014). "The value of multiple earthquake missions: the EEFIT L'Aquila Earthquake experience." *Bull. Earthquake Eng.*, 12(1), 277–305.

Roy, B. (1968). "Classement et choix en présence de points de vue multiples. Revue française d'automatique, d'informatique et de recherche opérationnelle." *Recherche opérationnelle*, 2(1), 57–75.

Saaty, T. L. (1990). "How to make a decision: The analytic hierarchy process." *Eur. J. Oper. Res.*, 48(1), 9–26.

Shiozaki, Y., Tanaka, Y., Hokugo, A., and Bettencourt, S. (2013). *Transitional shelter*, World Bank, Washington, DC.

Soltani, A., Ardalan, A., Boloorani, A. D., Haghdoost, A., and Hosseinzadeh-Attar, M. J. (2014). "Site selection criteria for sheltering after earthquakes: A systematic review." *PLoS Curr.*

UNHCR (United Nations High Commissioner for Refugees). (2000). *Handbook for emergencies*, 2nd Ed., Geneva.

Viñolas, B. (2011). "Applications and advances of MIVES methodology in multi-criteria assessments." Ph.D. thesis, UPC, Barcelona, Spain.

Wei, L., Li, W., Li, K., Liu, H., and Chenguse, A. L. (2012). "Decision support for urban shelter locations based on covering model." *Procedia Eng.*, 43, 59–64.

Zayyari, K., Beiky, L. V., and Parnoon, Z. (2012). "The study of environmental crisis and local distribution of green space in Tehran city." *Urban-Reg. Stud. Res. J.*, 4(14), 25–28.