Does the New 'FIX' Fit? Adaptive Building Reuse Affecting Local Sustainable Development: Preliminary Results

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Abstract
Adaptive building reuse constitutes a major factor for the city resource exploitation, to wit the local sustainable urban development. Economic potential and sustainability in the wake of an adaptive reuse project, given the several variables involved, is an important subject of study. The adaptive reuse of industrial buildings of cultural heritage in particular is known by the wider scientific community to add value to a city. This study attempts to explore all the value-adding parameters of such projects, focusing on the transformation of the old FIX factory into the National Museum of Contemporary Art - EMST in Athens, Greece, namely, the resulting city development, the social and economic effects, as well as the environmental footprint. The objective, based upon a Fuzzy-DEMATEL model analysis, is to identify critical factors influencing the local sustainable development through adaptive industrial building reuse, as well as to assess the direction and level of interaction between them, which will eventually serve as a tool for future decision-making in sustainable city development.

Keywords: adaptive reuse, sustainable development, industrial buildings

Introduction

The adaptive reuse of industrial buildings of cultural heritage is considered to be a pervasive concept. The contribution of the entire notion of what constitutes adaptive reuse, along with the heritage buildings importance assigned, seems to be more explicit in sustainable development than ever. Adaptation outlines renovation or restoration projects which do not entail changes of use (Holyoake and Watt, 2002 as cited in Bullen, 2007a), at least necessarily. Reuse can be translated to something exceptional, exclusive and sometimes even expensive. This paper, in order to approach its research objective, is framed within the following definition of 'adaptive reuse of industrial buildings of cultural heritage'; An industrial building conversion process, to undertake a change of use, retaining as much as possible of the original construction, while upgrading the performance to meet current standards.

As several researchers have highlighted, a quite significant amount of adaptive reuse of industrial buildings of cultural heritage examples exist (indicatively: Ball, 1999; del Pozo, Calderón Calderón, & Ruiz-Valdepeñas, 2016; Haidar & Talib, 2013; Ingalls & Moore, 2001; Shen & Langston, 2010; Mitoula, Theodoropoulou, & Karaki, 2013; *New into Old*, 2017), depicting sustainability in terms of economic impact, social life involvement, energy saving, functionality, etc. (Ijla & Broström, 2015), tending to elevate the matter in a field of scholarly study in its own right. Thus, the more adaptive reuse of industrial buildings of cultural heritage increases as a phenomenon, the bigger is the opportunity to positively affect the sustainable development of natural, social and cultural environments.

As Shen & Langston (2010) state, adaptive reuse of industrial buildings of cultural heritage is considered to be a core principle of the local sustainable development and communities have a lot to gain from such a transformative renewal (Lewin & Goodman, 2013). Accordingly, del Pozo et al., (2016) notes that the preservation field is a growing economy resource with numerous positive side effects. For instance, reuse projects add value into the heritage assets, converting them to be tourist resources that can contribute to urban sustainable development not only economically, but also ecologically, socially and culturally. Likewise, adaptive reuse of industrial buildings of cultural heritage bolsters the life cycle of material and resources and reduces waste by reusing structural elements and recycling materials, while safeguards the world's cultural heritage (Yung & Chan, 2012). This research interest can be attributed amongst others to the global industrial historical identity which involves a shared cultural heritage as well as to the nature and characteristics of building reuse. The article discusses adaptive reuse of industrial buildings of cultural heritage, with a focus in the local transformations of a city, which render, from a sustainability standpoint, new cultural poles of built-up, urban and tourist attraction and recreation.

The current research approaches one of the most famous case studies in the field of adaptive reuse of industrial buildings of cultural heritage in the recent history of Athens, Greece -The FIX Building- in order to examine the extent to which local sustainable development was (/is) influenced as a system of interrelated relationships. Late 1860, given the growing demand, the FIX Brewery moves its infrastructure to Andrea Syngrou Avenue in Koukaki, a southeast neighborhood of Athens with no visible signs of development at the time. Nearly one hundred years later, and in order to meet the opportunities presented by the industrial restructuring and development in Greece, the FIX Brewery administration decides to rebuild the industrial premises.

The new industrial building was completed in 1961. The design, by the architect Takis Zenetos and his colleague Margaritis Apostolidis, in their attempt to create a flexible, capable of changing and adapting to future industrial uses form, embraced the principles of the modern movement in architecture: a dynamic shape with austere linearity in order to give a sensation of the building extending to infinity, long openings to further stress the longitudinal axis and recreate a connection with its environment, open plans, use of clear-cut materials, etc.. Very soon, the new industrial building was destined to be a historic landmark of modern architecture and the city. Unfortunately, ten years later, FIX Brewery production was transferred away from the city center and the building was abandoned. Around 1994, the northern part of the building was demolished to make room for the subway construction works. This act was sharply criticized by architects, urban planner, heritage preservatives and scholars (N. Theodoropoulou, 2018). In 2000, preceded by a number of consultations and considerations the old FIX Brewery was decided to be adaptively be reused as the new house of the Hellenic National Museum of Contemporary Art (EMST) (www.emst.gr/en). The project was assigned to 3SK Stylianidis Architects and K. Kontozoglou, I. Mouzakis & Associate Architects and Tim Ronalds Architects, and was completed late 2014.

Figure 1The FIX Building as a factory (left) and as a Museum (right)

The current study will attempt to address the title pun question in terms of providing a number of reasons as to why the adaptive reuse of industrial buildings of cultural heritage consist of an important element in the entire spectrum of the sustainability concerns. To do so, a Fuzzy-DEMATEL model was applied in order to identify critical factors influencing the local sustainable development through adaptive reuse of industrial buildings of cultural heritage, as well as to assess the direction and level of interaction between them.

The overarching goal set for the scope of the current research is evidently not to invent a brand new way of thinking regarding adaptive reuse of industrial buildings of cultural heritage, but rather to highlight the direct relations among various existent concepts.

Methods

The selected methodological approach for this research had two major steps. Firstly, through an extensive literature review accompanied by field research, a comprehensive list of factors influencing the local sustainable development following the recent FIX Building reuse is proposed. Secondly, using a fuzzy-DEMATEL approach, the interrelationships among the factors are obtained.

Adaptive reuse of industrial buildings of cultural heritage: Generated factors affecting the local sustainable development

Table 1 The factors affecting local sustainable development via adaptive reuse of industrial buildings of cultural heritage projects.

PILLAR	F	FACTOR	Description	Literature
Economy	F1	ECONOMIC GROWTH	• Growing Investorsment • Local Business & Market Creation • Creating Jobs • Taxpaying • Increasing Property Values • Relieved demand on Local Authorities	(Kimball & Romano, 2011)(Moore & Ingalls, 2010) (Yuceer & Vehbi, 2014) (Lewin & Goodman, 2013) (Ijla & Broström, 2015) (Cano, Garzón, & Sánchez-Soto, 2013) (Tam, Fung, & Sing, 2016) (Haidar & Talib, 2013) (Yildirim & Turan, 2012) (Langston, Feng, Yu, & Zhao, 2008) (Loures, 2015) (Greffe, 2004)
	F2	TOURISM (CULTURAL) ECONOMIC GROWTH	• Attractive Cities • Visitors' Sentiment and Architecture • Promoting -cultural- tourism	(Orbasli, 2009)(Cano et al., 2013) (Yuceer & Vehbi, 2014) (Stamatiou, Lacroix, Gekas, & Mastorakis, 2008) (Gholitabar, Alipour, & Costa, 2018) (Agaliotou, 2015) (Wang, 2011) (Prat Forga & Cànoves Valiente, 2017) (Mitoula et al., 2013) (Kostakis, Lolos, & Doulgeraki, 2018) (Kostakis & Theodoropoulou, 2017)
	F3	LOCAL VALUE ENHANCEMENT	• Through their variety, character and a sense of familiarity and safety	(Orbasli, 2009)(del Pozo et al., 2016) (Lewin & Goodman, 2013) (Haidar & Talib, 2013)
Society	F4	QUALITY OF LIFE IMPROVEMENT	• Income Growth • Environmental Quality • Healthy & Hospitable Environment • Health • Safety • Leisure • Resilient and Sustainable city of Residence	(Bullen, 2007b) (Pickard, 1996) (Ijla & Broström, 2015) (Yung, Chan, & Xu, 2014) (Vlek, Skolnik, & Gatersleben, 1998) (Orbasli, 2009) (Langston et al., 2008)(Cano et al., 2013) (Mitoula et al., 2013) (Savvides, 2015)
	F5	COMMUNITY ACTION AND INVOLVEMENT EMPOWEREMENT	• Cultural sites provide programming that examine Homelessness, Poverty, and the need for Social Networks to support Community and inspire people to personal and Collective Action	(Bullen & Love, 2011) (Yung et al., 2014) (Yildirim & Turan, 2012) (Cano et al., 2013) (Maccannell, 2015)
Environment	F6	ENVIRONMENTAL MANAGEMENT	• Climate Change Mitigation • Eco-Building • Energy Efficiency • Renewable Energy Systems • Extending Life Cycle for Buildings, Materials and Resources • Landfill Demolition Waste Reduction • Reduce GHGs • Reduce Resources Consumption • Recycling	(Bullen & Love, 2011) (Langston et al., 2008) (Lewin & Goodman, 2013) (Ijla & Broström, 2015) (Conejos, Langston, Chan, & Chew, 2016) (Mohamed & Alauddin, 2016) (Hu, 2017) (Rodrigues & Freire, 2017) (Orbasli, 2009) (Suridechakul, 2015) (Akhtarkavan, Alikhani, & Ghiasvand, 2008) (Misirlisoy & Günçe, 2016) (Shen & Langston, 2010) (Conejos, Langston, & Smith, 2011) (Vardopoulos & Konstantinou, 2016a) (Vardopoulos & Konstantinou, 2016b) (Vardopoulos, 2017) (Vardopoulos, 2018)
	F7	LAND CONSERVATION	• Reduce Urban Sprawl	(del Pozo et al., 2016) (Lewin & Goodman, 2013) (Langston et al., 2008) (Dorsey, 2003) (Loures, 2015)
Culture	F8	PUBLIC ENVIRONMENTAL AWARENESS & EDUCATION	• Contribution to Educational potential, Cultural Skills and Knowledge • Public Environmental Awareness	(Embaby, 2014) (Sutter, 2008) (Kostakis, Theodoropoulou, & Mitoula, 2015) (Kyramarigiou & Vardopoulos, 2017) (Poulos, Stamopoulos, Vardopoulos, & Theodoropoulou, 2018)
	F9	TECHNOLOGICAL INNOVATION	• Technological Innovation Integration • Recovering Local Traditional Construction Techniques • Maintain Local Memory	(Hein & Houck, 2008) (Papalou, 2015) (Di Giulio, Zaffagnini, Brunoro, Longo, & Piaia, 2006)
	F10	LOCAL MEMORY AND CULTURAL IDENTITY PRESERVATION	• Identity • Diversity • Vitality • Aesthetic Enhancement • Retention of Visual Amenity	(Bullen & Love, 2011) (Tam et al., 2016) (Alias, Zyed, & Chai, 2016) (Misirlisoy & Günçe, 2016) (Lewin & Goodman, 2013) (Tsilika, 2017)
	F11	CULTURAL HERITAGE PROTECTION	• Safeguard the words' cultural and natural heritage • Heritage Preservation • Industrial Past	(Bullen & Love, 2011) (UN, 2015) (Alias et al., 2016) (Plevoets & Cleempoel, 2012) (Zhang, 2007) (Tsilika, 2014)

The questionnaire

The questionnaire was composed with the following five subsections: a: cover letter; b: introduction; c: sort factors description; d: explanations of how to be filled in; e: pair-wise comparisons of the factors. The experts were welcomed, providing their personal opinions, to evaluate the direct influence relationship -if any- and its strength or weakness degree among factors, scoring on a five point scale from 0 to 4. Each score was also expressed as a triangular fuzzy number. Additionally, in order to address the ambiguity of the subjective judgment of the experts, a linguistic variable was employed. The result is presented in Table 2.

For the scope of the current research recipients of the questionnaire were two abundant qualified and experienced experts[1], a government expert and a university scholar.

Table 2 Fuzzy Linguistic Variables

Linguistic Variable	Influence Score	Corresponding Triangular Fuzzy Numbers
Very high influence (VH)	4	(0.75, 1.0, 1.0)
High influence (H)	3	(0.5, 0.75 1.0)
Low influence (L)	2	(0.25, 0.5, 0.75)
Very low influence (VL)	1	(0.0, 0.25, 0.5)
No influence (NO)	0	(0.0, 0.0, 0.0)

The Fuzzy DEMATEL Model

In order for scholars to be able to examine the causal relationship of fuzzy variables and define the degree of interactive influence among them, they use the fuzzy-DEMATEL model which combines the fuzzy theory, holding the fuzzy linguistic aspect, with DEMATEL[2].

The influence factors for the system used in the current research were identified studying a vast amount of the literature in this topic, denoted as F_1, F_2, … , F_{11}.
The basic computational steps of the fuzzy-DEMATEL model taken in the current research, after are presented as follows:

Step A: Develop evaluation variables. First an influence integer score scale ranging from zero to four was developed to express degree of the strength or weakness of the relationship among factors. Then, instead of asking the experts to present their views and determine the direct influence among factors using the integer scale, and in order to address the human subjective view ambiguity, the conventional influence score scale was substituted with a fuzzy linguistic scale. Lastly, triangular[3] fuzzy numbers were used to determine the degree of influence. All the evaluation variables are presented in Table 2.

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[1] Typically individuals with a doctoral degree or at least ten years of experience

[2] The Decision Making Trial and Evaluation Laboratory - DEMATEL is a useful technique for visualizing the structure of complicated causal relationships with matrices or digraphs, employed by Fontela and Gabus in 1971 (Gabus & Fontela, 1972). The DEMATEL model can convert the relationship between the causes and effects of factors into an intelligible structural model of the system (Falatoonitoosi, Leman, Sorooshian, & Salimi, 2013).

[3] Based on the Li and Tzeng concepts (Chung-Wei & Gwo-Hshiung, 2009).

Step B: Collect experts' evaluations. A couple of experts were invited to conduct pairwise comparison in order to evaluate the interactive influence degree among the factors identified by using the fuzzy linguistic scale developed in Step A.

Step C: Receive final report. Through registering and entering all the above stated information about the matter raised to the corresponding pages of the Fuzzy Decision (www.fuzzydecision.com) software website, the final reports are extracted. At this point it should be noted that given certain delimitations -especially computational- set for the scope or the current preliminary research, from the total number of factors, it was possible to examine only three. Thus, through systematic study, it was made possible to reach to the conclusion that the three far-reaching factors to be considered are the F_2, F_5 and F_{11}.

Results and Discussion

The current research used a particular approach as previously described. The factors affecting local sustainable development via 'adaptive reuse of industrial buildings of cultural heritage' projects are presented in Table 1. The evaluation variables developed are presented in Table 2. Two experts provided their thoughts on the direct influence relationship and its degree of strength or weakness among factors using a fuzzy linguistic scale, and the results are presented in Table 3 and Table 4 respectively.

Table 3 Direct Influence Matrix by Expert A

No.	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}
F_1		H	VH	H	L	H	NO	VL	H	VL	VL
F_2	VH		VH	VH	VL	NO	VL	VL	VL	H	VH
F_3	VH	L		H	L	L	L	VL	VL	H	H
F_4	NO	L	H		L	L	NO	L	VL	L	L
F_5	H	H	H	H		H	L	H	NO	VH	H
F_6	L	L	VL	H	L		H	VH	VH	VL	L
F_7	H	VH	VH	VH	VH	VH		L	L	VH	L
F_8	L	L	H	L	H	VH	L		H	VL	L
F_9	H	VL	VL	H	VL	H	NO	H		VL	VH
F_{10}	L	VH	VH	VH	H	VL	VH	H	NO		VH
F_{11}	VH	VH	VH	VH	VH	H	H	VH	VH	VH	

Table 4 Direct Influence Matrix by Expert B

No.	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}
F_1		H	VH	H	L	H	NO	VL	H	VL	VL
F_2	VH		VH	VH	VL	NO	VL	VL	VL	H	VH
F_3	VH	L		H	L	L	L	VL	VL	H	H
F_4	NO	L	H		L	L	NO	L	VL	L	L
F_5	H	H	H	H		H	L	H	NO	VH	H
F_6	L	L	VL	H	L		H	VH	VH	VL	L
F_7	H	VH	VH	VH	VH	VH		L	L	VH	L
F_8	L	L	H	L	H	VH	L		H	VL	L
F_9	H	VL	VL	H	VL	H	NO	H		VL	VH
F_{10}	L	VH	VH	VH	H	VL	VH	H	NO		VH
F_{11}	VH	VH	VH	VH	VH	H	H	VH	VH	VH	

Using the variables scale (see Table2) Table 3 and Table 4 are respectively converted to Tables 5 and 6.

Table 5 Pairwise comparison by Expert A

No.	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}
F_1	**(0.00, 0.00, 0.00)**	(0.50, 0.75, 1.00)	(0.75, 1.00, 1.00)	(0.50, 0.75, 1.00)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1.00)	(0.00, 0.00, 0.00)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)
F_2	(0.75, 1.00, 1.00)	**(0.00, 0.00, 0.00)**	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.00, 0.25, 0.50)	(0.00, 0.00, 0.00)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.75, 1.00, 1.00)
F_3	(0.75, 1.00, 1.00)	(0.25, 0.50, 0.75)	**(0.00, 0.00, 0.00)**	(0.50, 0.75, 1.00)	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.50, 0.75, 1.00)
F_4	(0.00, 0.00, 0.00)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1.00)	**(0.00, 0.00, 0.00)**	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.00, 0.00, 0.00)	(0.25, 0.50, 0.75)	(0.00, 0.25, 0.50)	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)
F_5	(0.50, 0.75, 1.00)	(0.50, 0.75, 1.00)	(0.50, 0.75, 1.00)	(0.50, 0.75, 1.00)	**(0.00, 0.00, 0.00)**	(0.50, 0.75, 1.00)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1.00)	(0.00, 0.00, 0.00)	(0.75, 1.00, 1.00)	(0.50, 0.75, 1.00)
F_6	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.25, 0.50, 0.75)	**(0.00, 0.00, 0.00)**	(0.50, 0.75, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.00, 0.25, 0.50)	(0.25, 0.50, 0.75)
F_7	(0.50, 0.75, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	**(0.00, 0.00, 0.00)**	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.75, 1.00, 1.00)	(0.25, 0.50, 0.75)
F_8	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1.00)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1.00)	(0.75, 1.00, 1.00)	(0.25, 0.50, 0.75)	**(0.00, 0.00, 0.00)**	(0.50, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.25, 0.50, 0.75)
F_9	(0.50, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.00, 0.00, 0.00)	(0.50, 0.75, 1.00)	**(0.00, 0.00, 0.00)**	(0.00, 0.25, 0.50)	(0.75, 1.00, 1.00)
F_{10}	(0.25, 0.50, 0.75)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.50, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.75, 1.00, 1.00)	(0.50, 0.75, 1.00)	(0.00, 0.00, 0.00)	**(0.00, 0.00, 0.00)**	(0.75, 1.00, 1.00)
F_{11}	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.50, 0.75, 1.00)	(0.50, 0.75, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	**(0.00, 0.00, 0.00)**

Table 6 Pairwise comparison by Expert B

No.	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}
F_1	**(0.00, 0.00, 0.00)**	(0.50, 0.75, 1.00)	(0.75, 1.00, 1.00)	(0.50, 0.75, 1.00)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1.00)	(0.00, 0.00, 0.00)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)
F_2	(0.75, 1.00, 1.00)	**(0.00, 0.00, 0.00)**	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.00, 0.25, 0.50)	(0.00, 0.00, 0.00)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.75, 1.00, 1.00)
F_3	(0.75, 1.00, 1.00)	(0.25, 0.50, 0.75)	**(0.00, 0.00, 0.00)**	(0.50, 0.75, 1.00)	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.50, 0.75, 1.00)
F_4	(0.00, 0.00, 0.00)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1.00)	**(0.00, 0.00, 0.00)**	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.00, 0.00, 0.00)	(0.25, 0.50, 0.75)	(0.00, 0.25, 0.50)	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)
F_5	(0.50, 0.75, 1.00)	(0.50, 0.75, 1.00)	(0.50, 0.75, 1.00)	(0.50, 0.75, 1.00)	**(0.00, 0.00, 0.00)**	(0.50, 0.75, 1.00)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1.00)	(0.00, 0.00, 0.00)	(0.75, 1.00, 1.00)	(0.50, 0.75, 1.00)
F_6	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.25, 0.50, 0.75)	**(0.00, 0.00, 0.00)**	(0.50, 0.75, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.00, 0.25, 0.50)	(0.25, 0.50, 0.75)
F_7	(0.50, 0.75, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	**(0.00, 0.00, 0.00)**	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.75, 1.00, 1.00)	(0.25, 0.50, 0.75)
F_8	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1.00)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1.00)	(0.75, 1.00, 1.00)	(0.25, 0.50, 0.75)	**(0.00, 0.00, 0.00)**	(0.50, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.25, 0.50, 0.75)
F_9	(0.50, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.00, 0.00, 0.00)	(0.50, 0.75, 1.00)	**(0.00, 0.00, 0.00)**	(0.00, 0.25, 0.50)	(0.75, 1.00, 1.00)
F_{10}	(0.25, 0.50, 0.75)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.50, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.75, 1.00, 1.00)	(0.50, 0.75, 1.00)	(0.00, 0.00, 0.00)	**(0.00, 0.00, 0.00)**	(0.75, 1.00, 1.00)
F_{11}	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.50, 0.75, 1.00)	(0.50, 0.75, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	**(0.00, 0.00, 0.00)**

Certain calculations were performed in order to extract the results using specific formulas. Table 7 presents the mean of the pairwise comparisons as provided by the experts for the factors F_2, F_5 and F_{11}, along with the formula used. Accordingly Table 8 presents the normalized matrix and the respective formulas used. In Table 9 the total relation fuzzy matrix is presented as well as the computational formulas used. Finally, following further calculations employed using the total fuzzy relations matrices (see Table 9), the influential impact D, the influenced impact R, the degree of importance (D + R) and the causal degree (D - R) values are extracted and listed in Table 10. The defyzzy degree of importance (D + R) and causal degree (D - R) values are shown in Table 11. Lastly, the three selected factors were plotted on the horizontal axis according to the degree of importance (D + R) defuzzy value and in the vertical axis according to the causal degree (D - R) defuzzy value as depicted in Figure 1.

Table 7 Mean of pairwise comparisons

No.	F_2	F_5	F_{11}
F_2	(0.00, 0.00, 0.00)	(0.25, 0.50, 0.75)	(0.75, 1.00, 1.00)
F_5	(0.50, 0.75, 1.00)	(0.00, 0.00, 0.00)	(0.62, 0.88, 1.00)
F_{11}	(0.75, 1.00, 1.00)	(0.62, 0.88, 1.00)	(0.00, 0.00, 0.00)

$$\tilde{z} = \frac{\tilde{x}^1 \oplus \tilde{x}^2 \oplus \tilde{x}^3 \oplus \ldots \oplus x^p}{p}$$

Formula 1 **p: 2 (number of experts)**

Table 8 Normalized matrix

No.	F_2	F_5	F_{11}
F_2	(0.00, 0.00, 0.00)	(0.12, 0.25, 0.38)	(0.38, 0.50, 0.50)
F_5	(0.25, 0.38, 0.50)	(0.00, 0.00, 0.00)	(0.31, 0.44, 0.50)
F_{11}	(0.38, 0.50, 0.50)	(0.31, 0.44, 0.50)	(0.00, 0.00, 0.00)

$$\tilde{H}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l'_{ij}}{r}, \frac{m'_{ij}}{r}, \frac{u'_{ij}}{r}\right) = (l''_{ij}, m''_{ij}, u''_{ij})$$

$$r = max_{1 \le i \le n}\left(\sum_{j=1}^{n} u_{ij}\right)$$

Formula 2

Table 9 Total relation fuzzy matrix

No.	F_2	F_5	F_{11}
F_2	(0.31, 1.46, 7.00)	(0.35, 1.43, 6.67)	(0.60, 1.86, 7.33)
F_5	(0.53, 1.81, 8.00)	(0.25, 1.29, 7.00)	(0.59, 1.90, 8.00)
F_{11}	(0.66, 2.02, 8.00)	(0.52, 1.71, 7.33)	(0.41, 1.76, 7.67)

$$\tilde{t}_{ij} = (l^t_{ij}, m^t_{ij}, u^t_{ij})$$

$$[l^t_{ij}] = H_l \times (I - H_l)^{-1}$$

$$[m^t_{ij}] = H_m \times (I - H_m)^{-1}$$

$$[u^t_{ij}] = H_u \times (I - H_u)^{-1}$$

Formula 3

Table 10 Importance and cause effect fuzzy values

Factors	$\widetilde{D}_i + \widetilde{R}_i$	$\widetilde{D}_i - \widetilde{R}_i$
F_2	(2.78, 10.05, 44.00)	(-21.73, -0.55, 19.49)
F_5	(2.51, 9.43, 44.00)	(-19.62, 0.57, 21.87)
F_{11}	(3.20, 11.02, 46.00)	(-21.41, -0.02, 21.39)

$$\widetilde{D} = (\widetilde{D}_i)_{n\times 1} = [\sum_{j=1}^{n} \tilde{T}_{ij}]_{n\times 1}$$

Formula 4

$$\tilde{R} = (\tilde{R}_i)_{1\times n} = [\sum_{i=1}^{n} \tilde{T}_{ij}]_{1\times n}$$

Formula 5

Table 11 Importance and cause effect defuzzy values

Factors	D Sum	Rank	R Sum	Ranking	$\left(\widetilde{D}_i + \widetilde{R}_i\right)^{def}$	Rank	$\left(\widetilde{D}_i - \widetilde{R}_i\right)^{def}$	Rank
F_2	7.945	3	8.775	2	16.72	2	-0.83	3
F_5	8.595	2	7.745	3	16.34	3	0.85	1
F_{11}	8.9	1	8.91	1	17.81	1	-0.01	2

$B = defuzzy(\tilde{A})$ *if*:

$\tilde{A} = (a_1, a_2, a_3)$

$$B = \frac{(a_1 + a_3 + 2 \times a_2)}{4}$$

Formula 6

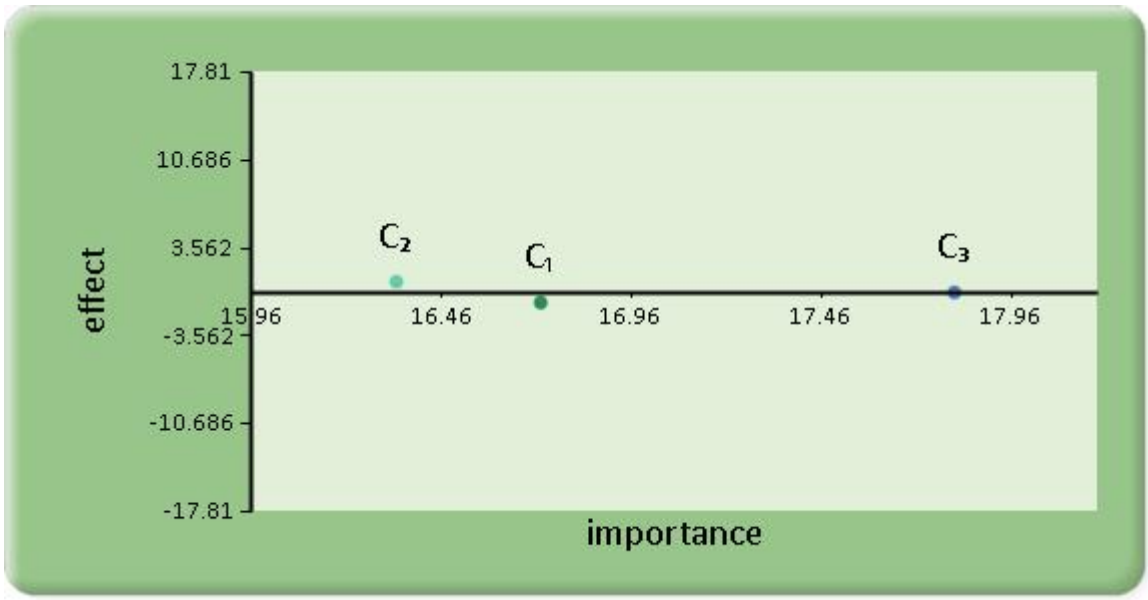

Figure 2 Interactive relationships of the three criteria.

Based on the coordinate positions of the degree of importance (D + R) and of the causal degree (D - R) the certain conclusions can be drawn. From a single factor perspective, both the degree of importance (D + R) and the causal degree (D - R) ranking should be considered to identify the critical factors. According to the causal degree (D - R) values, the factors affecting the local sustainable development through 'adaptive reuse of industrial buildings of cultural heritage' projects can be grouped into two categories; cause factors (positive) and effect factors (negative). Cause factors compared to effect factors, are considered to be the most fundamental, stable and initiative factors affecting the entire system. For that reason, special attention should be given during their analysis. As listed in Table 11, cause factor is the Community Action and Evolvement Empowerment (F_5) factor. In this case particularly, and because the influential impact D value is greater that its influenced impact R value, it certainly has a direct impact on other factors and its performance can directly affect the system objective. The Community Action and Evolvement Empowerment (F_5) factor while it owns a positive causal degree (D - R) value, it has

the third highest degree of importance (D + R) score with 16.34 and the third highest influential impact D. Thus it can be confirmed that Community Action and Evolvement Empowerment (F_5) cause factor has a great influence in the whole system and it should be stressed providing a basis on which to undertake long-term sustainability measures to improve local sustainable development as a result of adaptive reuse of industrial buildings of cultural heritage projects. On the other hand, the rest of the factors are more prone to change as too easily affected by other factors, a fact that suggests some short-term sustainability measures are need to improve the entire system. In particular, the Cultural Heritage Protection (F_{11}) factor has the highest degree of importance (D+R) score with 17.81, while the value of its influential impact D is 8.9, also ranking first. Although the causal degree (D - R) score is slightly less than zero, its influenced impact R value with 8.91 score obtains the highest score, therefore the Cultural Heritage Protection (F_{11}) factor is considered to be a factor in the system with an important influence. Similarly, the degree of importance (D + R) of the Tourism Economic Growth (F_2) factor is 16.72 and ranks second along with its influential impact D value which is 8.595. The Tourism Economic Growth (F_2) factor causal degree (D - R) value is negative, hence although a key factor it can be easily affected by other factors.

Nonetheless, there are certain delimitations set for the scope of the current paper and future intended research should further expand the above mentioned methodology and results. In this preliminary study, only three factors were computationally analyzed. Also, only two experts were approached, from government and university. Future research should analyze all proposed factors and further expand the experts' range and number to engineers, enterprise, industry associations and elected government officials. Meanwhile, given the educational background and professional experience variety within experts, naturally, it is considered that their view should have a specific weight. Thus, from this point of view, a non-ambiguous determination set of variables for the importance of the experts' judgment should be carried out. Furthermore, and since the redundancy of the information provided through the eleven factors is not addressed, future research in order to avoid possible unnecessary duplication of facts in the index system and improve the accuracy of the study, should first use an in depth interview analysis system. Moreover, perhaps the use of trapezoidal intuitionistic fuzzy numbers rather than the triangular fuzzy numbers might express further support through an advance computational accuracy to the arguments raised in the current research. In addition, in order to avoid possible biases and verify the robustness of the results, a sensitivity analysis[4] might be proven helpful. Similarly, an analysis from the sum calculations of the various factors dimensions discussed standpoint would make sense in order to obtain a multilevel conclusion drawn. Lastly, some more adaptive reuse of industrial buildings of cultural heritage representative examples should be respectively examined in order to validate these results.

[4] Sensitivity analysis could be undertaken using Chi-square tests in order to prove the consistency of the results under various experts' evaluations.

Conclusion

Adaptive reuse of industrial buildings of cultural heritage is an important global topic. In the context of sustainable development and the effects of environmental degradation caused by previous disregard, adaptive reuse has an important role to play. Adaptive reuse of industrial buildings of cultural heritage projects, adopting certain strategies can achieve an optimum balance among initial investments, energy savings, environmental impacts minimization, heritage preservation and urban regeneration.

The current study attempted to provide a number of reasons as to why the adaptive reuse of industrial buildings of cultural heritage consists an important element in the entire spectrum of the sustainability concerns. To do so, first this paper comprehensively considering and discussing all relevant matters pertinent to the local context, systematically proposes eleven factors affecting the local sustainable development via adaptive reuse of industrial buildings of cultural heritage projects, and in particular the FIX Building reuse, through literature review and field research, each one categorized accordingly to the four pillars of sustainability. Then, a Fuzzy-DEMATEL model was applied in order to assess the direction and level of interaction among them. The aforementioned method was selected because it enables variables causal relationship analysis including the level of interactive influence among them. Through systematic study, cause factor is the Community Action and Evolvement Empowerment (F_5) factor and effect factors are the Tourism Economic Growth (F_2) factor and the Cultural Heritage Protection (F_{11}) factor.

Grounded in practice, the study encompassing the real dilemmas captures the complicated adaptive reuse of industrial buildings of cultural heritage process and provides a reference point for future development projects or research. The FIX case is significant as it illustrates how solutions can be created as old industrial urban corridors become obsolete. To conclude, this paper argues that adaptive reuse of industrial buildings of cultural heritage with economic development activities, social regeneration, ecological efficiency, in addition to the cultural heritage preservation, serve the key concepts of sustainability and the sustainable development goals.

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