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Assessing the Adaptive Re-Use Potential of Buildings as Part of the Disaster Management Process

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Abstract**—**The technological paradigm of the disaster management field, especially in the case of governmental intervention strategies, is generally based on rapid and flexible accommodation solutions. From various technical solution patterns used to address the immediate housing needs of disaster victims, the adaptive re-use of existing buildings can be considered to be both low-cost and practical. However, there is a scarcity of analytical methods to screen, select and adapt buildings to help decision makers in cases of emergency. Following an extensive literature review, this paper aims to highlight key points and problem areas associated with the adaptive re-use of buildings within the disaster management context. In other disciplines such as real estate management, the adaptive re-use potential (ARP) of existing buildings is typically based on the prioritization of a set of technical and non-technical criteria which are then weighted to arrive at an economically viable investment decision. After a disaster, however, the assessment of the ARP of buildings requires consideration of different/additional layers of analysis which stem from general disaster management principles and the peculiarities of different types of disasters, as well as of their victims. In this paper, a discussion of the development of an adaptive re-use potential (ARP) assessment model is presented. It is thought that governmental and non-governmental decision makers who are required to take quick decisions to accommodate displaced masses following disasters are likely to benefit from the implementation of such a model.

Keywords**—**Adaptive re-use of buildings, assessment model, disaster management, temporary housing.

I. Introduction

A disaster is "a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources [1]." Among all of the subsequent outcomes of disasters on a society, one of the most sudden, and the one which causes the greatest damage can be considered to be the displacement of mass groups of people which in turn causes large scale sheltering/housing problems. The accommodation solutions for these displaced masses can either take the form of rapidly-deployable solutions (such as tents), or temporary housing in appropriate places (such as post-disaster camps or multi-storey interim houses). Among the various solution patterns, the adaptive re-use of any building or structure to accommodate disaster victims can be a considered as a relatively cheap and quick option.

Adaptive re-use is defined in a number of ways in different contexts. Broadly speaking, adaptive re-use is the act of finding a new use for a site or structure. Industrial buildings, educational buildings, sport centers, warehouses, office buildings, public buildings and many other types of buildings can be reused as residences, retail outlets, training centers, and for many other purposes [2]. Cantell [3] states that adaptive re-use initially emerged as a method of protecting historically significant buildings from demolition. Within this context, adaptation is often described as a "process by which structurally sound older buildings are developed for economically viable new uses [4]." Adaptive re-use became "a viable alternative to new construction and the land clearance of urban renewal" due to growing environmental concern during the 1960s and 1970s [3]. However, there has been limited published research on the adaptive re-use of buildings in the context of sustainability [5]. Building adaptation has also become an area of recent interest in the real estate sector, where it is classified as "*any work to a building over and above maintenance to change its capacity, function or performance [or] 'any intervention to adjust, reuse, or upgrade a building* [6], [7]." ARP is a conceptual framework which requires "*an assessment of physical, economic, functional, technological, social and legal obsolescence*" of a building [8]. ARP describes "the propensity of an asset to be 'recycled' to perform a significantly different function while keeping the basic attributes of the asset in place [7]."

When building adaptation becomes a strategic method of housing displaced populations after disasters, the assessment of the ARP of buildings is critical when making a choice among a set of building alternatives. Because there has been a lack of research on the topic, this paper aims to develop a discussion on the development of an *ARP assessment* model within the disaster management context. After a brief review of the adaptive re-use literature, the following sections of the paper show how the ARP assessment can be formulated as a multi-criteria decision making (MCDM) problem.

II. Adaptive Re-Use in the Real Estate Sector

A. General Overview

In the real estate sector, adaptive re-use is an investment decision that generally arises from the *obsolescence* of existing buildings and may be due to several different factors

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[2], [7], [9]. The adaptive re-use of existing structures "alters and improves physical and economic characteristics of the building, prevents deterioration and obsolescence, reduces the likelihood of redundancy and increases building's lifespan, short-term disuse of building [10]."

According to Vasilache [10], the real estate sector emphasizes three major aspects of adaptive re-use projects: Economic, environmental and social. From an *economic* point of view, the benefits of adaptive reuse are still under debate due to the risks associated with re-use projects. These economic risks include unforeseen expenses, costly interventions or barriers such as non-conformance with governmental health and safety standards [10]. In this context, the upgrading of an existing building may require several interventions concerning: "fire safety, egress provisions, disabled access requirements, smoke-free spaces, air circulation and cleaning protocols, toxic material avoidance and energy performance targets [7]."

On the other hand, the adaptation may not be an economically viable option when a building structure requires extensive strengthening [10]. In building re-use, the durability of the original structure may be considered the most important factor, and any building must be examined to determine if it is both sound and appropriate [11]. From an *environmental* point of view, adaptive reuse projects are seen as a means to use inner city resources and preserve green fields. The social dimensions of adaptation projects have also been highlighted in the literature as many decision makers believe that a vacancy "presents problems of insecurity and social uncertainty and may bring about criminality ranging from vandalism and graffiti to break-ins, illegal occupancy and fires [10]."

Loures and Panagopoulos [12] identified five principles to consider in adaptive re-use projects [13]: "They should:

- perform functions well for which they are redesigned;
- be long lasting and adaptable to new uses;
- respond well to their surroundings and enhance their context;
- have a visual coherence and create 'delight' for users and passers-by and;
- be sustainable – non polluting, energy efficient, easily accessible and have a minimal environmental impact".

Based on qualitative research data, the authors made four recommendations for re-use projects [12], [13]: "The site should not contain groundwater contamination; use concrete buildings if planning an addition; select a building with interior demising walls removed [and] select a building that has financial or development incentives promoting reuse [13]."

B.Assessment of ARP of Buildings in the Real Estate Sector

The ARP of an existing building can be seen as its capacity to meet a set of performance criteria which are prioritized and weighted for adaptive reuse. Accordingly, the assessment of the ARP of a given building becomes one part of a MCDM problem, which necessitates, *as a first step*, the consideration of various evaluation criteria (see Table I). Once a comprehensive list of performance criteria is formed, *the second step* of the process is the creation of a scoring system to assess the building's ARP.

TABLE I
EVALUATION CRITERIA FOR ADAPTIVE RE-USE

Evaluation criteria	Evaluation focus
Economic criteria	The economic alignment of the building asset with business requirements in the market in terms of costs (benefits-costs ratio; operating and maintenance cost; life cycle costs); financial resources; subsidies; exemptions; location, type, quantity and quality.
Functional criteria	The "fitness for purpose" of building assets including considerations of an appropriate and productive working environment in terms of configuration, layout and amenities.
Physical criteria	Physical condition, architectural evaluation; structural analysis; functional changeability, technical difficulties; material and deterioration; refurbishment feasibility; functional performance.
Service criteria	The satisfaction of users with building assets in service and their operating facilities.
Environmental criteria	The wider role of building assets and their impact on the built environment at the natural ecology and community level as well as their specific operational facilities. Criteria related to site layout; environmental impact; environmental quality of surroundings; energy usage.
Social criteria	Compatibility with existing social values; public interest and support; enhanced community; loss of habitat.
Legal criteria	Compliance with building codes; zoning laws; monument status; health and safety; land ownership.

Compiled from: [2], [10] and [14].

Various researchers have focused on the adaptive re-use of buildings and structures in the real estate sector. Tan et al. [2] developed a fuzzy adaptive reuse selection model for decision making when adapting vacant or under-utilized industrial buildings. By using a hypothetical example, they demonstrated the application of the method and its effectiveness for decision making. Geraedts and der Voordt [16] developed an instrument they call a "transformation potential meter" to assess the transformation potential of an asset at both the location and building level. The authors reported that its application in the market "revealed its utility for mapping the potential of given office buildings for transformation into residential accommodation"**.** Wilkinson [7] proposed a predictive model for the preliminary assessment of adaptation potential (PAAM) in existing office buildings which was based on building adaptation events between 1998 and 2008 in Australia. PAAM was developed to be "used by a non-expert to make an initial assessment of a building's general suitability for 'alterations and extensions' adaptations".

III. UNDERSTANDING DISASTER CONTEXT

The motivations behind the adaptation projects in natural disaster cases are quite different from those of profit-oriented decision makers. It is critical to understand the peculiar conditions of such disasters in order to be able to filter out a large amount of adaptive re-use criteria and make the remainder relevant to the temporary accommodation of displaced populations. Beyond survival, the temporary accommodation of disaster victims has several psychological, physical and social welfare dimensions [17], [18]: Bridging the gap until durable housing is available, temporary or transitional settlements "should provide adequate protection against the environment; sufficient thermal comfort, fresh air and protection from the climate; be culturally acceptable; contribute to personal safety and security, dignity, health and wellbeing; enable normal household duties and maximize local livelihood activities".

In the relevant literature, the adaptive re-use of existing structures is classified under the "collective centers" category as one transitional settlement option or typology [18]-[20]. Also referred to as "mass shelters", collective centers are generally located in pre-existing structures such as public buildings and community facilities including schools, barracks, community centers, town halls, gymnasiums, hotels, warehouses, disused factories and unfinished buildings [21]. According to UNHCR [21], "they are often used when displacement occurs inside a city itself, or when there are significant flows of displaced people into a city or town".

Corsellis and Vitale [20] argue that collective centers are especially appropriate for the short-term accommodation of displaced populations "*while their transit to other* [temporary settlement] *options is being arranged*".

Transitional settlement in collective centers may carry several advantages and disadvantages. The advantages are [21]: Disaster victims can be accommodated immediately without disrupting accommodation in the hosting area; "services such as water and sanitation are immediately available, though these may be inadequate if the numbers are large and the need to construct additional structures specifically for the victims is avoided."

There are also many disadvantages since collective centers "can quickly become overcrowded; sanitation and other services can become overburdened; equipment and structure can be damaged; supporting infrastructure of the building (water, electricity, sanitation) will deteriorate quickly from concentrated use..." In addition, the lack of privacy or means of personal protection can also become problematic. Table II shows examples of the technical criteria (or risks) associated with the use of pre-existing structures to accommodate displaced masses.

It appears reasonable to conclude that the use of pre-existing structures as transitional settlement alternatives after disasters (in comparison to the adaptation projects in the real estate sector) requires the consideration, prioritization and weighting of a larger set of quantitative and qualitative evaluation criteria, which makes it a typical *MCDM problem*. Indeed, MCDM methods have been used in a limited number of studies in the disaster management context. Omidvar et al. [15] for example applied a set of MCDM methods to pinpoint the best available options for the geographical selection of temporary sites in Iran and highlighted *the specification of appropriate criteri*a as being the most important matter with regard to the application of such methods.

Table III is a list of factors that decision makers may consider when they make decisions to evaluate the ARP of buildings to accommodate displaced populations after disasters. The authors have categorized about 140 criteria under five sub-titles: *location and land use; architecture; technical; economic; and user-related*. Considering that disaster management is an interdisciplinary field which requires the contribution of professionals from diverse areas of expertise including engineering, design, psychology and management, the acquisition of in-depth qualitative data through interviews in the initial stage of an assessment can be quite instrumental in the refining of the criteria list offered in Table III and the identification of any missing elements. Accordingly, the composition of the experts involved in the weighting of the criteria may change depending on the type and the scale of the disaster.

TABLE II
TECHNICAL CRITERIA FOR ASSESSING THE SUITABILITY OF SITES FOR COLLECTIVE CENTERS [22:109]

Evaluation criteria	Explanation
Structure	The building may not be strong enough to accommodate the number of people; alterations may be required such as partition walls.
Layout, walls and partitions	It must be possible to subdivide the space to permit basic security and privacy.
Water and sanitation	It must be possible to upgrade the existing provision to meet the needs of a high-density population
Energy supply / heating	Lighting must be safe and sufficient; space heating is required in cold climates, which is expensive to install or renovate and to fuel.
Cooking facilities	Family-based cooking is rarely safe and feasible, so facilities and management are required for communal cooking.
Building and equipment safety	The building and services need to be safe (for example, fire escapes, asbestos-free, gas installation, electrical wiring)

IV. EVALUATION OF ARP OF BUILDINGS AS A MCDM PROBLEM

In the management field, a family of tools collectively referred to as multi-criteria decision-making (MCDM) has been developed and made available. The selection of the most appropriate building with the highest ARP from among a set of alternatives can be easily formulated as a MCDM problem. MCDM methods allow for the "investigation and integration of the interests and objectives of multiple actors since the input of both quantitative and qualitative information from every actor is taken into account in form of criteria and weight factors".

The decision making process typically involves five stages as shown in Fig. 1 [22]: Step one is the *problem definition* stage where the actors, the objectives, the constraints and the possible points of conflict in the decision making process and the evaluation criteria are clarified. Step two includes the *assignment of criteria weights*. These weights show the relative importance of the criteria under consideration. Step three includes the *construction of the evaluation matrix*. At the end of this step, the MCDM problem can be assessed in matrix form (Fig. 2), "*where* x_{ij} *is the evaluation given to alternative* i^{th} *with respect to criterion* j^{th}, W_j *is the weight of criteria j, n is the number of criteria and m is the number of alternatives*".

TABLE III
EVALUATION CRITERIA FOR THE ADAPTIVE RE-USE OF BUILDINGS

Location and Land Use	Architectural	Technical (Civil-Mech.- Electrical)	Financial (Economical)	User- Related
Roads and Accessibility	**Design**	**Structural**	**Costs**	**Demography of Victims**
Physical state of the roads	Aesthetics (form, color, texture)	Building height/depth/width	Rental/purchasing cost of land/building	Age of user
Transport	Monumental status	Number of storeys	Establishment/ Contractor/ Construction	State of Health
Ease of access	User capacity of the building	Floor plate size	Operational cost	Gender
Pedestrian access	Ease of access to building	Shape of floor plate	**Finance**	Income
Vehicle access	Way-finding	Regular (rectangular, toothed)	Source of finance (Gov/ NGO/ etc.)	Education (disaster incl.)
Accessibility by heavy trucks	Elevators and staircases	Irregular (trapezoid, L, etc.)		Occupation
Technical Infrastructure	Service ducts and corridors: vertical circulation, service elements, raised floors, etc.	Service core location		Religion
Functioning energy distribution system	**Supportive spaces**	Structural grid: ideal and economical limit of span and fully interchangeable		**Ergonomic needs**
Functioning site drainage system	Availability of Storage areas	Degree of attachment to other buildings		Spatial, furniture, HVAC, etc.
Functioning sewer system	Laundry & Shower	Structure type		**Psychological needs**
Site work - preparation of the site	Common spaces	Reinforced concrete		Level of providing user privacy
Access to network water supply	Leisure time activities	Steel frame		Level of protecting user dignity
Proximity to facilities	Eating and cooking areas	Masonry		Cultural appropriateness of spaces
Parking space	Amount of parking places	Prefabricated		Public acceptability
Proximity to security services	Balcony and terraces	Wood frame		**Physiological needs**
Proximity to healthcare facilities	Atria: open areas, interior gardens, etc.	Other		Sanitary sufficiency (WC, shower, dish washing, laundry)
Proximity to education facilities	**Technology**	Floor strength		Drinking water availability
Proximity to public transport facilities	Natural ventilation: optimized airflow, quality fresh air, increased ambient air intake, etc.	Distance between columns		Type of personal sheltering/accommodation unit
Proximity to public administrative facilities	Natural lighting: inclusion of natural daylight, efficient lighting systems, etc.	Frame		**Social needs**
Proximity to cultural facilities	Orientation: microclimate siting, prevailing winds, sunlight	General structural quality (Durability, stability, fabrics and materials)		**Time scale**
Proximity to green spaces and playgrounds	Acoustic/ thermal insulation (Floor façade openings and roof)	Year of construction		Duration of accommodation
Market proximity	Glazing system (sun & temperature control)	State of foundation		
Proximity to places of worship	Façade and Windows (light & air)	**Electrical installation**		
Distance to monumental buildings and protected areas	**Functional**	Pipes ducts electricity system		
General characteristics of the land	Building's response rate to sheltering function	Generator and fuel tank		
Plot size	Technological convertibility	Ease of maintenance		
Land use	Convertibility: divisibility, elasticity, multi-functionality	Accessibility to shafts & installations etc.		
Commercial, Residential, Industrial, Office and retail, Mixed-use, Educational Land and property ownership Occupation - Multiple or single tenants	Flexibility: space capability to change according to newly required needs, plug-and-play elements, etc. (ability to extend laterally or vertically)	Lightning protection		
Density of occupation/population	Expandability (volume and capacity)	**Mechanical installation**		
Demographic structure of the area	Spatial flow: mobility, open plan, fluid and continuous	Sanitary, refuse and sewage disposal, water supply for the new function		
Health& Safety Environment	**Material**	Type of heating ventilation & AC system		
Solid waste disposal	Durability of materials and components	Water (Potable, storm, waste water)		
Distance to highly damaged areas	Detail Quality of Buildings (performance of the operational elements, such as doors, windows, ceilings, roof members and fascia boards)	Water tank		
Lower vector-borne disease risk	Disassembly: options for reuse, recycle, demountable systems, deconstruction, modularity, etc.			
Proximity to the neighborhoods/homes of affected people	Furniture, household appliances, accessories, fixtures			
Lower disaster risks such as flooding, landslides, etc.	Quality of Material and workmanship			
A suitable distance from hazardous areas	Visual quality / quality of craftsmanship of structure and finishes			
Urban noise pollution	**Health& Safety (Building)**			
Air quality	Fire escape routes, fire alarm & fire extinguishing systems			
Odor	Security and protection			
Ecological footprint	Conformance to access & exit evacuation codes			
Prevailing climate: changing climatic conditions				

Source: Compiled by authors from the literature

Step four includes the “selection of the appropriate MCDM method, where "the data and the degree of uncertainty are key factors for the decision-maker when selecting among several multi-criteria methods”. Finally, step five includes the *ranking of alternatives* to arrive at the final decision.

There are several MCDM methods, and these are usually implemented by specialized software. These methods are used separately or in a combined way, where several criteria and sub-criteria come into play in a decision making process.

A quick review of the MCDM literature shows that the Analytical Hierarchy Process (AHP) has been frequently used by many researchers, in cases where large amounts of decision criteria and sub-criteria can be structured in a hierarchical form for decision making. The use of AHP is illustrated in Fig. 3 as an example of how MCDM tools can be applied to assess the ARP of buildings.

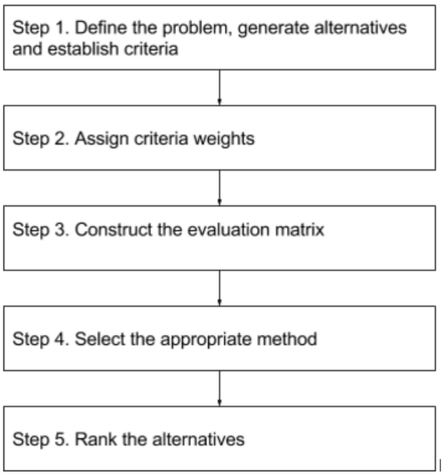

Fig. 1 Process of selecting a building with the highest ARP [22]

Criteria $C_1, C_2, \ldots, C_n$
Weights $W_1, W_2, \ldots, W_n$
Alternatives

$$\begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{bmatrix} \quad \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

Fig. 2 Matrix form of a MCDM problem [22]

Developed in the 1970s by Saaty [23], AHP is commonly used to turn decision makers' (experts') subjective judgments into objective measures in a quantitative form to help individual or grouped decision-makers prioritize alternatives and determine the optimal alternative by using pairwise comparisons. It has been a favorite tool in many fields such as engineering, food, business, ecology, health, and government [24]. Based on the criteria identified in Table III, Fig. 3 illustrates the structure of a sample decision hierarchy targeted at selecting the most appropriate building alternative for adaptive re-use to inhabit displaced populations. According to Fig. 3, there are five main criteria categories to be considered, namely: *Location and land use, architectural, technical, financial and user related criteria.*

Once the MCDM problem has been hierarchically structured in collaboration with a group of experts drawn from different disciplines and public authorities, these criteria can then be scored by a larger group of experts to calculate their relative weightings. The weighting of the criteria by multiple experts will "*avoid the bias decision making and provides impartiality*" [25]. As shown in Table IV, the AHP method "performs pairwise comparisons to measure the relative importance of elements at each level of the hierarchy and evaluates alternatives at the lowest level of the hierarchy in order to make the best decision among multiple alternatives" [24].

The higher the weight, the more important the corresponding criterion is.

TABLE IV
THE FUNDAMENTAL SCALE OF PAIRWISE COMPARISON FOR AHP - THE SAATY [23] RATING SCALE

Intensity of importance	Definition	Explanation
1	Equal importance	Two criteria contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one criterion over another
5	Strong importance	Experience and judgment strongly favor one criterion over another
7	Very strong on demonstrated importance	A criterion is favored very strongly over another
9	Extreme importance	The evidence favoring one criterion over another is one of the highest possible order of affirmation
2,4,6,8	When compromise is needed between the above values	These can be used to express intermediate values.

TABLE V
PAIRWISE COMPARISON MATRIX OF THE MAIN CRITERIA WITH RESPECT TO THE SELECTION OF BUILDING WITH THE HIGHEST ARP

	Location and land use	Architectural	Technical	Financial	User-related criteria	Priorities
Location and land use	1	1/4	1/6	1/4	1/8	0.036
Architectural design	4	1	1/3	3	1/7	0.122
Technical	6	3	1	4	1/2	0.262
Financial	4	1/3	1/4	1	1/7	0.075
User-related	8	7	2	7	1	0.506

* Hypothetical numbers to illustrate the problem are taken from [23].

TABLE VI
PAIRWISE COMPARISON MATRIX OF THE MAIN SUB-CRITERIA WITH RESPECT TO LOCATION AND LAND USE

	Roads and accessibility	Technical infrastructure	Proximity to urban facilities	Priorities
Roads and accessibility	1	1/3	1/6	0.091
Technical infrastructure	3	1	1/4	0.218
Proximity to urban facilities	6	4	1	0.691

* Hypothetical numbers to illustrate the problem are taken from [25]

Tables V and VII show a hypothetical sample AHP output. Table V compares the main criteria (location and land use; architectural; technical; financial and user-related) listed on the left, one by one with each other, with respect to the selection of the building with the highest ARP (main goal). Table VI compares the sub-criteria on the left with the sub-criteria above with respect to the “location and land use” sub-criteria. The sub criteria priorities in Table V are weighed by the priority of their parent criterion 'location and land use' (0.036) to obtain their global priority. Table VII illustrates the synthesis of data from previous tables by multiplying each ranking by the priority of its criterion or sub-criterion and adding the resulting weights. The last column of Table VII shows that Building B has the highest ARP with an overall priority of (0.333), followed by building D (0.262), building C (0.214) and building A (0.193). The AHP also gives a Consistency Ratio (CR). This is an effective measure of the consistency of evaluations made by different decision makers when building each of the pairwise comparison matrices. In practice, if the CR is much in excess of 0.1, the judgments of the experts are deemed not trustworthy, and the pairwise comparisons might then be revised to achieve a higher consistency.

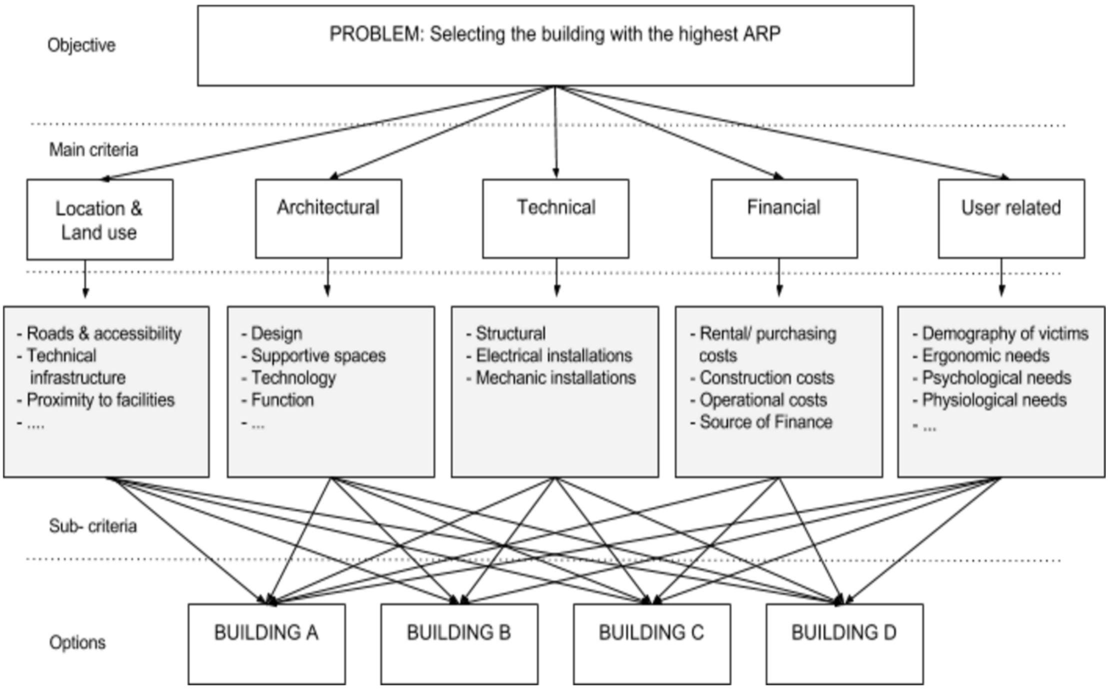

Fig. 3 Structure of a decision hierarchy for selecting the most appropriate building for adaptive re-use

TABLE VII
SYNTHESIZING TO OBTAIN THE FINAL RESULTS

Criteria	Location and land use (0.036)			Architectural (0.122)	Technical (0.262)	Financial (0.075)	User-related (0.506)	Overall priority
Sub-criteria	Roads and accessibility	Technical infrastructure	Proximity to Urban facilities					
Global weights (criteria * sub-criteria)	(0.091)	(0.218)	(0.691)					
BUILDING A	0.003	0.008	0.025	Relative weights of other main and sub-criteria are calculated similarly				0.193
BUILDING B	0.295	0.084	0.062					**0.333**
BUILDING C	0.496	0.055	0.115					0.214
BUILDING D	0.131	0.285	0.249					0.262

* Hypothetical numbers to illustrate the problem are taken from [23]

V. CONCLUSION

The accommodation of displaced masses of people after natural disasters requires quick decision making. The assessment of the ARP potential of buildings can be a critical practice, especially when displacement occurs inside cities, and also when considerable numbers of people may flow into cities. This theoretical paper has demonstrated that the ARP assessment of buildings can be formulated as a MCDM problem. There is a scarcity of knowledge regarding the application of analytical tools to assess the ARP of buildings, and this is true even of the real estate sector, which has totally different motivations when adapting pre-existing buildings. The use of MCDM tools such as the Analytical Hierarchy Process (AHP) or other similar methods within the disaster management context requires the consideration of the peculiar conditions of disaster in question and the technical collaboration of experts from different disciplines. Pro-active approaches in the disaster management field place an emphasis on disaster preparedness with a more holistic and long-term approach. The assessment of the ARP of various buildings in collaboration with the relevant public authorities prior to any disasters should be considered a valuable contribution to such pro-active strategies. The design of digital databases and interfaces which are adaptable to different types of disaster scenarios can also be used to facilitate the collaboration of interdisciplinary teams and significantly shorten the durations of such assessments in a dynamic environment.

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