Identification of Social Sustainability Criteria in Building Energy Retrofit Projects

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Abstract: Building energy retrofits aim to reduce the energy consumption of existing facilities. The most significant impact of any energy retrofit project is during the operation phase of a building, when a building's users are directly impacted. This study focuses on the building operation phase by evaluating the social dimension of sustainability in energy retrofit projects. This study aimed to identify, categorize, and organize the social sustainability criteria of energy retrofit projects in existing buildings. A three-stage methodology was used that selected qualified experts in the targeted population, employed a Delphi technique to identify criteria for measuring social sustainability in energy retrofit projects, and used concept mapping to organize the identified social criteria. The study identified 19 social sustainability criteria that can be categorized in six clusters: occupants' health and comfort impact, society enhancement, cultural and community education, project stakeholder enhancement, building quality and technology enhancement, and socioeconomic growth. An empirical framework was developed for considering the impact level of social sustainability criteria in energy retrofit projects, including three levels: building, community, and society. The proposed framework can be used by practitioners who seek to consider or evaluate the social impacts of energy retrofits as well as policy makers who investigate the social aspects or social costs of energy reduction programs. **DOI: 10.1061/(ASCE)CO.1943-7862.0001610.** *© 2018 American Society of Civil Engineers.*

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Introduction

Building energy retrofits aim to reduce the energy consumption of existing facilities. Improving energy efficiency through energy retrofits, as a sustainable development, can generate benefits or savings for building owners and/or occupants in terms of economic criteria (e.g., reducing operating costs and optimizing life cycle economic performance), environmental criteria (e.g., reducing greenhouse gas emissions and preventing fossil fuel depletion), and social criteria (e.g., enhancing occupant comfort and health as well as creating job opportunities in the home improvement sector) (Jafari and Valentin 2017).

An energy retrofit is defined as a physical or operational change in a building itself, its energy-consuming equipment, or its occupants' behavior in order to reduce the amount of energy needed and convert the building to a lower energy-consuming facility (Jafari and Valentin 2017; Syal et al. 2014). Various retrofitting measures that improve building performance in terms of energy efficiency can be classified into four basic categories including: controlling measures, load reduction measures, enveloping measures, and renewable energy technologies (Jafari and Valentin 2018; Malatji et al. 2013).

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Like any construction project, the design and construction phases in building energy retrofit play an important role; however, the most significant impact of any energy retrofit project is during the building operation phase, in which a building's users are directly impacted during the service life of the building. Therefore, the consideration of the impact of such projects on occupants and users is an important issue that needs more consideration. As sustainable developments, building energy retrofits can affect sustainability in terms of economic, environmental, and social dimensions. While economic and environmental criteria of building energy retrofits have been addressed in prior research, the social criteria of energy retrofits are less well developed. Therefore, this study aims to identify the social sustainability criteria of energy improvements in existing buildings and to develop an empirical framework to organize and categorize these criteria for further consideration. First, a pre-evaluation survey was used to select the most qualified experts in the targeted population. Then, a Delphi technique was employed to identify criteria for measuring social sustainability in energy retrofit projects and to create a list of these social sustainability criteria using a series of two survey rounds. Finally, a concept-mapping approach (consisting of multidimensional scaling and hierarchical cluster analyses) was used to organize the identified social criteria and develop an empirical framework for considering social sustainability criteria in energy retrofit projects, using another survey round. The results of the developed framework can be used by practitioners for planning and designing energy retrofit projects and for evaluating a project's sustainability level.

Literature on Social Sustainability

In the construction research field, the economic and environmental dimensions of sustainability have been broadly investigated, but the social dimensions of sustainability need further expansion

(Kaminsky and Javernick-Will 2015). The social dimensions of sustainable construction cover improvements in both quality of life and in the relationships between all living beings, communities, the built environment, and the natural environment (Ye et al. 2015). The literature on social sustainability in construction projects argues that, although they are intangible, the social benefits of a project should be considered as strongly as the economic and environmental impacts (Toole and Carpenter 2013).

Social sustainability has been defined in different ways (Zuo et al. 2012), such as: "a series of processes for improving the health, safety, and well-being of current and future generations" (Valdes-Vasquez and Klotz 2013a); "a life-enhancing condition within communities, and a process within communities that can achieve that condition" (McKenzie 2004); "the social and cultural consequences to the society in various aspects from both short-term and long-term perspectives" (Marafa 2002); and "policies and institutions that have the overall effect of integrating diverse groups and cultural practices in a just and equitable fashion" (Toole and Carpenter 2013). The common idea among these definitions is that social sustainability targets both the current and future interactions of a process with human beings. More recently, Karakhan Ali and Gambatese John (2017) defined social sustainability in construction as "a life-enhancing process to accomplish social equality among all construction stakeholders in terms of health, education, economic welfare, and other human rights" (Karakhan Ali and Gambatese John 2017). These stakeholders can include a wide variety of parties, from owners to designers, construction workers, and (most importantly for energy retrofit projects) occupants and users.

In the field of civil engineering, several studies have tried to investigate social sustainability in the built environment. Kaminsky and Javernick-Will (2015) reviewed the literature regarding social sustainability in infrastructure to analyze sanitation infrastructure with legitimacy theory. They focused on a particular part of social sustainability that is concerned with internal organizational participants, excluding both external stakeholders and social justice concerns. Karakhan Ali and Gambatese John (2017) assessed, quantified, and classified worker health and safety risks associated with the construction, operation, and maintenance of sustainable projects across the US construction industry. Ye et al. (2015) hypothesized on the effects of market competition on the sustainability performance of the construction industry. Their results showed that market competition can positively influence industrial sustainability with regard to its social dimensions. Shen et al. (2011) introduced key assessment indicators for assessing the sustainability performance of an infrastructure project. They used a list of 10 social aspects of sustainability of an infrastructure project including: effects on local development; provision of employment opportunities; project function; scale of serviceability; provision of ancillary amenities to local economic activities; public safety; public sanitation; land use and its influence on the public; protection to cultural heritage; and promotion of community development (Shen et al. 2011). Toole and Carpenter (2013) provided an overview of the prevention-through-design concept and suggested that prevention through design should be a required aspect of social equity on capital projects. Valentin and Bogus (2015) investigated the correlation between social sustainability and public opinion for building and infrastructure projects (Valentin and Bogus 2015).

One way to evaluate social sustainability in construction projects is to identify and measure social sustainability criteria. These criteria can be used to understand, evaluate, and measure social sustainability in construction projects. A few research studies have tried to identify social sustainability criteria in construction projects. Gilchrist and Allouche (2005) outlined 22 sources of social costs associated with construction projects in urban environments and grouped them under four headings: traffic, economic activities, air and water pollution, and damage to the physical environment (Gilchrist and Allouche 2005). Valdes-Vasquez and Klotz (2013a) identified 50 social considerations in construction projects, based on input from 25 experts in academia, industry, and government. They also used the concept-mapping method to organize the identified criteria into six categories that define social sustainability in construction projects: stakeholder engagement, user considerations, team formation, management considerations, impact assessment, and place context. Sierra Leonardo et al. (2016) identified 36 social sustainability criteria assessed at each stage of the life cycle of Chilean public infrastructure, using the Delphi method with 24 Chilean experts consulted in a series of three rounds. They concluded that the most relevant criteria, considering life cycle stages, were stakeholder participation (design and demolition stages), external local population (design stage), internal human resources (construction and demolition stages), macrosocial action of socioenvironmental activities (construction stage), and macrosocial action of socioeconomic activities (operation stage) (Sierra Leonardo et al. 2016). Zuo et al. (2012) highlighted 26 criteria to measure social sustainability in the context of construction by conducting interviews with 16 industry professionals. They also grouped these indicators into three categories: internal stakeholders, external stakeholders, and macrolevel issues.

The literature on social sustainability refers to construction projects and emphasizes that stakeholder considerations can be one of the most important social criteria, especially in the planning and design phases. These studies, however, are mostly general in terms of construction or infrastructure projects, and they rarely provide enough details about social sustainability criteria in specific projects. Specifically, an energy retrofit project, as a sustainable development based on upgrading an existing building, may have different issues from, and—depending on the project—more or less complex phases than the construction of a new building, but it could also have a significant impact on the building's users during the service life of the building. This type of project is more user-oriented, and the identified social sustainability criteria could play an important role in planning, operating, and evaluating the project. Therefore, investigating the social dimensions of sustainability in such projects during design, construction, and, most importantly, operation is important. With respect to the contribution of the aforementioned studies, there is still a lack of research that considers the social aspects of sustainability, specifically in energy retrofit projects (in both the construction and operation phases).

Recently, Jafari et al. (2016) investigated the social benefits of a sustainable energy retrofit project, assuming that the social impact area of sustainable buildings can be classified into three different levels as suggested by the US Department of Energy: building level, which is the direct impact on a building's occupants; community level, which is the indirect impact on the neighborhood surrounding the building; and society level, which is the indirect impact on the government and utility companies (Department of Energy 2015). Focusing on the social effects of energy retrofit practices on building occupants, Jafari et al. (2016) used a pilot survey to rate four main identified social criteria: health, comfort and satisfaction, productivity, and security. This study, however, did not include a comprehensive framework, which is still needed, to define, categorize, and consider the social sustainability criteria of energy retrofit project in existing buildings.

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Methodology

To explore the social sustainability criteria within energy retrofit projects and develop an empirical social sustainability framework, a combination of a Delphi method and a concept-mapping approach was adopted in this study.

The Delphi method is a "systematic and interactive research technique for obtaining the judgment of a panel of independent experts on a specific topic" (Hallowell and Gambatese 2010). A Delphi method was used to aggregate expert opinions on the topic of social sustainability in energy retrofit projects. For a rigorous implementation, this article followed the Delphi method guidelines for construction research proposed by Hallowell and Gambatese (2010).

In addition, a concept-mapping approach was used to develop an empirical conceptual map that categorized the social sustainability criteria that were identified through the Delphi method. In general, the concept-mapping method integrates the structured group tasks of idea generation, sorting, and rating with two-dimensional scaling and cluster analyses in order to determine a well-defined quantitative set of results (Kane and Trochim 2007). This study followed the conceptual mapping guidelines for construction research proposed by Valdes-Vasquez and Klotz (2013b).

The research methodology consisted of three main stages and different series of surveys (Fig. 1). Each stage and type of conducted survey is explained in detail in this section.

Stage 1: Expert Selection

In any survey study, one of the most important factors is the level of expertise of the expert participants. Nevertheless, the characteristics required to define an individual as an expert are equivocal (Hallowell and Gambatese 2010). The experts should be selected in a strategic and unbiased process. Following Hallowell and Gambatese (2010), the first step used in this study to select final participant panelists was to identify the potential experts based on two parameters: membership in a nationally recognized committee in the focus area of the research, and authorship of relevant publications. The next step included sending an invitation for participation to potential experts and inquiring about their professional backgrounds. The invitation used in this study also included a self-assessment section for the experts, which consisted of a five-scale assessment about their knowledge and/or experience regarding the topic at hand. The self-assessment included four topics: sustainability in the construction environment, sustainable developments, social factors and social costs influencing construction projects, and energy efficiency improvements and energy retrofits.

A diverse group of highly qualified experts is desired for effective implementation of the Delphi method in any construction expert research. To meet a minimum level of qualification using the point system shown in Table 1, it was suggested that the panelists score at least one point in four different qualification requirement categories and a minimum of 11 total points in order to qualify for participation (Hallowel and Gambatese 2010).

As Hallowell and Gambatese (2010) suggested, 8–12 expert participants is a good number for Delphi studies in construction research. In this study, the invited experts were evaluated based on the qualification scores and their self-assessment results, and 11 of them were chosen to participate as the expert panelists in the next survey.

Stage 2: Delphi Technique

A Delphi study consists of multiple rounds of data collection through the use of controlled feedback and iteration in order to

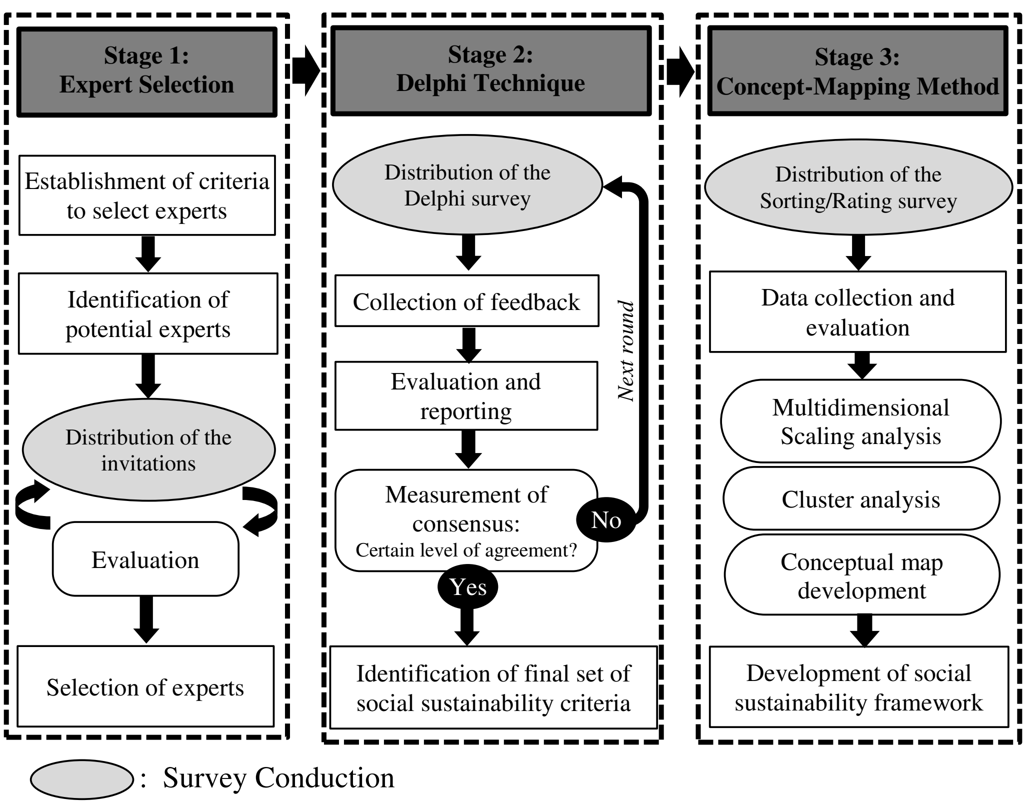

Fig. 1. Research methodology.

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Table 1. Point system for the qualification of expert panelists

ID	Qualification requirements	Points
A	Primary or secondary writer of peer-reviewed journal article	2
B	Invited to present at a conference	0.5
C	Member (or chair) of a nationally recognized committee	1(3)
D	At least 1 year of professional experience in the construction industry	1
E	Faculty member at an accredited institution of higher learning	3
F	Writer or editor of a book (or book chapter) on the topic of construction	4(2)
G	Advanced degree in the field of civil engineering or other related fields	1-4
	BS	1
	MS	2
	Ph.D.	4
H	Professional registration	3

Source: Adapted from Hallowell and Gambatese (2010), © ASCE.

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facilitate an efficient group dynamic process (Hallowell and Gambatese 2010). This should be done in the form of an anonymous, written, multiple-round survey process. Using multiple rounds to generate ideas helps to improve convergence on a collective opinion as a result of each round (Hallowell and Gambatese 2010). In a Delphi study, the survey procedure can be stopped when a predefined level of agreement, that is, a consensus, is achieved (von der Gracht 2012). Researchers have used many different measures to determine the level of agreement among expert panelists. Von der Gracht (2012) reviewed the existing consensus measurements in Delphi studies and stated, "in keeping with most other Delphi studies, consensus was defined as 51% agreement among respondents." A summary of Delphi studies in construction engineering and management (CEM) research by Valdes-Vasquez and Klotz (2013b) also indicated that an acceptable level of agreement could be reached in two to six rounds.

The goal of the Delphi method used in this study was to aggregate the expert opinions regarding social sustainability criteria in energy retrofit projects. In this stage, multiple rounds of surveys were suggested through the use of controlled feedback and iteration. For the first round of the Delphi study in this research, a preliminary questionnaire was designed after reviewing the relevant literature and consulting with experts in the subject area. To design the survey, an initial list of social criteria that may be impacted by energy retrofit projects [including seven social sustainability criteria, mostly from the Jafari et al. (2016) pilot study] was drawn from a literature review. The survey consisted of an introduction to the topic, containing a description of the study method and objectives, as well as the list of seven social sustainability criteria for energy retrofit projects. The survey participants were asked to evaluate the criteria by agreeing or disagreeing with each criterion, providing detailed feedback, and suggesting additional social criteria based on their knowledge and experience.

At the end of each round of the Delphi study, a modified list of social sustainability criteria was created, based on the feedback and suggestions from the experts. Then, using the inputs from each round, the level of agreement for each criterion was measured, using two main rules:

1. If an expert agreed on the criterion or if the modified criterion addressed the expert's feedback or suggestion, an agreement for that criterion by the expert was assumed (agree = 1); and
2. If an expert disagreed regarding the modified criterion or if the modified criterion did not include the expert's suggestion, a disagreement for that criterion by the expert was assumed (disagree = 0).

At the end of each round, the level of agreement for each social criterion and the whole social criteria list was measured. To ensure accuracy in this study, the survey process was considered to be completed when (1) more than 50% agreement was achieved for each social criterion; and (2) more than 80% agreement was achieved for the social criteria list. At the end of each round, if the consensus thresholds were not achieved, the modified list of the social sustainability criteria were used in the next round of the survey and forwarded to the experts for their evaluation, feedback, and/or suggestions. If the consensus thresholds were achieved, the modified list would become the final list of social sustainability criteria in energy retrofit projects. The result of this stage was the finalized list of social criteria aggregated from the expert panelists.

Stage 3: Concept-Mapping Method

To develop a conceptual map for the social sustainability criteria in energy retrofit projects, the identified criteria needed to be sorted and rated. Therefore, a final survey was designed to sort the identified criteria based on their similarities and rate them based on their importance.

In the sorting section of this final survey, each panelist was asked to group the identified social criteria into logical categories/groups according to their own judgment. Participant guidelines for sorting were as follows (Kane and Trochim 2007; Valdes-Vasquez and Klotz 2013b):

- Read through the final list of identified criteria.
- Sort the social criteria based on similar themes or content. Each criterion must be put into only one group. Give each group a name to describe its theme or contents.
- Do not create groups according to their priority or value, with labels such as "important" or "hard to do."
- Do not create groups such as "miscellaneous" or "other" to group dissimilar criteria.
- There may be a group with only one social criterion, if that criterion is unrelated to other criteria. Each criterion must be sorted into a group.
- If a statement can be categorized into two or more groups, select the group that you consider to be the most appropriate.
- Create as many groups as needed but avoid putting each criterion in a separate group.

In the rating section of this final survey, the panelists were asked to follow a prompt rating statement, using a five-point scale: not important (0), slightly important (1), moderately important (2), important (3), and very important (4). Following Valdes-Vasquez and Klotz (2013b), the list of social criteria was randomized. The randomization of the criteria list prevented the criteria with similar meanings from being listed together in order to minimize the influence of their being listed together on the rating results.

After the expert participants completed both the sorting and the rating survey, a concept map of the social sustainability framework for energy retrofit projects was developed using the following steps, as suggested by Valdes-Vasquez and Klotz (2013b):

1. A multidimensional scaling (MDS) analysis was adopted to generate a two-dimensional point map of distances between the identified social criteria. In the point map, each point represents a criterion. In addition, the distance between points represents how often the expert panelists placed these criteria into the same groups (Kane and Trochim 2007). Using the point map,

the relationship of each social criterion to the other criteria was indicated.

2. A cluster analysis was adopted to generate a cluster map from the point map coordinates. A cluster map includes a series of clusters that organize and categorize the final list of social criteria selected during the Delphi method (Valdes-Vasquez and Klotz 2013b). For this analysis, the coordinates obtained from the MDS were used to group concepts according to their proximity by computing their Euclidean distance, using Ward's (1963) algorithm. This algorithm is normally used to form (bottom-up) hierarchical groups of mutually exclusive clusters.
3. A combination of the cluster map and data collected from Likert-scale responses was used to develop a three-dimensional rating map. In the rating map, the average importance rating of each cluster was presented, calculated by averaging the rating of all criteria in each cluster (Kane and Trochim 2007).

Once the maps were generated, researcher expertise was required to interpret the results. The central decision in interpreting the results was selecting the final cluster solution, that is, the number of clusters that best fit the data (Valdes-Vasquez and Klotz 2013b). The process started with the highest number of clusters and then followed a downward process. Rosas and Kane (2012) summarized the range of the number of clusters in previous conceptual mapping literature to be from 6 to 14 clusters for data sets of 45 to 100 ideas. The next step was to label the clusters based on the insight of the researchers, the information collected from the respondents, and the literature review (Valdes-Vasquez and Klotz 2013). The final step was to describe the meaning of each cluster and to analyze the correlation or agreement between the clusters. In addition, a practical framework was developed to transform the results into an empirical scheme.

Profile of the Expert Panelists

To adopt the described Delphi method, 39 potential experts were preselected based on the two aforementioned parameters: membership in a nationally recognized committee in the focus area of the research, and authorship of relevant publications. The preselected experts included academic experts in the US Accreditation Board for Engineering and Technology (ABET) accredited colleges who had at least one peer-reviewed journal publication on the topic of sustainability in construction. Then an invitation was sent to the panelists for participation in the study. In the invitation, the purpose of the study was clearly stated, and supplementary information about energy retrofit projects, energy retrofit measures, and the sustainable impact of these types of projects was provided. Social sustainability was defined for the participants as mentioned previously. The invited experts were also asked to assess their knowledge and experience related to the topic, using the aforementioned self-assessment tool. Based on the response rate, the profiles, and the self-assessments, 11 experts were selected as members of the expert panel. A panel consisting only of academic experts could be considered to lack an industrial viewpoint. However, since 8 out of 11 of the panelists held a professional registration, it can be concluded that the selected panel was able to represent industry experience as well.

The panelists are characterized in Table 2 by the qualification criteria provided in Table 1. As shown, all 11 panelists exceeded the required minimum score of 11 total points.

In addition, the results of the panelists' self-assessments are presented in Fig. 2. The results show that, on average, the panelists had high knowledge of and experience in the topic of sustainability in the construction environment, high knowledge of and experience in the topic of sustainable development, moderate to high knowledge of and experience in the topic of social factors and social costs influencing construction projects, and high knowledge of and experience in the topic of energy efficiency improvements and energy retrofits.

Table 2. Panelists' profiles and qualifications

Expert panelist	Qualification ID								Total points
	A	B	C	D	E	F	G	H	
#1	2	0.5	3	1	3	0	4	3	16.5
#2	2	0.5	1	0	3	0	4	3	13.5
#3	2	0.5	1	1	3	0	4	0	11.5
#4	2	0.5	3	1	3	4	4	0	17.5
#5	2	0.5	0	1	3	4	4	3	17.5
#6	2	0.5	0	1	3	4	4	3	17.5
#7	2	0.5	3	1	3	0	4	3	16.5
#8	0	0.5	1	1	3	0	4	3	12.5
#9	2	0.5	3	1	3	0	4	3	16.5
#10	2	0.5	1	1	3	0	4	0	11.5
#11	2	0.5	3	1	3	0	4	3	16.5
Average	1.8	0.5	1.7	0.9	3.0	1.1	4.0	2.2	15.2

Note: See Table 1 for qualification IDs.

Results and Discussion

In total, four surveys were deployed and completed in this study. All the surveys were designed in an online platform and sent to the expert panelists by email. The first survey, as mentioned previously, was the invitation for participation, which targeted the expert panelists' profiles. The second and third surveys were used to generate the list of social sustainability criteria in energy retrofit projects using a Delphi method. The last survey was conducted to sort and rate the identified social sustainability criteria in order to develop a conceptual map. All the expert panelists participated in the first three surveys; however, for the last survey (the rating and sorting survey), only 10 out of the 11 experts participated. The results of the surveys are summarized and analyzed in this section.

Listing Social Sustainability Criteria

After each round of the Delphi method, the list of social criteria in energy retrofit projects was altered by removing, merging, or revising the existing social criteria in the list according to suggestions from the expert panel members. Additional social criteria identified by the participants were also added to the list.

In summary, seven social criteria were presented to the expert panel for their evaluation in the first survey round of the Delphi study. Based on the feedback received from the panel in round 1, the list was modified and expanded to 21 social criteria; however, the required level of agreement was not achieved in the first round. Therefore, the new list was presented to the panelists in the next round of the Delphi study. A list of 19 social criteria in energy retrofit projects resulted from the feedback received in round 2, following the method described. At the end of round 2, the required level of agreement was achieved; therefore, 19 social sustainability criteria were considered as the final list. The final list of social criteria resulting from the two survey rounds of the Delphi study is presented in Table 3.

Because of the diverse areas of expertise of the panelists, the feedback received in each round of the Delphi method was comprehensive. However, as expected, feedback received on specific topics sometimes was in conflict. In those cases, the authors

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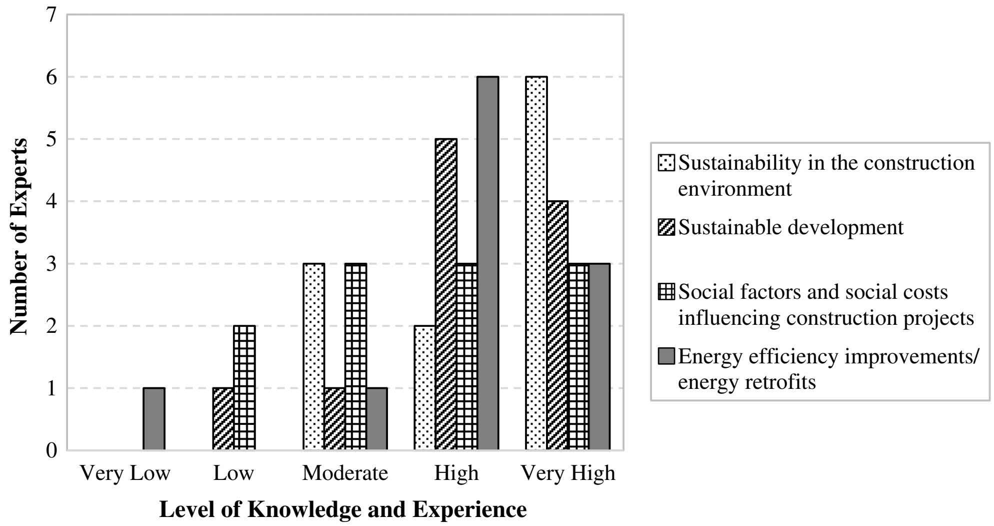

Fig. 2. Panelists' self-assessment results.

Table 3. Social sustainability criteria in energy retrofit projects

ID	Social sustainability criteria	Importance rating
SC01	Impacting occupants' health	3.56
SC02	Impacting occupants' thermal comfort	3.33
SC03	Enhancing productivity and efficiency of occupants in working environments	3.33
SC04	Improving reliability through diverse power generation sources	3.22
SC05	Enhancing stakeholders' feeling of well-being and satisfaction through the positive contribution to the environment	2.89
SC06	Providing job opportunities for local, regional, or national sustainable renovation and manufacturing companies	3.00
SC07	Reducing the dependence on external energy providers and foreign nations	2.67
SC08	Improving social equity when providing energy efficient facilities for low-income occupants	3.67
SC09	Improving durability related issues of the buildings	3.56
SC10	Encouraging neighbors and community to adopt the culture of energy efficiency	3.22
SC11	Improving the connections among people in a community	2.22
SC12	Increasing energy efficiency literacy among occupants and communities	2.78
SC13	Educating the next generations of stakeholders for enhancing the trend of energy efficiency culture	3.56
SC14	Improving the application of energy efficiency technologies and innovative ideas	2.89
SC15	Reducing exposure to the risk of increases in energy prices	2.78
SC16	Reducing occupant fatigue through improved artificial lighting and increased use of natural lighting	3.67
SC17	Decreasing the occupants' and community's exposure to noise	2.78
SC18	Increasing the marketability of the building	2.78
SC19	Enhancing collaboration and education opportunities among the design, construction, and operation teams in the energy retrofitting sector	3.22

collected and summarized all the panelists' feedback about those specific topics and achieved a conclusion that represented the most frequent response about the topic.

For the final survey (rating and sorting survey), the experts rated the importance of the 19 social sustainability criteria by using a Likert-type scale, with 0 indicating little importance and 4 indicating high importance. The importance rating averages of the identified criteria are also shown in Table 3. As the results show, there are five social sustainability criteria that were rated important to very important (more than 3.5 out of 4), as follows:

- SC08: Improving social equity when providing energy efficient facilities for low-income occupants;
- SC16: Reducing occupant fatigue through improved artificial lighting and increased use of natural lighting;
- SC01: Impacting occupants' health;
- SC09: Improving durability related issues of the buildings; and
- SC13: Educating the next generations of stakeholders for enhancing the trend of energy efficiency culture.

Similarly, the lowest rated social sustainability criteria in terms of importance (less than 2.7 out of 4) are as follows:

- SC11: Improving the connections among people in a community; and
- SC07: Reducing the dependence on external energy providers and foreign nations.

Even the lowest rated criteria were evaluated as having some importance, which further supports the inclusion of all 19 criteria in the following analyses.

Concept-Mapping Analysis

Results of the fourth and final survey (rating and sorting survey) were used to develop a conceptual map. To assess perceived similarities and differences among identified social criteria, an MDS analysis was performed on the collected sorting data, using Statistical Package for the Social Sciences (SPSS) version 25. In an MDS analysis, to evaluate the validity of the two-dimensional model in relation to the original aggregate matrix, a diagnostic statistic called the stress value, which represents the general forms of loss functions in MDS, is determined. MDS programs automatically minimize stress to obtain the MDS solution. A higher stress value implies that there is a greater discrepancy in the distances on the map. An average of 0.28 or less has been identified as an acceptable

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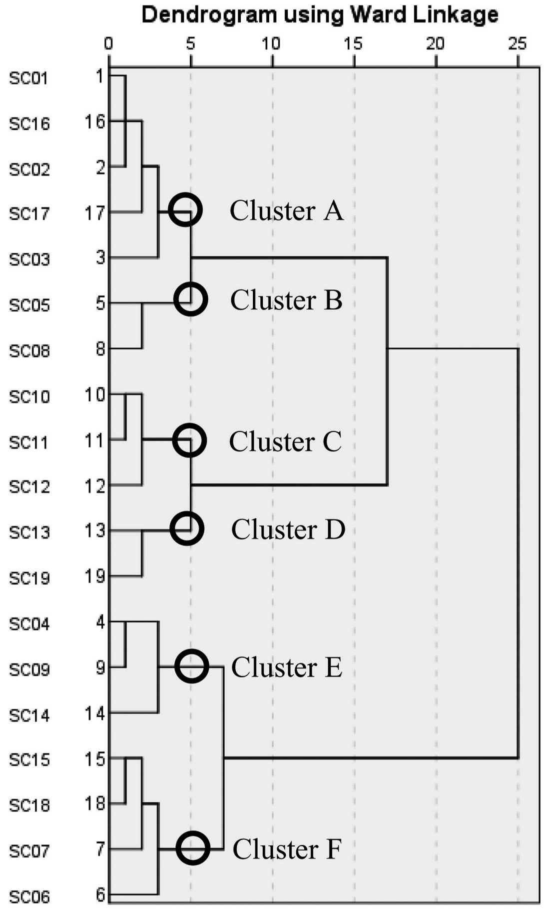

Fig. 3. Tree diagram of cluster analysis.

stress value in concept-mapping studies (Kane and Trochim 2007; Rosas and Kane 2012). This study achieved an acceptable stress value of 0.033 for the MDS analysis.

Then, to group similar concepts, a cluster analysis was performed using the same software (SPSS) and the coordinates from the MDS analysis. Typically, in this type of hierarchical cluster analysis, several clusters are developed sequentially, beginning with each social sustainability criterion individually and continuing until all criteria are integrated into one aggregated cluster, providing several interpretable maps. As a result, the clusters were developed sequentially as seen in Fig. 3. The segmented vertical line in the figure indicates the point at which the clustering solution best represents the data based on the analysis of the researchers. Due to lack of a mathematical criterion to select the number of clusters (Trochim 1989), the researchers' judgment based on the literature review was used to determine the number of clusters that best fit the data. This decision was also based on keeping a logical conceptual representation. In addition, based on the collected data, the expert panelists grouped the social criteria in a range of four to seven groups. For the research presented in this study, the selected number of clusters was six, labeled A–F in Fig. 3.

As previously mentioned, the experts also rated the importance of the 19 social sustainability criteria in energy retrofit projects by using a Likert-type scale. To calculate the importance level of each cluster, the average importance level of the criteria grouped into that cluster was calculated, to develop the rating map. The point map, cluster map, and rating map are merged in Fig. 4.

Conceptual Map Interpretation

The next step in the analysis was to identify the names that best identify each cluster. This selection of names began by reviewing the cluster names created by the experts. The resulting names for each of the six clusters originating from this analysis, as well as the content of each, are as follows (Table 4).

Cluster A: Occupants' Health and Comfort Impact

This cluster, which is rated as having the second most important social impact of energy retrofit projects (average rating of 3.33), consists of five social sustainability criteria that address the impact of energy retrofit projects on occupants and building users. Energy retrofits may have a wide variety of impacts on building occupants and users. For example, energy retrofit measures usually try to reduce air exchange, which may cause an inverse impact on occupants' health. However, by providing proper individual controls

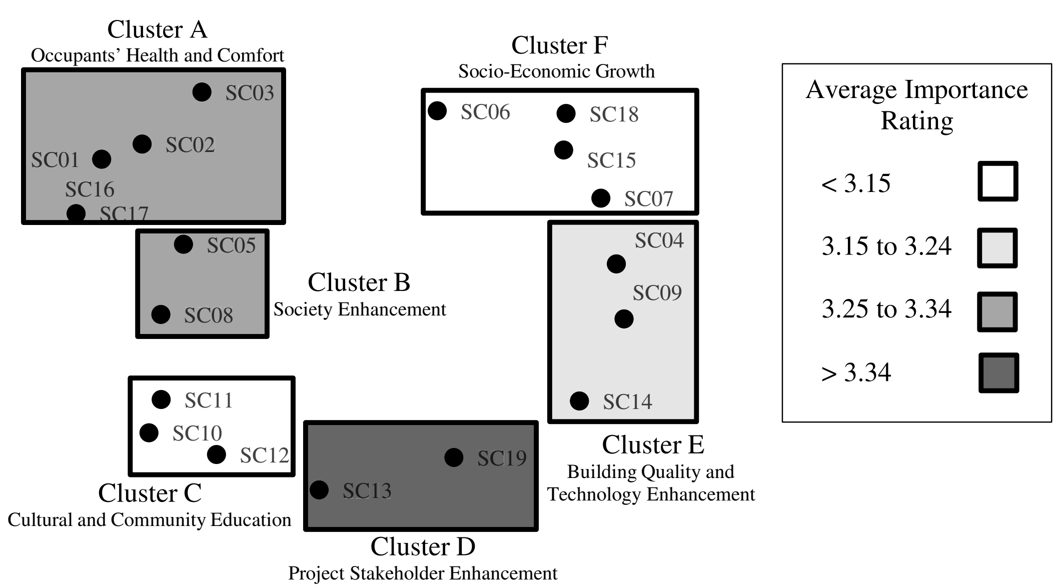

Fig. 4. MDS and cluster analysis.

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Table 4. Social sustainability framework

ID	Social sustainability criteria	Bridging value
	Cluster A: occupants' health and comfort impact	Average = 0.24
SC01	Impacting occupants' health	0.00
SC16	Reducing occupant fatigue through improved artificial lighting and increased use of natural lighting	0.00
SC02	Impacting occupants' thermal comfort	0.28
SC17	Decreasing the occupants' and community's exposure to noise	0.38
SC03	Enhancing productivity and efficiency of occupants in working environments	0.56
	Cluster B: society enhancement	Average = 0.75
SC05	Enhancing stakeholders' feeling of well-being and satisfaction through the positive contribution to the environment	0.76
SC08	Improving social equity when providing energy efficient facilities for low-income occupants	0.74
	Cluster C: cultural and community education	Average = 0.44
SC10	Encouraging neighbors and community to adopt the culture of energy efficiency	0.39
SC11	Improving the connections among people in a community	0.47
SC12	Increasing energy efficiency literacy among occupants and communities	0.48
	Cluster D: project stakeholder enhancement	Average = 0.71
SC13	Educating the next generations of stakeholders for enhancing the trend of energy efficiency culture	0.61
SC19	Enhancing collaboration and education opportunities among the design, construction, and operation teams in the energy retrofitting sector	0.81
	Cluster E: building quality and technology enhancement	Average = 0.49
SC04	Improving reliability through diverse power generation sources	0.39
SC09	Improving durability related issues of the buildings	0.50
SC14	Improving the application of energy efficiency technologies and innovative ideas	0.58
	Cluster F: socioeconomic growth	Average = 0.52
SC15	Reducing exposure to the risk of increases in energy prices	0.34
SC18	Increasing the marketability of the building	0.45
SC07	Reducing the dependence on external energy providers and foreign nations	0.30
SC06	Providing job opportunities for local, regional, or national sustainable renovation and manufacturing companies	1.00

for temperature and ventilation, occupants' comfort and satisfaction may increase. In addition, by increasing the use of natural lighting or using improved artificial lighting, energy retrofits may reduce occupants' fatigue and therefore enhance productivity and efficiency in working environments. Further, by upgrading building mechanical systems, energy retrofits may decrease the occupants' and the community's exposure to noise. All of these qualities are grouped into a cluster called occupants' health and comfort impact.

Cluster B: Society Enhancement

This cluster, which is rated as having the third most important social impact of energy retrofit projects (average rating of 3.28), consists of two social sustainability criteria that address enhancements in the social equity and well-being of society as a result of energy retrofitting. By converting buildings to be an energy-efficient facilities, building owners contribute to a better society with regard to the environment, and this may enhance their feeling of well-being and satisfaction. Providing energy-efficient facilities for low-income people can improve social equity in a diverse society. All of these qualities are grouped into a cluster called society enhancement.

Cluster C: Cultural and Community Education

This cluster, which is rated as having the least important social impact of energy retrofit projects (average rating of 2.74), consists of three social sustainability criteria that address the educational impact of energy retrofit projects on occupants' and/or communities' culture or behavior. An energy retrofit project in a community can demonstrate the impact of energy retrofits to the entire community, and it may increase the number of energy retrofit projects and the culture of energy efficiency in that community, resulting in improved connections among the people in that community. In addition, it may also increase energy efficiency literacy among occupants and communities. All of these qualities are grouped into a cluster called cultural and community education.

Cluster D: Project Stakeholder Enhancement

This cluster, which is rated as having the most important social impact of energy retrofit projects (average rating of 3.39), consists of two social sustainability criteria that address the impact of energy retrofit projects on project teams and/or other stakeholders. As sustainable developments, energy retrofit projects can enhance collaboration opportunities among design, construction, and operation teams in the energy retrofit sector. In addition, they can educate the next generations of stakeholders, enhancing the trend toward an energy efficiency culture. All of these qualities are grouped into a cluster called project stakeholder enhancement.

Cluster E: Building Quality and Technology Enhancement

This cluster, with an average rating of 3.22, consists of four social sustainability criteria that address improvements in the quality of buildings and enhancements in the technological aspects of buildings resulting from the implementation of energy retrofit projects. For example, energy efficiency with respect to building envelopes is expected to address air leakage through walls and roofs and to prevent thermal bridges. If this work is done properly, it can help reduce the chance of condensation, which may result in improving durability-related issues for the building. Energy efficiency awareness may also improve the application of energy efficiency technologies and innovative ideas in energy retrofit projects. These technologies can result in innovations like using diverse power generation sources for buildings, which may improve power reliability. All of these qualities are grouped into a cluster called building quality and technology enhancement.

Cluster F: Socioeconomic Growth

This cluster, which is rated as having the second least important social impact of energy retrofit projects (average rating of 2.81), consists of four social sustainability criteria that address the indirect economic impact of energy retrofit projects on individuals, communities, or society. Improving energy efficiency through building energy retrofits can decrease the amount of energy needed for

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operating buildings. As a result, exposure to the risk of increases in energy prices can be reduced, and dependence on external energy providers and foreign nations can also be reduced. In addition, improving energy efficiency can be beneficial for owners by increasing the marketability of buildings and can be beneficial for society by providing job opportunities in sustainable renovation and manufacturing companies. All of these qualities are grouped into a cluster called socioeconomic growth.

Although the identified social sustainability criteria and defined clusters are evaluated for energy retrofit projects, there are commonalities between the results of this study and the literature on social sustainability in construction projects. For example, Zuo et al. (2012) used a framework to categorize social sustainability criteria in construction projects into three groups—internal stakeholder, external stakeholder, and macrolevel issues. The six defined clusters of social sustainability in energy retrofit projects can also be categorized based on the same framework: occupants' health and comfort impact, project stakeholder enhancement, and building quality and technology enhancement can be categorized into internal stakeholders; cultural and community education can be categorized into external stakeholders; and society enhancement and socioeconomic growth can be categorized into macrolevel issues.

Valdes-Vasquez and Klotz (2013a) categorized social sustainability criteria in the design and planning phase of construction projects into six clusters: stakeholder engagement that addresses collaboration among the various stakeholders; user considerations focusing on the productivity, safety, health, and security of the final users; team formation concerning the selection of design and construction firms that have a sustainability focus; management considerations influencing the health, safety, and productivity of the temporary and final users by including prevention techniques to minimize occupational hazards and risks during the construction and operation phases; impact assessment considering a social impact assessment of the surrounding community and a health impact assessment of the users; and place context, analyzing the location of the project in terms of user needs (Valdes-Vasquez and Klotz 2013b). Although some of these clusters explicitly focus on the design and planning of sustainable projects and may not be applicable to smaller projects such as energy retrofit projects (e.g., management consideration or place context), other clusters are comparable to the clusters that this study has defined. For instance, occupants' health and comfort impact is comparable to user considerations; project stakeholder enhancement is comparable to stakeholder engagement and team formation; and cultural and community education and society enhancement are comparable to impact assessment. Also, there are other clusters (building quality and technology enhancement and socioeconomic growth) that were not considered in the Valdes-Vasquez and Klotz (2013a) study because they are not applicable to all construction projects but are applicable to energy retrofit projects.

In addition, the most relevant social criteria in construction projects based on Sierra et al. (2016) can be compared to the results of the current study. For example, criteria such as stakeholder participation, internal human resources, and macrosocial action of socioenvironmental activities imply the same intuition as project stakeholder enhancement, occupants' health and comfort impact, and society enhancement, respectively. The remaining defined clusters are exclusive to energy retrofit projects.

Social Sustainability Practical Framework

The developed conceptual map illustrates that social sustainability criteria in energy retrofit projects can be grouped into six clusters. However, it cannot provide any information about the level of interaction between energy retrofits and human beings, which is the main idea of social sustainability. The US Department of Energy (2015) stated that the social impact of sustainable buildings can be realized at different levels—buildings, the community, and society in general (both positively and negatively). Although it provided some examples of sustainable designs, it did not provide a framework for identifying and categorizing their benefits. Such a framework could be used in planning, operating, and evaluating the impact and effectiveness of energy retrofit projects. Therefore, to develop a more practical framework, the authors again analyzed the content and the relationships among the determined clusters. As suggested by Kane and Torchim (2007), as a backup to human judgment regarding the appropriateness of a cluster solution, the bridging value from the cluster analysis can be calculated and used. The bridging value, ranging from 0 to 1, tells how often a statement was sorted with others that are close to it on the map or whether it was sorted with items that are farther away on the map (Kane and Torchim 2007). Lower bridging values indicate a tighter relationship with other statements in the cluster. Higher bridging values indicate greater discrepancies in the distances to other statements in the cluster (Valdes-Vasquez and Klotz 2013b). The bridging value for each criterion and the average bridging value of criteria in the same clusters are shown in Table 4. Clusters with lower average bridging values usually represent better content in the conceptual map. For example, cluster A (occupants' health and comfort impact) has the smallest bridging value and, therefore, the most cohesiveness among all clusters. In contrast, the bridging value for cluster B (society enhancement) is the highest among all clusters, which means that the criteria in cluster B have more connectivity with some of the nearby criteria outside the cluster.

Based on this information, an empirical social sustainability framework was formed with three different levels—building level, community level, and society level—which represent the social impact of energy retrofit projects on building occupants, people living in a community, and society as a whole, respectively. Since the building level could be part of the community level and the community level could be a part of the society level, an onion diagram (concentric circles) was used to present the framework in a better way. This framework is shown in Fig. 5.

The first level of the proposed framework is the building level, which includes clusters A (occupants' health and comfort impact) and E (building quality and technology enhancement). These criteria are grouped together because they influence either the building itself or its occupants and users. In cluster A, the criterion with the highest bridging value (SC03: Enhancing productivity and efficiency of occupants in working environments) can be categorized beyond the building level and can affect people in communities; therefore, it is added to the community level. In addition, the criterion with the second-highest bridging value in cluster A (SC17: Decreasing the occupants' and community's exposure to noise) can affect either occupants or communities, as its name implies. Therefore, it is added to both the building level and the community level. In cluster E, the criterion with the highest bridging value (SC14: Improving the application of energy efficiency technologies and innovative ideas) can also affect people in society; therefore, it is added to the society level.

The second level of the proposed framework is the community level, which includes cluster C (cultural and community education). The influence of the criteria in this cluster reaches beyond the building level but do not have as global reach as the society level. In this cluster, the criterion with the highest bridging value (SC12: Increasing energy efficiency literacy among occupants and communities) can either affect occupants or communities, as its name

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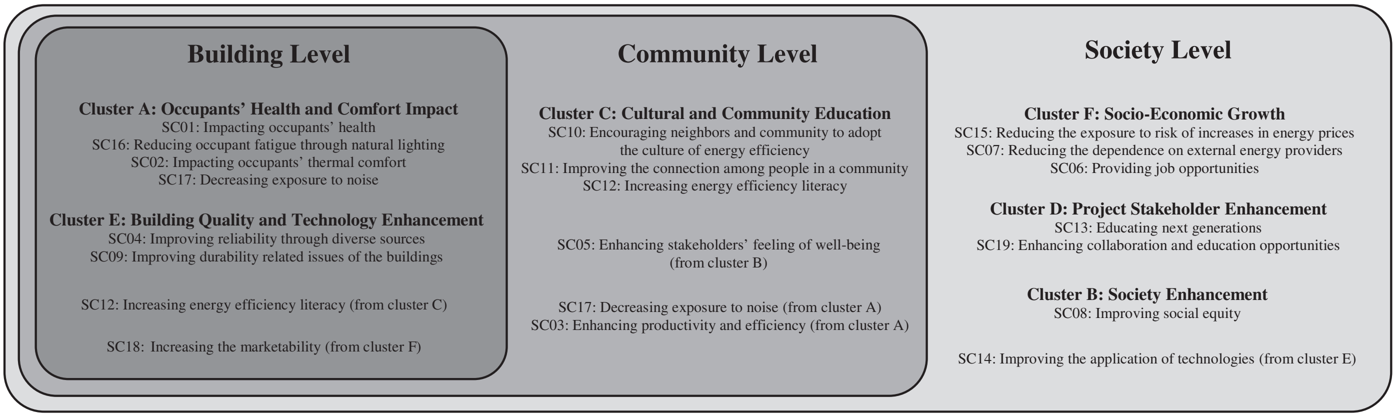

Fig. 5. Proposed social sustainability framework in energy retrofit projects.

implies. Therefore, it is added to both the building level and the community level.

The last level of the proposed framework is society level, which includes clusters B (society enhancement), D (project stakeholder enhancement), and F (socioeconomic growth). In cluster B, the criterion with the highest bridging value (SC05: Enhancing stakeholders' feeling of well-being and satisfaction through the positive contribution to the environment) can affect the people in a community. Therefore, it is added to the community level. In addition, the criterion SC18 (Increasing the marketability of the building) in cluster F mainly affects occupants. Therefore, it is added to the building level.

The proposed framework (Fig. 5) can be used as a practical guide to assess the social dimension of energy retrofit projects considering different impact levels. Although there may be different types of investors in energy retrofit projects (Jafari and Valentin 2018), the proposed framework can be used to identify and evaluate the social impact level of a project despite of who the investors are. For example, for an investor who is the building owner, social sustainability factors on the building impact level may be more important than factors on other levels; however, for a governmental energy program, the society impact level factors might be the main factors to consider in the energy retrofit decision-making process. The new framework (the social factors identified and the levels to which they pertain) allows energy retrofit decision makers to choose which factors to consider based on their objectives and the levels they are the most interested in impacting. In addition, the developed practical model serves decision makers who are seeking to consider the social impacts of energy retrofitting in their decisions and policy makers who are investigating the social benefits or social costs of energy reduction programs. The social sustainability criteria in energy retrofit projects provided in the proposed framework can help practitioners in energy retrofit projects consider the social dimension of energy retrofits in their sustainable designs and construction or in their sustainability assessment process. Both the conceptual map with the six clusters (based on the MDS and cluster analysis) and the proposed framework with three levels (based on the authors' interpretation of the literature, the data, and the conceptual map) can help define and categorize social sustainability in energy retrofitting and energy efficiency improvement projects.

Conclusions

The social dimension of sustainability in projects such as building energy retrofits, which highly interact with users and occupants during the service life of a building, was targeted in this study. This study contributed to the body of knowledge by (1) identifying a list of 19 social sustainability criteria for measuring social sustainability in energy retrofit projects; (2) grouping these identified social sustainability criteria into six clusters: occupants' health and comfort impact, society enhancement, cultural and community education, project stakeholder enhancement, building quality and technology enhancement, and socioeconomic growth; and (3) identifying the impact level of social sustainability in energy retrofit projects by proposing an empirical framework formed with three different levels: building level, community level, and society level. The results of this study can be used by practitioners as a guide to consider the social sustainability dimension in sustainable construction—specifically in building energy retrofit projects. It can also be used as a sustainability assessment tool for evaluating the social sustainability of energy retrofit projects on different impact levels.

Although the findings are limited to energy retrofit projects, the same approach can be used for any other sustainable project. This study considered and used only academic experts as panelists. However, because 8 out of the 11 panelists carry a professional registration, it could be concluded that the selected expert panel was able to represent industry experience as well. In addition, the identified social sustainability criteria may be site-specific because of the small group of respondents. For future research, a broader population with a combination of both academic and industry experts can be targeted. In addition, future research opportunities exist for the identified criteria to be further assessed, analyzed, and established as indicators for social sustainability assessment.

Data Availability Statement

All data generated or analyzed during the study are included in the published paper. Information about the *Journal*'s data-sharing policy can be found here: http://ascelibrary.org/doi/10.1061/(ASCE)CO.1943-7862.0001263.

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