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Multi-Criteria Decision Making in the Social Sustainability Assessment of High-Rise Residential Buildings

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Abstract. Factors such as global urbanization, scarcity of land, and rising land prices will increase the need for high-rise buildings. Population growth has led to dense life in residential high-rise buildings (RHRB). On the one hand, RHRB have benefits such as the maximization of land use. On the other hand, disadvantages such as ignoring features of cultural context, difficulties in guaranteeing natural ventilation and the high maintenance expenses are considered as their weaknesses. According to previous studies, most current RHRB do not consider social cohesion and local identity. Studies have proven that dimensions of social sustainability have been scarcely considered. The main objective in sustainability assessment of RHRB consist in reducing the environmental impact and increasing the efficiency and residents' satisfaction. Recent studies have considered modern methods for assessing the sustainability; in this regard, multi-criteria decision-making (MCDM) approaches are one of the most common alternatives to assess sustainability. The aim of this research is to develop a MCDM tool oriented to specifically assessing sustainability by using the Integrated Value Model for Sustainability Assessment (MIVES). The MIVES approach allows minimizing subjectivity in decision making while objectively integrating economic, environmental and social factors. In this paper, a new sustainability assessment model, which has been specifically configured to analyse social parameters for high-rise residential buildings, is presented. The findings show that most of the RHRB aspects positively affect the characteristics of the buildings and surroundings, while also affecting the psychological needs of humans.

1. Introduction

At present, over half of the global population lives in cities. In 1950, 30 % of the world's population lived in urban areas. The percentage of these residents increased by 47 % in 2000 and is expected to reach 60 % by 2030 [1]. The World Commission on Environment and Development formally introduced the term “sustainability” through the Brundtland’s Report ‘Our Common Future’. Sustainable development includes three categories: society, environment, and economy, which affect each other and, as the result, enhance the life quality [2]. There is an increasing need for growth as well as increased density in urban areas; nevertheless, due to scarcity of land and its cost, especially in mega cities, developers and builders have no alternative but to build up high-rise buildings (RHRB, hereinafter) [3]. There are also researchers, urban planners and stakeholders that consider that RHRBs make an essential contribution to urban life and, for this reason, should be promoted [4]. According to



some studies, for example [5], the economic returns of sustainable buildings has been proven. The results of the research provide an insight into the exploitation of the housing market in a country, but the policy implications of the economic return on investment in the real estate market may be widespread for emerging markets.

Evidence suggests that high-rise housing can be a successful built form as long as appropriate management practices and allocation policies are implemented, and the problems of providing reasonable comfort conditions at affordable levels of expenditure on fuel are addressed [6]. RHRBs have many benefits for investors. For instance, the overall cost of land, preliminaries, foundations, and roofing is much lower for high-rise buildings when compared to single story horizontal developments of the same magnitude. Maximum utilization of land, enable to build more on a land parcel as compared to a low-rise. Land is at a very high premium in almost all cities of the world and therefore, high-rise is the only feasible option. RHRBs are suitable for countries with limited land because the price of the land is expensive. For example, island countries such as Japan, Trinidad and Tobago have limited space for radial or horizontal expansion. In Japan, shortage of land is solved by building manmade islands (filling) which are stabilized for building.

On the one hand, negative effects, from the social point of view, of living in RHRB can be grouped within five categories: crime and informal social control; mental health; impacts on families and children; and physical health effects [7]. High-energy consumption for construction in height, for the elevators system (up to 15% energy consumption of the entire building), and for maintenance and cleaning-up the building could be the main drawbacks from the environmental point of view. Finally, negative impacts on urban scale (windstorms, wide shadow, and lighting prevention) should also be taken into consideration.

On the other hand, positive effects, from the social point of view, of living in RHRBs can be grouped within three categories: provide a complete set of amenities; high density and aesthetical qualities; and compressed cities and reduced transportation. Positive effects, from the environmental point of view, of RHRBs can be grouped within three categories: compact cities and reduced volume of urban infrastructure networks; optimal land use due to population concentration, reduced urban and suburban development and reduced damage to the environment; the potential of creating a mixed-use building. Indeed, RHRBs are the natural response to expensive and scarce land and dense population [8,9].

The objective of this conference paper is to present a new sustainability assessment model based on MIVES method particularly oriented to RHRBs emphasizing the social indicators. The MIVES method can be used to assess viable solutions for sustainability while considering economic, environmental and social requirements. Previous studies are mostly focused on environmental and economic sustainability assessment of RHRB, social aspects having been set aside. Nonetheless, published research [7] states that negative social and psychosocial issues are related to RHRB and, therefore, the social requirement must be urgently introduced and objectively considered into sustainability studies.

2. Methodology

A holistic approach was used in this paper to present a general model for social sustainability assessment of RHRB. Four phases are needed to develop the method: (1) data collection; (2) data analysis; (3) model design; and (4) model application, as shown in figure 1. Phases 1 and 2 are done, and Phase 3 is currently in progress. In the data collection phase, the necessary information on RHRBs was obtained through comprehensive literature reviews, recovery reports, surveys, and high-rise guidelines. In the data analysis phase, the characteristics of RHRBs were defined. Then, the defined characteristics were assessed to distinguish the negative and positive points according to their strengths, weaknesses, opportunities, and constraints as mentioned in the collected data. In the model design phase, the requirement tree is based on the local characteristics of the case study and its demands. In the model application phase, the weights of the indices will be evaluated by a group of multidisciplinary experts by means of the analytical hierarchy process (AHP) [10], based on previous studies and local characteristics. In this research, the Integrated Value Model for Sustainable

Assessment (MIVES) method, a multi-criteria decision-making (MCDM) system is presented as a model to support decision-makers in selection of the most preferable alternatives in terms of sustainability. In order to use the best method in this research, other methods for assessing sustainability have been analysed as presented in table 1 [11-16]. In the MIVES method, building evaluations are carried out based on the following steps:

- First, the problem is defined. This step usually involves designing an engineering system in line with sustainability criteria.
- In the second step, the requirement tree is designed. The tree is a hierarchical scheme in which the different characteristics of the product or process to be assessed are defined in an organized way. It normally has three levels: requirements, criteria and indicators. Then, weights are assigned to the requirements, criteria and indicators and a value function is defined for each indicator.
- In the next stage, different alternatives are evaluated by means of the model and a sustainability index is obtained for each one of them.
- In the final step, the alternatives are ranked according to their index and the best ones is selected.

By using the proposed model, the resulting buildings are more sustainable, because all three dimensions of sustainability are simultaneously analysed. Using MIVES method, the alternatives can be compared according to the relevant criteria and sub-criteria, this is very significant, and the decision-making process is most readily done for decision makers and stakeholders. MIVES enables the alternatives to be compared regarding different criteria and sub-criteria [17] and this is very significant in this research. By means of the weights, it is possible to express the importance of the criteria and prioritize them. For instance, if the weight of the criteria A is 50% and the weight of the criteria B is 25%, the importance of the criteria A is twice the importance of the criteria B. Most importantly, MIVES method can be combined with other decision-making methods such as AHP and Delphi. Hence, the chosen method is MIVES because this model can evaluate the criteria and identify the most important indicators. MIVES can solve a number of decision problems based on a specific set of decision criteria. MIVES is a MCDM model to support decision-makers in selecting the most preferable alternatives in terms of sustainability.

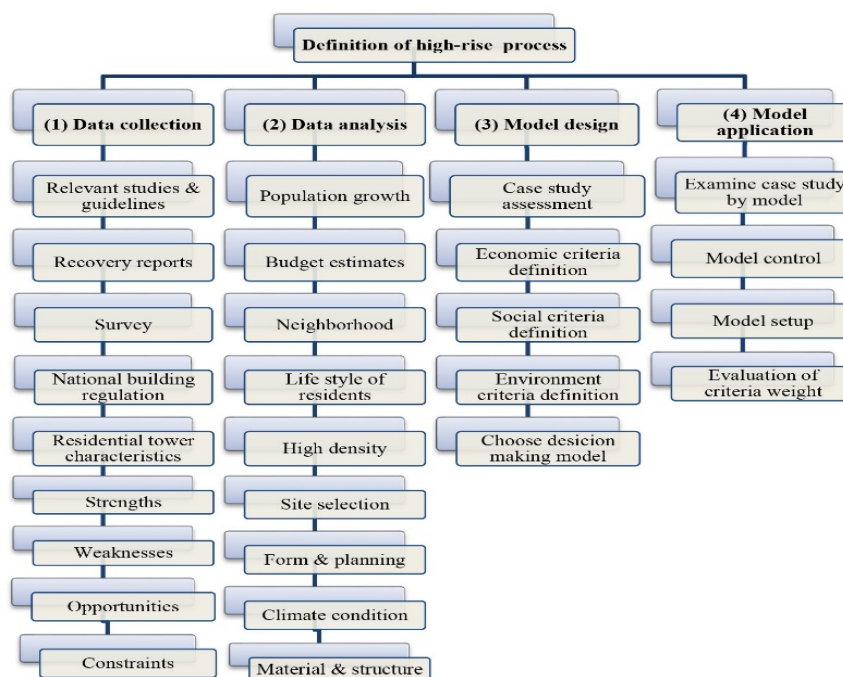


Figure 1. Method for sustainability assessment based on MIVES adapted from [17].

Table 1. Review of methods that can be used to assess sustainability ([11-16])

Method	Description	Advantage	Disadvantage
MCA	Multi Criteria Analysis (MCA) is a decision-making framework to evaluate a problem by giving an order of preference for multiple alternatives based on several criteria that may have different units.	<ul style="list-style-type: none"> - Possibility of weighting the criteria. - Single score for overall evaluation. - Use of criteria with their own dimensions 	<ul style="list-style-type: none"> - The subjectivity of the weighting step that is needed to value the different criteria. - Difficult inter-comparison of case studies - It relies on input from experts and stakeholders.
LCA	LCA is a multi-criteria analysis for compiling and evaluating the environmental impacts of a product over its entire life cycle.	<ul style="list-style-type: none"> - Optimization of the procurement process. - Improvement of the return on investment. - Avoidance of problem shifting to other issues or areas, comprehensiveness through ‘cradle-to-grave’ approach. 	<ul style="list-style-type: none"> - Uncertainty in the decision process. - Complex process that requires considerable time and data input. - Dependence of normalization on reference scenario. - Difficulties in interpreting the results.
Delphi approach	Delphi Approach is suitable for building assessment themes that are considered multidimensional and require a consensus-based approach	<ul style="list-style-type: none"> - Possibility to use a questionnaire. - Interdisciplinary approach (architects, engineers, project managers, and building surveyors). 	<ul style="list-style-type: none"> - Guidelines for determining consensus, sample size and sampling techniques. - Time delays between rounds in data collection process (multiple data collection, analysis, processing). - It can be time consuming.

3. Sustainability assessment of high-rise residential buildings

According to MIVES, a requirement tree was developed to assess the sustainability of RHRB based on data collected from an extensive technical literature review and seminars with multidisciplinary engineers and architects who are expert in this subject. First, in order to better understand the process of MIVES, the general requirement tree is presented in figure 2. The first level of the tree includes the environment, economic and social requirements; the second hierarchical level includes eleven criteria; and the last level includes twenty indicators. Unlike the requirements and criteria, the indicators are measurable variables to quantify each alternative building. The Environmental requirement (R1) assesses the environmental effect of the building during its entire life cycle. Indeed, it assesses both of the positive and negative impacts that can be generated on the surroundings of a RHRB. The economic requirement (R2) measures the economic impact of a RHRB, both direct and indirect, during the entire life cycle. The economic requirement aims to minimize the cost of project construction and project maintenance. The Social requirement (R3) assesses the social effects on residents, pedestrians and people that works or live in the surroundings.

4. Criteria of social sustainability

4.1. Safety

The first Fire safety engineering is concerned with the prevention of fire risk and the promotion of safety. To this end, fire safety engineers have a large array of fire safety measures at their disposal, including building layout, alarm systems, pressurized stairs, fire doors, evacuation lifts, passive fire protection boards and sprinkler systems, to name a few. Arguably, all of these safety measures reduce

the fire risk, or at the very least can generally be considered not to worsen the safety level [18]. One of the most challenging issues in earthquake engineering is structural damage determination, monitoring and resistance in earthquake conditions. Earthquakes cause damages to structures and can result in great human casualties and economic loss. A fraction of the kinetic energy released from earthquakes is transferred into buildings through soils.

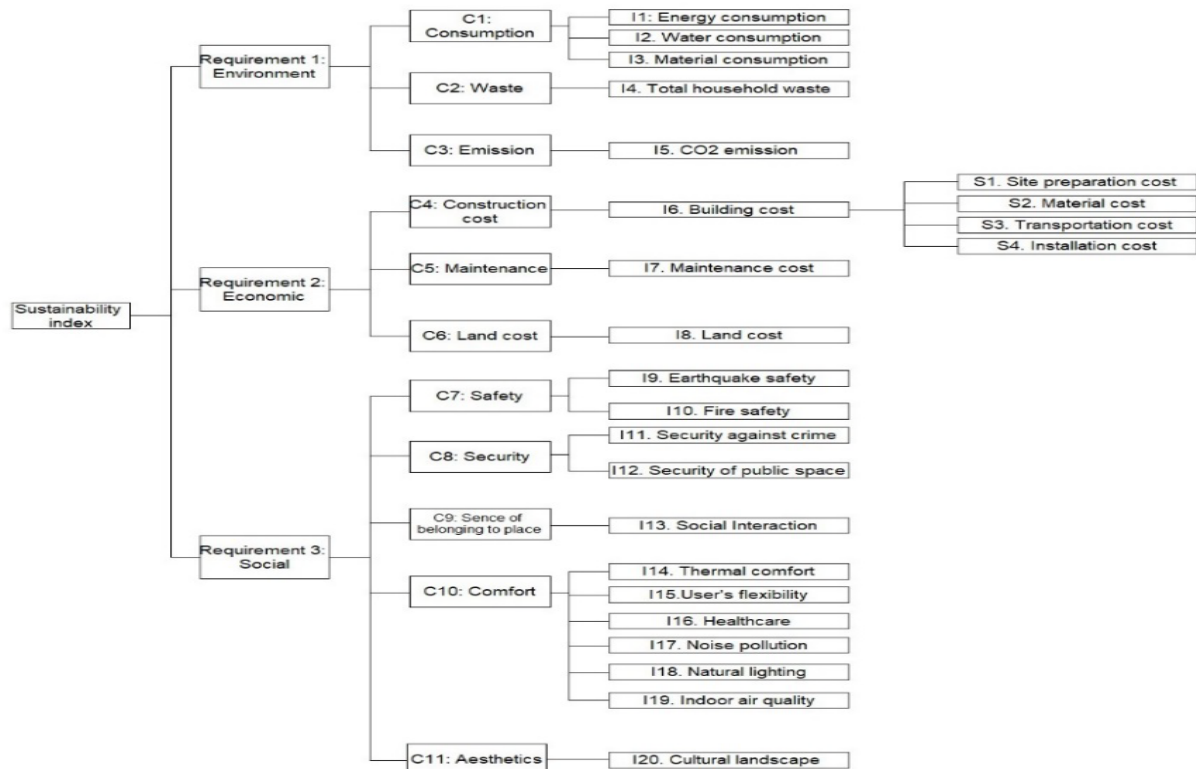


Figure 2. General requirement tree

4.2. Security

Social spaces in contemporary tall buildings tend to be highly secure environments, whereas in the past, staircases and dark corridors had been places of crime and fear. Since the reduction of crime and the fear of crime in RHRB is important for inhabitants, the public entrances of these type of buildings should be controlled. This encourages people to use common facilities in which they are likely to encounter only other resident families. Peace and security from crimes are important objectives the house design should achieve to protect the users in internal or external spaces. Communal spaces such as streets become unsafe for play and other activities due to the fear of encountering a speeding vehicle. In case of RHRB, all social spaces and units are safely within the confines of the building, with no threats of vehicular traffic.

4.3. Sense of belonging to a place

Sense of place has been argued to be affected by density in terms of how it affects the appearance and aesthetics of the physical environment. Factors that can affect the sense of belonging to a place can be categorized as presented in figure 3.

4.4. Comfort

Comfort has traditionally been studied from the perspective of the physics of the environment and the physiology of the occupant, in terms of three factors: thermal comfort, acoustical quality and air quality. Comfort is mainly used as a proxy for occupant satisfaction or a comfort provision. However,

comfort standards are derived from group-level laboratory data and may not reflect the full range of individual comfort zones that is typically found in a real world building [19].

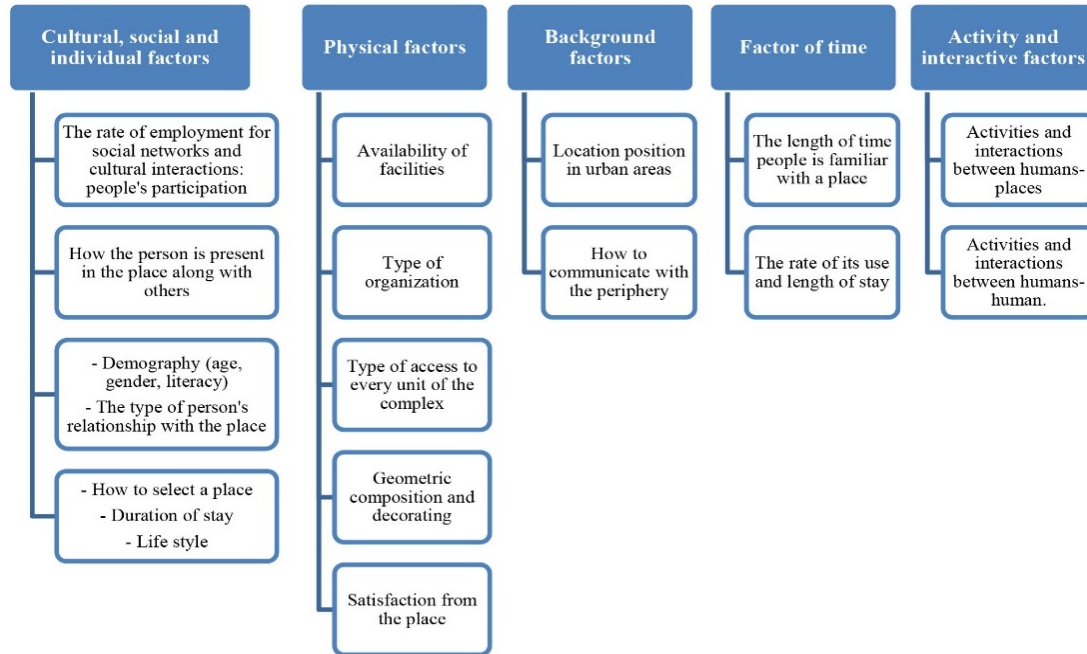


Figure 3. The parameters in sense of belonging to place

4.5. Aesthetics

Vitruvius, who lived in the 1st century B.C., developed aesthetic concepts in his book “De Architecture” in architectural education. Such principles as Stiffness (Firmatias), Utility (Utilitas), and Beauty (Venustas) are used as assessment criteria, which are also applicable today. Vitruvius, in his work titled “Ten Books in Architecture”, has highlighted that essential principles of architecture include order, integrity, rhythmic movement, symmetry, proportion, compatibility, and economy [20].

5. Definitions of social indicators

The Social requirement (R3) assesses the social effects on residents. The health and welfare of people are prioritized above any other consideration. The indicators are defined next:

- *Earthquake safety indicator (I9)* evaluates the strength of the building against earthquake.
- *Fire safety indicator (I10)* assesses the durability of building structures against fire, based on comparing minimum international fire resistance times.
- *Security against crime indicator (I11)* evaluates the security system against crime, level of security in each residential space, protection of residents’ privacy and safety from external threats.
- *Safety of public space indicator (I12)* assesses the sense of safety in the public space.
- *Social Interaction indicator (I13)* evaluates social relations and neighbours’ interactions-participation. Social interaction between family members, and allowing children to play without disturbing their neighbours could be easily encouraged through courtyards and semi-private domains.
- *Thermal comfort indicator (I14)* assesses heating, ventilating and air conditioning (HVAC) system for satisfaction of residents.
- *User’s flexibility indicator (I15)* evaluates the flexibility of the spaces for the satisfaction of the residents. For instance, flexible and changeable layout, space for resident’s autonomy and

participation, open and semi-open spaces, privacy and spatial hierarchy of spaces, natural and green spaces, multi-functional spaces and the quality and breadth of the input spaces.

- *Healthcare indicator (I16)* includes the following components: appropriate sanitation -mental and respiratory health- mental and physical health. Healthcare levels are divided into four categories: (1) Hygiene, (2) Environment and health, (3) Mental Health Effects, (4) Physical Health Effects.
- *Noise pollution indicator (I17)* evaluates the noise pollution and its impact on RHRB. ‘Unwanted sound’ is the definition of noise, which is seen as an environmental stressor and aggravation. It aggravates the comfort conditions of the occupants, changes social behavior and causes annoyance. Noise pollution is one of the determinants of the quality of residential environment.
- *Natural lighting indicator (I18)* refers to the utilization of natural light by utilizing sustainability techniques. This indicator alludes to the utilization of natural light by utilizing sustainability strategies.
- *Indoor air quality indicator (IAQ), (I19)* assesses the air quality within and around buildings and structures, especially as it relates to the health and comfort of residents of the building.
- *Cultural landscape and cityscape indicator (I20)* assesses the viable factors in the design of landscape and cityscape. Cultural landscape puts forward that the belonging, social position, respectability, the intellectual aesthetic satisfaction necessities of the individual will be met.

6. Conclusions

Based on a review of the literature on high-rise residential buildings, it is concluded that the social dimension of sustainability is the less studied from the three dimensions (social, environmental and economic) in RHRB. Therefore, there is a need for research on this area in order to improve the decision-making in the design of RHRB. In the model considered in this research, social criteria are very important because much of the earlier studies have focused on economic and environmental issues, ignoring the fact that the dimension of social sustainability has the greatest impact on the satisfaction of residents. This way, with increased satisfaction, return on investment will be faster.

Residential social criteria are effective for assessing human relationship with physical environment (housing). Establishing social interactions with other neighbours is very important in separating residents from psychological pressures even for a short time.

This paper highlights the social sustainability aspects. In this paper, a new sustainability assessment model, which has been specifically configured to analyse social parameters for RHRB has been presented. This model takes into account the following aspects: maximizing the well-being of residents in RHRBs, minimizing the negative impacts on inhabitants, and focusing on the parameters that affect social sustainability. This research defines an assessment model based on the MIVES methodology, which has been demonstrated to be an effective strategy to conduct multi-criteria decision processes for a sustainability analysis of each alternative. This tool, with its many features, helps decision makers to choose the best solution for designing such buildings. In addition, this tool enables the single score for overall evaluation, the comparison of the design alternatives and its prioritization while minimizing the subjectivity in the decision-making process. The proposed model:

- Assists decision makers in observing and comparing the sustainability value of all alternatives.
- Presents a generic requirement tree that can be applied to any design of RHRB because the sustainability criteria are the same. However, some indicators and weights should be adjusted according to the specific analysis of the case study.
- Suggests that social sustainability has an overlap with other aspects of economic and environmental sustainability. The five criteria to be considered in the design of RHRB to move towards social sustainability are safety, security, sense of belonging to a place, comfort, and aesthetics.

The findings show that most of the RHRB aspects positively affect the characteristics of the buildings and surroundings, while also affecting the psychological needs of humans. The concluding outcome of this paper is that the social sustainability principle can be a guideline to help increase the satisfaction of residents in design of RHRBs. One of the reasons for examining the issue of sustainable development from the social aspect is that, Studies on RHRB have focused on energy consumption efficiency more than studying the social and cultural dimension. Therefore, this study aims to focus on the dimension of social sustainability.

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