A Novel Combination Scheme of the Modified TOPSIS and ITARA in Housing Assistance and Building Assessments

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Abstract: - Disasters chatter properties and fragilize their safety and sustainability. Whether man-made or natural hazards, they render the buildings' habitability, functionality, and operationality inappropriate. Thus, stakeholders directly assess the damages and plan for adequate and accurate housing support of the surveyed blocks. These plans and strategies cope with the complexity of the occurring problems and highlight the support priorities and their types for a set of damaged buildings. Therefore, combining multi-criteria decision-making tools and implementing their techniques in defining suitable measures is of paramount necessity. This paper presents a modified approach for the combination of ITARA and TOPSIS while coping with the RRP and standardizing approaches. To the best of our knowledge, the proposed combination scheme is a novel approach to categorizing distressed buildings regarding their required assistance, priorities, rank reversal problem, threshold criteria, and alternatives.

Keywords: - Building assessment, buildings sustainability, decision-making, disaster deficiencies solutions, housing support, ITARA, MADM, MCDM, RRP, RTOPSIS, TOPSIS

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Nomenclature
DM: Decision Maker
ITARA: Indifference Threshold-Based Attribute Ratio Analysis
MADM: Multi-Attribute Decision-Making
MCDM: Multi-Criteria Decision-Making
MODM: Multi-Objective Decision-Making
NIS: Negative Ideal Solution
PIS: Positive Ideal Solution
RRP: Rank Reversal Problem
TOPSIS: Technique of Order Preference by Similarity to Ideal Solution

1 Introduction

Disasters menace the citizens' lives and challenge stakeholders to improve their buildings' sustainability to withstand these uncontrollable forces. Catastrophes' resilience is crucial to saving inhabitants who are prone to these forces. Whether a natural disaster, inadvertent collapse, or intentional destruction, decision-makers (DM) mitigate the caused damages by assessing the properties and making decisions to maintain their sustainability, [1]. Therefore, DMs follow a bold guideline to score the construction criteria and to prioritize and organize housing support. Thereby, the unified criteria matrices and weight are regarded to lay the foundation for decision-making, [2], [3]. In light of literature reviews, the main weakness of the MCDM tools is their rank reversal problem, where the final decision is subject to the considered criteria and alternatives. Thus, the proposed modification for the combined methods grants their resistance to modification in the decision-making matrices, [4] – [8]. While the modified ITARA determines weights, its threshold alternatives segregate between alternatives' required support in TOPSIS. This paper highlights the main criteria in the aforementioned MCDM problems and determines the acceptable management method for the situations, [9] – [17].

2 Criteria Identification

The foundation stone for the buildings' assessments and repair is their adequate condition assessment. Surveyors have to clearly examine and estimate the damage severity after a disaster. As aforementioned, several criteria shall be assessed and considered to determine whether or not a distressed building requires demolishing (in major damages) or retrofit/repair (in minor distressed conditions). While the safety and sustainability of a property are vital for design acceptance and implementation, these latter shall not be constrained by distress or catastrophe, [18], [19]. Each DM shall assess, test, and declare the severity of damages solely in his/her specialty field. Then, when combining the preface of the multiple fields, the final decision is thereby consistent and exact, [20]. To score each criterion, experts shall apply visual inspections and non-destructive tests to gather their expertise and observations and reflect their status in the method's process, [21] – [30]. Building distresses are usually a consequence of the asset's lack of maintenance, extreme loading conditions, and their design mismatch with standards and codes, [31] – [39]. However, whether the assessed block is deficient or represents no visual sign of distress, experts shall cover the following:

a) The damage record of the building.
b) The past experienced disasters.
c) The aging factor of the construction.
d) The residual strength of the concrete and structural skeleton.
e) The serviceability's reliability of mechanical and electrical systems.
f) The detected distresses and their rate.
g) The reinforcement and soil conditions.
h) The suggested plan for rehabilitating and retrofitting or strengthening the block.

Referring to the commonly applied assessment strategies, [40] – [50], two types of studies were detected:

- Partial (where a block section/ part is considered).
- Complementary (where a detailed investigation of the several sections is mandatory for decision-making).

The first type is not adequate when planning for housing support for a set of alternatives, it may be applied for esthetic purposes of minor deficient fields, [51]. Thus, is never compliant with standardizing the assessment, and the MCDM poses a hazard. On the contrary, the second type is accurate however its complexity rends its application time-consuming and expensive. Therefore, the proposed method shall overcome these latter cons and bridge the interest gap between property shareholders, contractors, NGOs, government, and building occupants, [52], [53]. The conflicting interests and visions interfere with the implementation of the topology and sometimes they made decisions. MCDM shall conclude the support priorities and type for each asset, [54].Even though most of the literature denied MCDM approaches, these methods reveal the appropriate status of the stakeholders' interests and the assets' performance. Consequently, referring to the selected criteria and their contribution to MCDM as depicted in Figure 1, DM defines the consistent pairwise comparison matrix, [55], [56]. The frequently occurred criteria in MCDM in the studies are:

a) Cost;
b) Health, age, and safety;
c) The physical condition of the property;
d) Occupancy;
e) The executed maintenance;
f) Sustainability.

Fig. 1: Multiple criteria decision analysis steps.

The MCDM is based on these fundamental attributes to prioritize and differentiate among distressed properties, [57]. Cost or allocated budget shall not interfere with the support of the block since it affects the entourage and its occupants may not be reimbursed for their living outside it. Additionally, even if the NGO and government can invest the budget in helping multiple assets instead of severely deficient ones, this monetary limitation shall never deprioritize the assistance and services, [58].

Therefore, this criterion is neglected in the decision-making process for the delivery date for the final model, [59], [60]. The occupancy of the building variates the rapidity of response. As previously mentioned, this work aims to simplify the assessment process and later on the MCDM. Derived from the subsequent literature out-turns, [61]-[74] the selected criteria for the MCDM while assessing a damaged building are as represented in Table 1. These criteria are considered to benefit criteria, meaning that their highest score reflects their best condition and vice versa, [75], [76].

Table 1. Identified Criteria for Decision-Making on Building Services through Literature Review.

Criterion	**Definition**
Code Compliance	Compliance of the complex system with the most current building codes (in other words: compatibility of subsystems and their compliance with their relevant standards).
Structural Condition and Safety	Existing conditions (based on the concrete, the foundation, the design, the soil, and loading factors) of the property during the decision-making process for the maintenance activity in addition to the threats to health and safety posed by the distressed concrete building.
Electrical Condition	Existing condition and the safe operational status of the property during the decision-making process for maintenance.
Mechanical Condition	Existing condition and the safe operational status of the property during the decision-making process for maintenance.
Habitable and Aesthetic Conditions	Existing condition (including paints, cladding, windows, doors, housewares, etc.) of the property during the decision-making process for maintenance.
The severity of Past Experienced Damages	If the asset has been damaged by previous hazards and hasn't been adequately served (retrofitted or maintained).
Occupancy	Purpose of the building occupancy where the equipment is located, such as classroom, lab for research, office, meeting space, living quarters, or parking, etc.
Lack of Sustainability and Building Aging Factors	Impact of the lack of preventative maintenance practices for asset sustainability and the aging factor of the structure.

3 MCDM Approach

To select the suitable and convenable MCDM tools, DMs have to clarify their intentions whether for the objective (MODM), attributes (MADM), or their combination, as well as regarding the adopted solving method whether outranking, value-based, or choosing by advantages, [77]. Regarding the topic and the implementing parties, housing support prior to a catastrophe shall be based on the test results for the main attributes and the outranking to find the pairwise comparison, [78].

The implementation of TOPSIS and a reliable weighing mechanism will lead to the prioritizing and classification of the alternatives, [79]. To enhance the ranking based on the distances to the optimum solution, TOPSIS was developed.

The RRP is found in the procedure independently of the TOPSIS chosen approach. García-Cascales and Lamata suggested in [40] the alteration in the normalization of the matrices to free the results and distances from their relation with the variable alternatives. In light of this approach, in addition to the work of Mufazzal and Muzakkir in [80] concerning the calculation of each alternative's distance from the optimal option inside a range of certain decision problems and computing the proximity index, the Max normalization approach divides the performance ratings by the highest performance rating of each criterion j, noting that x_{ij}^{max} refers to the best threshold alternative, [81], [82]:

$$n_{ij} = \frac{x_{ij}}{x_{ij}^{max}}, \text{for } i = 1, \dots, m;\ j \in \text{Benefit} \quad (1)$$

$$n_{ij} = 1 - \frac{x_{ij}}{x_{ij}^{max}}, \text{for } i = 1, \dots, m;\ j \in \text{Cost} \quad (2)$$

The decision matrix is modified to include threshold alternatives that will reflect the least and best situations in addition to the intermediate sectional phases, [83]. After selecting the appropriate version of R-TOPSIS, TOPSIS extended to RRP, weighting methodology shall be identified. ITARA, the enhanced indifference threshold-based attribute ratio analysis technique generates the weights in a consistent and RRP-independent approach, while TOPSIS is employed to obtain the other levels, [84], [85]. On the other hand, several combinations founded the work and MCDM of multiple DM. For instance, ITARA, the indifference threshold-based attribute ratio analysis, in combination with TOPSIS suits the weight identification aims of the researchers, [86]-[90]. ITARA-TOPSIS grants indicating, evaluating, and solving the problem in the process of taking decisions and managing the situations. The indifference threshold-based attribute ratio analysis (ITARA) method can produce more dependable weights for the MCDM factors that enable the DM to categorize and prioritize the buildings' services. The suggested model improves the model's ability to analyze while addressing some of the drawbacks and restrictions of earlier MCDA models, [91], [92]. The following is a list of this model's novel characteristics:

1. ITARA method with the extensions and improvements of the TOPSIS technique will highlight the results and solutions in a sustainable, yet reliable process.
2. ITARA method effectively identifies critical threshold parameters to facilitate selecting the suitable service for the damaged building while overcoming the risks and uncertainties.
3. Engineering data from expert surveys and assessments serve as the foundation for the input data and affect the MCDM's efficacity in the post hazards assets assessments.
4. The results of the selected combination are robust where the risk factors are tamed.
5. The threshold values indicate the level of permissible dispersion among services and discriminate among their status. When there is a difference between two adjacent service modes that is either less than or greater than the threshold, it indicates that the DM shall consider different tactics and processes.
6. While the ITARA scheme only takes into account the distance between services and thresholds, TOPSIS will prioritize the alternatives.

ITARA is also modified since the considered alternatives will only be threshold alternatives to enable DMs to generate and generalize a unified weighting for the different criteria and situations, [93]. After assigning weights, Classical TOPSIS is modified to cope with RRP by introducing five new alternatives to the original matrix, the best alternative, the worst alternative, and three threshold alternatives, Ap_1, Ap_2, and Ap_3. Those new alternatives are based on the preferences of the decision maker; they can also be based on engineering specifications or codes, [94]. To derive the PIS and NIS, respectively, the best and worst alternatives will be used as references. Accordingly, to the logic behind the indifference threshold of the ITARA method, the three threshold alternatives contribute to the comparison with the PIS and NIS and in categorizing the results regarding their required services and MCDM score as illustrated in Table 2.

Table 2. Alternatives Respective Categories.

Score Range	**Action**
$A_{best} > A_i > Ap_1$	Repair
$Ap_1 > A_i > Ap_2$	Repair ASAP
$Ap_2 > A_i > Ap_3$	Demolish
$Ap_3 > A_i > A_{worst}$	Demolish ASAP

The implementation of the proposed method is accomplished in two complementary stages as subsequently represented in Figures 2 and 3.

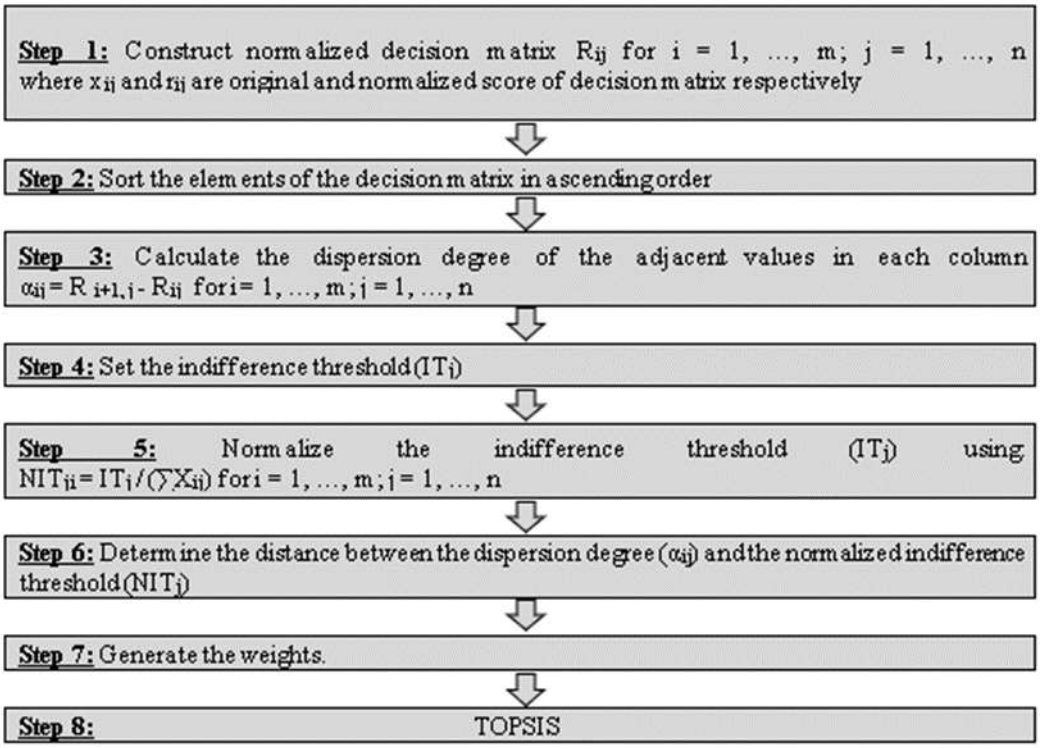

Fig. 2: Stage 1: Stepwise procedure for performing ITARA methodology.

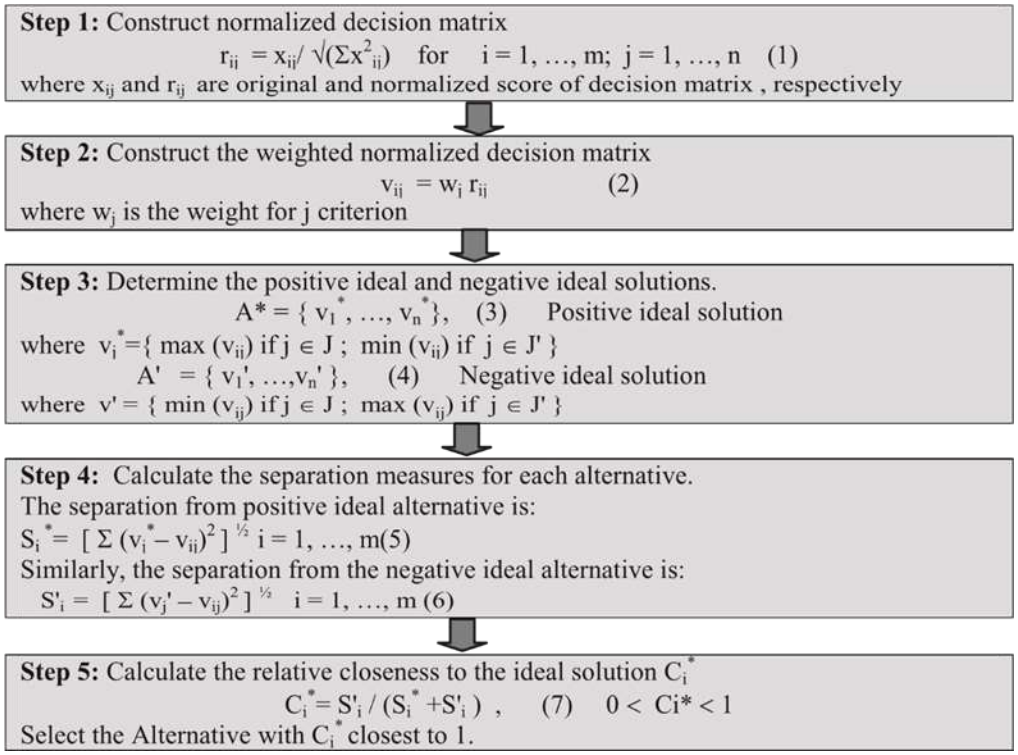

Fig. 3: Stage 2: Step-by-step instructions for using the TOPSIS approach.

Table 3. ITARA Threshold Alternatives.

	Criterion	Code Compliance	Structural Condition and Safety	Electrical condition	Mechanical condition	Habitable and aesthetic conditions	Severity of Past Experienced Damages	Occupancy	Lack of Sustainability and building aging factor
a_{ij}	A_{worst}	20	5	20	10	5	80	10	90
	Ap_3	50	20	40	40	15	65	40	80
	Ap_2	75	60	50	50	50	50	60	40
	Ap_1	90	80	70	70	70	35	80	20
	A_{best}	100	100	100	100	90	5	90	5

Table 4. ITARA Indifference Threshold Alternatives.

ITj	5	5	5	20	30	15	20	35

Table 5. ITARA Weights.

wj	15.71%	19.69%	17.00%	11.30%	7.28%	12.48%	9.33%	7.20%

Regarding the aforementioned, Tables 3 and 4 were integrated to aggregate Table 5.

Notably, ITARA was implemented to determine the different weights for the criteria using the five TOPSIS threshold alternatives, [95], [96]. Then, the performance of each criterion is introduced to the categorization of the three assessed buildings in Table 6. At last, Table 7 was interpreted with the modified TOPSIS to discriminate the support and its priority among distressed properties.

Table 6. Assessment Tests Results.

	Criterion	Code Compliance	Structural Condition and Safety	Electrical condition	Mechanical condition	Habitable and aesthetic conditions	Severity of Past Experienced Damages	Occupancy	Lack of Sustainability and building aging factor
	Weight	15.71%	19.69%	17.00%	11.30%	7.28%	12.48%	9.33%	7.20%
	Objective	MAX	MAX	MAX	MAX	MAX	MIN	MAX	MIN
a_{ij}	A_{worst}	20	5	20	10	5	80	10	90
	Ap_3	50	20	40	40	15	65	40	80
	Ap_2	75	60	50	50	50	50	60	40
	Ap_1	90	80	70	70	70	35	80	20
	A_1	60	73	90	80	40	60	60	50
	A_2	70	56	80	45	75	55	30	70
	A_3	30	35	40	45	15	70	15	80
	A_{best}	100	100	100	100	90	5	90	5
	x_{ij}^{max}	100	100	100	100	90	80	90	90

Table 7. ITARA-RTOPSIS Housing Support for the Assessed Blocks.

	Closeness to ideal		
C_j^*	0.0000	A_{worst}	
	0.2433	A_3	Demolish ASAP
	0.2481	Ap_3	
	0.5249	A_2	Demolish
	0.5251	Ap_2	
	0.6143	A_1	Repair ASAP
	0.7324	Ap_1	
	1.0000	A_{best}	

Before applying any MCDM tool, it is primordial to compare and discriminate among them to contribute to a consistent and adequate selection and categorization. Thus, TOPSIS was chosen with a variation in its normalization to overcome the RRP, [97], [98]. The modification of this technique by adding five threshold alternatives facilitated the classification of the housing and serving assistance. These alterations to the classical TOPSIS emerged in its applications in several fields and by different parties. Thus, even if the alternatives are ranked using the classical basic approach, the thresholds alternatives can reflect their realistic status, [99], [100].

Despite the survey constraints, weighting the decision criteria using ITARA formulated sustainable crisp values for DMs. ITARA application for the added five category thresholds is suitably compliant with the objective approach especially since these latter alternatives are independent of the presently surveyed blocks/properties. Thus, these weights can also be applied in several fields, times, locations, and situations. The DM can directly implement the ITARA outcomes in the modified R-TOPSIS damaged constructions, [101], [102].

In conclusion, in the assessment of Beirut blast damages, this paper not only addressed the appropriate assistance for each Beirut distressed property but performed as a framework for the multiple catastrophes. As aforementioned, adding surplus criteria might turn into a disadvantage for the proposed combined tools and hinder their efficacity, therefore having a wide criteria range will encompass sub-criteria or interests but never alter the MCDM process since DMs assess and scale each criterion regarding their skills, expertise, and background. Applying this scientific survey and scaling enable each DM to consider his/her respective criteria, without variating others. Hence, the group decision-making will separately concentrate on criterion scaling, and the NGO or government after gathering the different scales/ criterion apply ITARA and thereafter the TOPSIS extensions and combinations. Moreover, the rank reversal problem was solved using R-TOPSIS and a Max – normalization technique for the decision matrix. Thus, even if a modification in TOPSIS parameters occurred or an addition of a criterion in ITARA the weight and rank will never be affected, [103].

4 Conclusion and Future Work

The world has witnessed several disasters that produced stresses on the habitability of the built-unit as well as on their residential operations. The assessments of these assets are crucial to check their compliance with international standards and safety codes as well as to identify the accurate and adequate support measures to sustain their functionality. The soil and foundations shall be assigned in the structural condition assessments to ascertain that the base has not been displaced or lowered in level and that the beams and columns resisted the shock waves. These latter assessments shall thereafter consider the concrete quality and status via adequate and scientific approaches. Whether natural disasters or man-made disasters, buildings can be toppled or destroyed due to tension, compression, shear, bending, and torsion forces. These forces not only influence the concrete skeleton of a building but also its internal systems. The electrical and mechanical systems and components are assessed, retrofitted, repaired, or replaced to grant their safe and reliable use. Thereby, the DM can assist in collecting more information about the building's history, occupancy, and

aesthetical criteria. Determining a preset and unified scale and criteria are subjected to the assessments structuring the definition of housing assistance. To conclude, the proposed combination technique is, to the best of our knowledge, the first worldwide in categorizing distressed buildings regarding their required assistance, priorities, rank reversal problem, threshold criteria, and alternatives. For future work, we plan on applying our modified approach for the integration of ITARA and TOPSIS in decision strategies in the context of environmental hazards. Individual households, governments, and international organizations can benefit from our approach to identifying, assessing, and responding to potential environmental threats or risks. In addition, a synthetic aperture radar remote sensing-based service, [104]-[108], can be developed using our innovative decision-making approach to visualize deterioration and displacement in buildings, bridges, and other infrastructure. This service will produce images that can be used for critical purposes such as infrastructure management, disaster prevention, and disaster risk reduction.

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