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THE IMPORTANCE OF FLEXIBILITY IN ADAPTIVE REUSE OF INDUSTRIAL HERITAGE: LEARNING FROM IRANIAN CASES

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Abstract

In recent years, the significance of industrial heritage has seemed to become a growing trend in the international heritage studies. Concerning their attributed values, and the crucial needs for urban development, this branch of cultural heritage has been considered the important grid of cities. This has caused a great acceptance of adaptive reuse practices especially among developing countries which is a smart response to an ongoing debate to reach sustainable development. The flexibility of these buildings and sites seems an important criterion, which can be improved through adaptive reuse practice. Therefore, this research aims to introduce the concept of flexibility in industrial heritage sites, evaluate its criteria among adaptive reuse practice, and make a comprehensive flexibility model for it. Indeed, the final goal is to determine the condition that based on the flexibility model, the adaptive reuse practice would be a proper way of encountering these sites. A historical-interpretation research method, analytical-description techniques, and questionnaire-based interviews are applied in this research. Results indicate that flexibility has genuinely been considered in this practice. Analysing flexibility techniques, this paper suggests a valuable framework to achieve the flexibility of industrial heritage as the presupposition of successful adaptive reuse in these sites.

***Keywords**: Industrial heritage; Adaptive reuse; Flexibility; Iran*

Introduction

The notion of industrial heritage nowadays has seemed to become a critically important branch of the multidisciplinary field of heritage studies in many parts of the world due to its significance since 1999 by official establishing of TICCIH (The International Committee for the Conservation of the Industrial Heritage). Concerning the importance of industrial heritage in terms of cultural, historical and technical values, they are considered highly significant structures. This is mainly why countries tend to preserve them as the important part of human culture [1-3], and more specifically remains of industrial culture [4]. They in turn, demonstrate humankind efforts to have a better life on the one hand, and a great deal of job opportunities they provided people with during industrial era on the other hand [5]. Consequently, adaptive reuse has become one of the accelerating trends in heritage studies as a profitable strategy [6], which tends to develop the potential of growth in these sites. This strategy could help communities, governments, and developers to reduce the environmental, social, economic [7], trustworthiness of culture [8], and even energy inefficiency problems [9, 10] at the cost of some

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minor changes. Therefore, adaptive reuse is mainly an urban/regional planning strategy [11-13] rather than just an architectural reuse.

Flexibility, one of the influential factors in the adaptive reuse process in many heritage scholars' opinion, could support all the advantages of the cultural heritage reuse through fewer changes and low-budget projects. The flexible method of cultural heritage management potentially concerns about both historic characteristics of these sites through preservation and urban development simultaneously which could lead to sustainable management [14]. Despite the prevalence of this attitude for industrial heritage in Iran, it needs further and deeper studies. This research aims to discuss and clarify the concept of flexibility in industrial heritage management and describe flexibility criteria by which an adaptive reuse practice can potentially be improved.

Moreover, by analyzing the research findings a comprehensive model of flexibility of the industrial heritage in Iran is made. According to this model, the conditions when adaptive reuse attitude is a proper way to treat can be recognized.

Materials and Methods

Questions and Goals

In this research, we aim to response to the following questions: What is the main idea of flexibility for adaptive reuse practice of industrial heritage sites? What is the role of the flexibility in improvement of adaptive reuse practices? In addition, how the flexibility could be a measurable variable to choose the way of encountering industrial heritage sites?

Research Method

To reach the goals and answer the research questions the "historical interpretation", "analytical-description" techniques, as well as "historical studies" are applied in this research, which foster the evidence evaluation. "Fact findings", "fact assessment", "fact organization", and "fact analysis" are the major steps of this "historical interpretation". In addition, the existence of various judgments about a subject has been taken into account [15]. Moreover, the data collection of this paper draws on "in-situ observation" and questionnaire-based interviews. Amongst industrial heritage sites and buildings in Iran, the ones that adaptively reused are selected as the statistical population to assess flexibility. The questionnaire is filled by 30 professors in the field of architecture and heritage studies and professional accomplished Iranian architects for each case.

Literature Review

Flexiblity

Since Walter Gropius, put the emphasis on the significance of "the flexibility" for "the modern lifestyle" in 1954 [16], this term has become one of the most appealing one in the field of architecture. Both terms "Flexibility" and "adaptability" are used interchangeably and considered by some authors [17, 18] to have overlapping meaning. Nevertheless, some researchers have been separated these concepts. For instance, Bernardes and Hanna believe that term "flexibility" has been used indiscriminately with "agility" and "responsiveness" [19]. On the other hand, Groak conceives that flexibility means the capability of different physical arrangements during extensions or some other changes, while adaptability is the capability of different social uses, which in turn, means the opportunity to use a same space for various functions [20, 21]. However, in the field of architecture the term flexibility seems to be more popular than other terms. Figure 1 illustrates a graph showing how these terms have appeared in books (written in English) over the previous years. It clearly proves that the usage of the "Flexible Architecture" term has been always more widespread.

Despite ongoing arguments, authors in various fields tend to focus on this concept from their specific area of expertise. Therefore, taking all these opinions into account, a comprehensive definition of flexibility seems feasible.

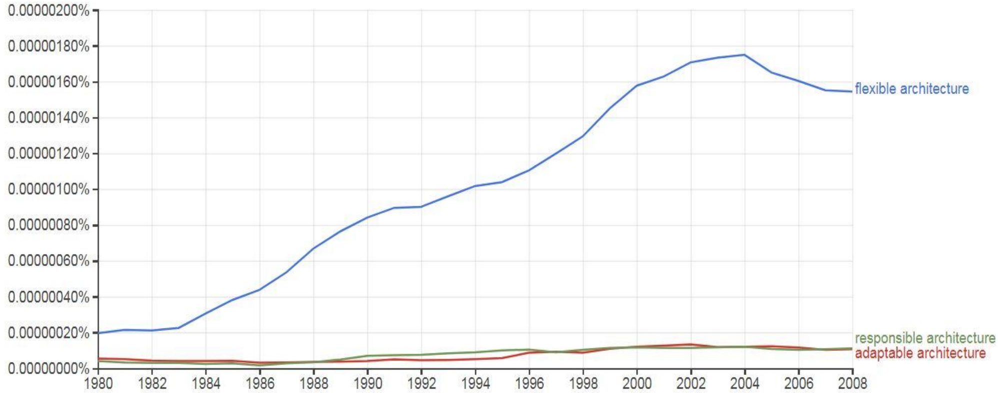

Fig. 1. The usage of the terms "Sustainable Architecture", "Flexible Architecture" and "Adaptable Architecture" over time [22]

Table 1. Different aspect of flexibility in various fields

Author	Field	Cost	Design	Performance	Measure	Reference
Zelenovic	Manufacturing system		X		X	[23]
Trigeirgis & Mason			X			[24]
Saleh et al.		X	X			[25]
Araujo and Spring				X		[26]
Ross et al.			X	X		[27]
Bernardes & Hanna			X			[19]
Groak	Building design		X			[21]
Shabha			X			[28]
Gann & Barlow			X			[29]
Friedman & Krawitz		X	X			[30]
Kendall			X	X		[31]
Sadafi et al.			X	X		[32]
Estaji			X	X		[33]
Morlok and Chang	Transport system			X		[34]
Taneja et al.		X		X		[35]
Nelson et al.	Computer Science	X	X	X		[36]

Table 1 indicates that the usage of "flexibility" not only can be found in the literature of architecture but also in different research fields. While "Measure" column is for researchers who believe the flexibility is measurement tool for some potentials of new or existing architectural construction, "Design" means the flexibility interferes directly with the design of a system. "Performance" is marked when the existence of a tangible link between flexibility and system performance is suggested and "Cost" refers to authors who assume the flexibility is linked to the costs and saving money.

For almost all researchers, flexibility has been seen an intrinsic feature of the system, except Zelonovic and Ross who believe flexibility is a transition and a measurement tool to evaluate the capacity of a system to adapt respectively. Consequently, the meaning and usage of flexibility is limited to a specific scientific area and it has a wide range of meaning. Therefore, a deep dive is needed to the definition of flexibility in the specific area that directly related to the topic of this research.

Flexible Architecture

One of the main reasons that convinces architects to (re)think about the flexibility is the unsustainability of traditional construction as it causes expenditure of resources [37, 38].

Indeed, this attitude in construction industry can lead to promote the global sustainability by reducing construction costs and also resource depletion [39]. Various definitions of flexibility in architecture are heavily criticized for ambiguity and their vague language. Hence, to reach a comprehensive definition of flexible architecture and to determine the accurate criteria, a deep overview of this idea from various points of view is crucial. Table 2 illustrates different indicators of flexibility in architecture according to different authors.

Table 2. Criteria and indicators of flexibility in architecture based on Estaji's work [33]

Criteria	Indicators	Definition	Reference
Adaptabiliy	Expandability	Ability to Add to the quantity of space	[40]
	Upgradability	Ability to accommodate potential performance requirements	
	Extendibility	Possibility of adapting to additional user demands	[41]
	Partition-ability	Ability to split up, rearrange or combine spatial units	
	Multi-functionality	Possibility of using or deploying for several functions	
	Expansion	Ability to extent the use of the surface	[42]
	Transferability	Ability to Change of location	
	Redesign-ability	Ability to changing the layout of the user units	
	Connect-ability	Ability of adjacent spaces to be connected through sliding dividers	[17, 43]
	Divisibility	Ability to divide a larger unit	
	Neutral-functionality	Having spaces without specific use	
	Convertibility	Ability to allow changes in usage/function	[44]
	Rearrangeability	Ability to change the layout of spaces	[45]
	Refittability	Ability to change the performance	
	Combinability	Ability to generate combinations of basic components	[46]
	Polyvalency	Ability to be used in different ways without adjustment	[47]
	Transformability	Ability to change of shape and arrangement of spaces	[33]
	Scalability	Ability to change the size	
	Visitability	Possibility that allow people with disabilities to use complex	[48]
Dismantling and material reuse	Lifetime Compatibility	Lack of strong interconnect short lifetime components with those having longer life times	[40]
	Responsive	Being Smart, Intelligent, Automated	[33]
	Recyclability	The ability of reuse (space, component and material)	
	Disaggregatability	Capability of material to be reusable or reprocess-able	[44]
	Dismantlability	Capability of being demolished safely, efficiently and quickly	
	Demount-ability	Ability to reconfigure/ dismantle	[49]
Installation and disassembly	Parallel Disassembly	Capability to disassemble components simultaneously not sequential	[40, 50]
	Logistical deconstruction	Capability to handling and locating components logistical after disassembly and storage them	[51]
	Optimize components	Using a low number of components and larger ones	[52]
	Simple technology	Using as simple technology and tools as possible	
	light components	Using lighter components	[53]
	Durability	Selecting materials, assemblies and systems that require less maintenance, repair and replacement	

Taking all these above indicators into account, an extensive definition of flexibility seems to be clear. Indeed, flexibility is a mixture of these indicators and consequently, a building can be called flexible, only if it can accommodate changes and lowering material, transport, energy consumption and waste and pollution [54]. Therefore, such structure can lead to economic, environment and social sustainability [55] by providing these indicators. Similar in their essence, indicators of flexibility can be categorized into four criteria which already have been introduced by Sadafi and her colleagues [32]. Each criterion can in turn, enhance the flexibility and the general evaluation of these criteria can indicate the rate of flexibility of a building:

- Adaptability
- Dismantling and material reuse
- Installation and disassembly
- Durability

By respecting to their efforts to find effective strategies for increasing flexibility of buildings for each criterion, admittedly, durability has not been adequately examined in their works. While evaluating flexibility in general may distinguish durability from other criteria, according to the focus of this paper, which is built environment (a specific branch of cultural heritage), this criterion plays an essential role in the evaluation process. To reach and even increase or in this case evaluate the flexibility of a building numerous researchers have tried to offer specific strategies to reach the flexibility. Tables 3, 4, and 5 show strategies for each criterion by which in design process the flexibility can be improved and they can be used for evaluating flexibility in built environments according to various authors.

Table 3. Strategies for enhancing flexibility through improving adaptability

Strategy	Indicators of Adaptability																			Reference
	Visitability	Polyvalency	Transferability	Refittability	Rearrangeability	Redesignability	Combinability	Connectability	Divisibility	Partitionability	Neutral-functionality	Multi-functionality	Convertibility	Transformability	Upgradability	Scalability	Expansion	Extendibility	Expandability	
Increase regularity in building pattern					X		X	X	X	X			X	X		X	X		X	[53]
Increase simplicity in system and materials				X	X	X								X	X	X	X	X	X	
Give Specifications for connections, system installations		X	X	X	X	X	X	X	X	X		X	X	X	X				X	[56]
Reduce inter-system and intra-system interactions		X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	[57, 58]
Increase system predictability				X		X	X		X			X	X	X	X	X	X	X	X	
Improve flow through system layout	X	X		X	X	X	X			X			X	X	X		X	X		
Use prefabricated components			X		X	X	X	X					X	X	X	X	X	X	X	[50]
Use modular coordinate system		X		X	X	X	X	X	X	X			X	X	X	X	X	X	X	
have over capacity feature					X	X	X	X				X	X	X	X	X	X	X	X	[59]
Optimize Use of interior space for optimal resource use	X	X	X	X	X	X						X	X	X	X					[60]

Table 4. Strategies for enhancing flexibility through improving Dismantling and material reuse

Strategy	Indicators of Dismantling and material reuse						Reference
	Demountablility	Dismantlability	Disaggregatability	Recyclability	Responsive	Lifetime Compatibility	
Use of high-quality recyclable materials		X	X	X	X		[52, 61]
Use of lightweight materials		X			X		[57]
Provision for identification different materials	X		X	X	X		
Use of exchangeable materials	X	X	X	X	X		[62]
Reduce the number of material types			X			X	[60]
Use of easily separable materials	X	X		X	X		[53]
Avoid secondary finishes	X	X		X		X	[50]
Use of materials without hazardous components	X	X	X		X		
Make insuperable subassemblies of materials			X	X	X		[63]
Use interchangeable components for materials	X	X	X	X	X		[58]
Separate the components with different life cycles		X		X		X	[64]

Table 5. Strategies for enhancing flexibility through improving Installation and disassembly

Strategy	Indicators of Installation and disassembly: light components	Simple technology	Optimize components	Logistical deconstruction	Parallel Disassembly	Reference
Integrate installation system with structural system						[65]
Restrict the distribution of functions and facilities						
Separate infill and structural elements						[40, 50]
Increase the physical adjacency of access points						[57]
Enhance the phase system installation						[58]
Use mechanical methods of water protection instead of chemical sealants and adhesives						[64]
Limit the number of components						[53]
Use flexible building interface						[66]
Transparency and accessible components						[67]
Clear process of disassembly						[40, 50]
Use hierarchy of disassembly based on life span						[60]

Adaptive Reuse Strategies

Even though applying new functions to existing buildings does not seem a complicated or new phenomenon, the theoretical debate over adaptive reuse of cultural heritage started in the 19th century between two attitudes; restoration-movement led by Eugène Emmanuel Viollet-le-Duc (1814-1879), and the anti-restoration movement, led by John Ruskin (1819-1900) and his fellow William Morris (1834-1896). Despite this historic background, much of the true inspiration came from adaptive reuse practices documented in Sherban Cantacuzino's works [68, 69] which indicates valuable examples of adaptive reuse.

Indeed, adaptive reuse method encourages people, experts and all involved communities to think out of the box before jumping to the conclusion on what we should do with these useless buildings or infrastructures. Many experts defined the potential of this practice during the 1980s [14, 70, 71]. As Brebbia has defined, through three distinguishable perspectives, adaptive reuse could be analysed which are typological, technical, and strategic approaches [72]. In this research, we focus on the third approach: strategic approach. This approach mainly discusses the process and strategies applied for converting significant buildings. These reuses take place through various changes in different layer of the building, which adapt the building with new purposes [73]. Undoubtedly, devoting enough time, energy and money for these changes is inevitable. However, these items could be economised through lower construction and acquisition cost [74] if the building has the capacity to accommodate changes over a long time. These changes can be happened in different layers of building system and according to Brand (1995) these layers can be categorized into six layers: site, skin, structure, service, space plan and stuff [75].

Although the pace and the type of changes tend to be differed from one layer to another, the general change is the aggregate of slight changes in each layer. General changes in the building can be divided into 3 different changes through adaptive reuse practice based on Slaughter (2001) point of view: changes in function, capacity and flow [58]. The assessment of changes in each type can be conducted based on three types of transformations: "spatial", "structural", and "elements and material [66] and each transformation needs specific requirements. Indeed, the building should respond and provide requirements for each transformation and in this way, it can accommodate changes. Figure 2 shows requirements of each type of change based on transformation, it should be mentioned that durability is necessary for each change and therefore it does not appear in this figure.

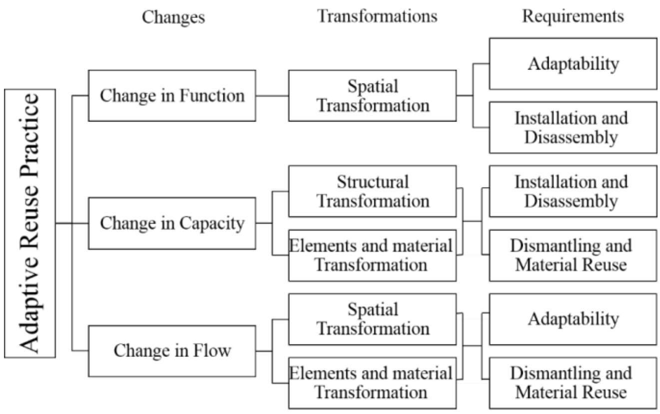

Fig. 2. different possible changes of a building through adaptive reuse process, their transformations and requirements based on Sadafi and her colleagues' work [28]

Industrial Heritage

Industrial heritage was initially mentioned in England during the 20th century has been the matter of debates amongst expert. It includes remained examples of industrial culture which enjoys historic, technological, architectural and scientific values [2, 76]. Possessing countless values in various perspectives, industrial heritage sites should be conserved as an intangible heritage alongside local people as an integrated system [77]. While, these buildings and structures describe the history of architectural and technological development and a symbol for social-cultural values of their time [78], they are now threatened by immediate destruction. Utilizing these sites as future-oriented economic resources with strong potential for the generating a new identity which connects future to the past [79] has turned into a popular trend among governments [80]. Conservation of heritage sites through adaptive reuse practice can improve the physical conditions of the environment and preserve their unique values as well [81-85]. The crucial question is that "Should all industrial heritage sites be protected through this method?" We discuss that only the ones with proper conditions in terms of flexibility should be protected through adaptive reuse practice and other sites that do not have this condition should be treated in some other ways. To reach a certainty in testing this hypothesis we analysed adaptive reuse practice of industrial heritage sites in Iran as case study.

Industrial Heritage of Iran

The term industry in Iran before the industrial revolution had referred to limited activities in small workshops namely; carpet, cloth weaving, poetry, and structures for using energies like windmills and water mills. While during the 19th century, some vast changes took place just in Europe, but over time, the impact of these changes extended beyond boundaries of Europe and many different parts of the world experienced “the Industrial Revolution” and its consequences in different ways [84]. Started at Qajar dynasty (1795-1925) because of urgent need for military technology and the establishment of modern schools in Iran, the process of industrialization in Iran significantly developed, and transport infrastructures, more than 270 factories, government buildings, and national railroad were among the most critical ones. This phenomenon caused the formation of a new civil society and created notable changes in the method and process of human life of this era through industrial structures and buildings [86]. Therefore, almost all industrial sites and buildings of Qajar and Pahlavi era as signs of the dominant industrial culture and the evidence of industrialization process in Iran are known as industrial heritage of Iran.

According to a very accurate survey, which has been conducted in Iran by TICCIH in recent years, more than 350 industrial heritage have been identified and more than 250 sites and buildings have been accurately investigated that the summary of this research can be found in Samadzadehyazdi and her colleagues' work [7]. Table 6 illustrates the classification of industrial heritage structures in Iran with updates.

Table 6. Identification of industrial heritage in Iran

Group	Function	Number identified	Number Investigated	Adaptively Reused	HAving Original Function	Partly Having Original Function	Partly Abandoned	Abandoned	Partly Destroyed	Destroyed
Buildings	Factory	199	127	13	63	2	7	19	14	9
	Worshop	8	0	0	0	0	0	0	0	0
	Reservoir	3	3	0	0	0	0	2	1	0
	Wheat Silos	4	4	0	2	2	0	0	0	0
	Slaughterhouses	1	1	1	0	0	0	0	0	0
	Airports	12	12	0	11	0	0	0	1	0
	Train Stations	41	40	1	36	1	1	0	0	1
	Mills	3	3	0	1	0	0	0	2	0
	Fire Stations	1	1	0	1	0	0	0	0	0
	Customs Buildings	1	1	0	0	0	0	1	0	0
Sites	Oil Wells	2	2	1	0	0	0	0	1	0
	Refineries	2	2	0	2	0	0	0	0	0
	Brick Furnaces	14	12	2	3	0	0	5	2	0
	Lighthouses	1	1	0	0	0	0	1	0	0
	Dames	5	5	0	4	0	0	1	0	0
	Energy production sites	6	5	3	3	0	0	0	0	0
	Transmission sites	7	5	4	0	0	0	0	0	1
	Road tunnels	3	3	0	3	0	0	0	0	0
	Railway bridges	34	29	0	28	0	0	0	1	0
	Wharves	6	4	0	3	0	0	1	0	0
Total		353	263	25	160	5	8	30	22	11

Among all industrial heritage buildings and sites in Iran that have been investigated, only 25 sites or building have been adaptively reused and based on the goal of this research these ones are selected as case studies to evaluate flexibility in them. The exact information of these sites can be found in Table 7.

Table 7. All adaptive reuse practice of industrial heritage in Iran

Category	No.	Project	Location	Time: Cons-truction	Time: Reuse	Function: Original	Function: Current
Factories	1	Shams Factory	Tehran	1931	1992	Beer factory	Enqelab cultural centre
	2	Pashmine factory	Tabriz	1935	1995	Wool blanket factory	Drug research centre
	3	Pashmbaf factory	Esfahan	1935	1996	Spinning and weaving	Broadcasting Building-
	4	Beryanak factory	Tehran	1922	1997	Sock weaving factory	museum of wildlife
	5	Khosravi factory	Tabriz	1931	1975	Leather factory	University
	6	Eghbal factory	Yazd	1931	2003	Spinning and weaving	Science and technology centre
	7	Qoorkhane	Tehran	1925	2004	weapon factory	Entrance of subway
	8	Shiraz textile factory	Shiraz	1938	2008	Spinning and Textile	Tar-o-Pud-e-Zaman museum
	9	Momtaz factory	Tehran	1980	2009	Spinning and	Commercial centre

Category	No.	Project	Location	Time		Function	
				Cons-truction	Reuse	Original	Current
						weaving	
	10	Se setare factory	Zanjan	1940	2014	Match factory	Match museum
	11	Garmsar cotton	Garmsar	1925	2015	cotton factory	Science and technology centre
	12	Argo factory	Tehran	1889	2016	Beer factory	Institute of culture and art
	13	Pars Factory	Semnan	1932	2018	Spinning and Textile	City council building
Energy	14	Harandy power plant	Hamedan	1931	1998	Power plant	Museum of electrical industry
	15	Kerman power plant	Kerman	1933	2015	Power plant	Museum of electrical industry
	16	First gas station	Abadan	1927	2017	Gas station	Gas station museum
Oil	17	Oil well no. 1	MIS	1908	2018	Oil well	Oil museum
Transmission	18	Kurdi Radio	Kermanshah	1960	2005	Radio station	Artists Forum
	19	Pergola mansion	Tehran	1940	2009	Wireless station	The museum of radio
	20	Radio station	Tehran	1940	2009	Radio Station	Iran broad casting building
	21	Rasht post office	Rasht	1931	1994	post office	Post museum
Railway	22	The old railway	Tehran	1882	2019	Railway infrastructure	Public urban space
Slaughter house	23	Slaughterhouse	Tehran	1944	1991	slaughterhouse	Bahman Cultural centre
Brick Furnace	24	Rastegar moqadam furnace	Mashhad	1930	2014	Brick furnace	Park
	25	Kure milyuni	Dezful	1925	2016	Brick furnace	Park

Results and Discussion

By acknowledging this fact that the observation shows that roughly 10% of investigated industrial heritage buildings and sites in Iran have been adaptively reused and they might not be adequate to be the best representative of these structures, yet somehow, they are the only reuse examples of industrial heritage in Iran and all of them are analysed (Fig. 3).

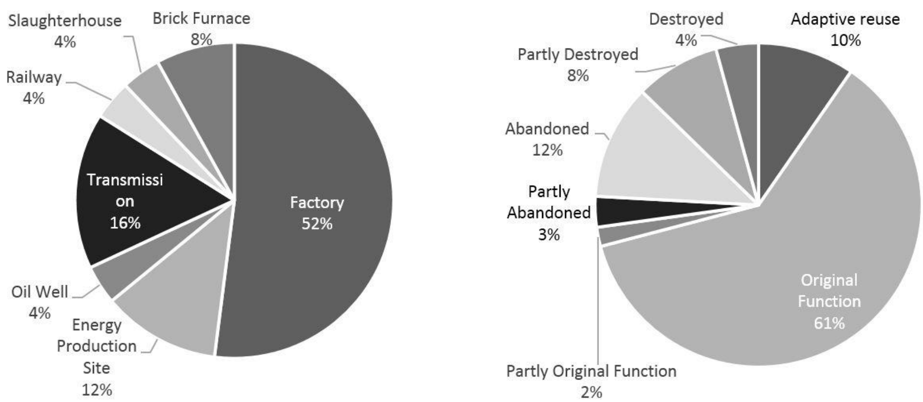

Fig. 3. Classification of industrial heritage of Iran Adaptive reuse practice (left) and all industrial heritage sites and buidling (right)

Being in danger of demolition, 24% of the industrial heritages of Iran have various possible potential and that is why they have to be protected. Adaptive reuse practice as a smart way of treating these sites can protect industrial heritage's cultural values as well as decrease construction costs and wastes, which can lead to contribution to energy efficiency that is crucial to today's environmental issues.

Consequently, the flexibility of this practice as an influential factor according to hypothesis of this research is analysed. In order to reach that a questionnaire-based interview based on criteria of flexibility, which had been extracted before, was made. Filled by 30 professors in Architecture and cultural heritage discipline and professional accomplished Iranian architects, this questionnaire seeks to evaluate flexibility through each criterion and their strategy.

The results of questionnaire (Fig. 4) confirms that the rates of flexibility for all cases are more than 50% and the average of this variable for all cases is 55%. It means that all adaptive reuse practices of industrial heritage have a proper situation in terms of flexibility and even the lowest mean score of each criterion is more than 50% and it shows the strength each criteria of flexibility in case studies. "Durability", "Adaptability", "Dismantling and material reuse" and "Installation and disassembly" can gain highest to lowest mean score among cases respectively. Having the highest score among aspects of flexibility, "Durability" can be regarded as the most significant criteria by which the flexibility could change. It is followed by "Adaptability" which is directly related to spatial features that enable structure to accommodate changes.

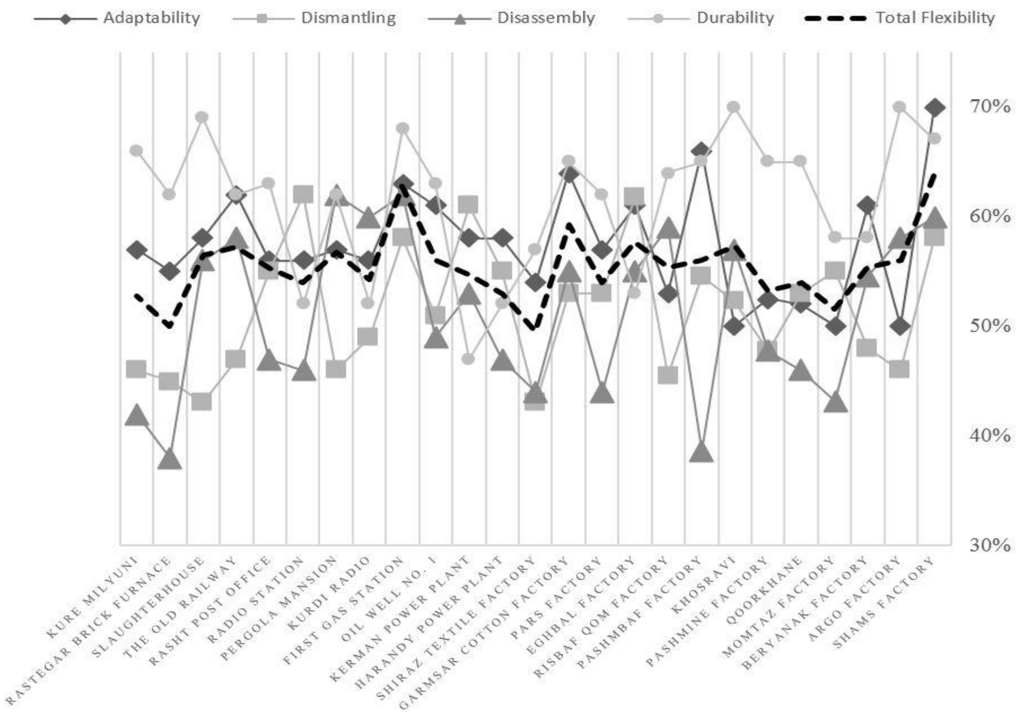

Fig. 4. Scores of the indicators of flexibility for each case

By analysis of the responses, a result clearly shows that the "Durability" in terms of material, components and technology is drastically crucial to flexibility. On the other hand, "Adaptability" that has the most relationship with architectural spaces and design is ranked as the second significant critical factor to determine flexibility in adaptive reuse practice of industrial heritage of Iran. While, other aspect of flexibility, "Dismantling and material reuse" and "Installation and disassembly", mainly related to technical aspect of building or site gain the lowest mean score, yet their score is above 50% and more than average.

Conclusions

Containing countless various values (such as cultural, technical, etc.), industrial heritage has been assumed as a new kind of cultural heritage that can play a significant role in the development of each society. Recognizing these sites can lead to the enhancement of productive spirit of society, as they are the evidence of humankind efforts for better life through different industries. These values alongside with features like having large scale and locating in proper urban grids make these sites very special. On the one hand, they are in danger of disappearing just because of economic profitability. On the other hand, they have a great potential to be revitalised as a cultural and profitable place through thoughtful ways of treating them. Adaptive reuse practice as one of the popular strategies for encountering industrial heritage sites tends to protect intangible values of this heritage through some monuments, which refers to industrial spirit of original industrial function, as well as enhance urban development by proposing to add values to these sites by applying a new function. This specific type of reuse can save their outstanding values and can add economic profitability to these sites, which corresponds to data from the literature [88-93].

Flexibility as one of most important features of each structure plays a major role in this attitude towards industrial heritage. This variable can accurately define that how much an industrial heritage building or site has the potential to be reused. This feature includes four criteria including; "Adaptability", "Dismantling and material reuse", "Installation and disassembly", and "Durability". Consequently, by analysing these criteria and the strategy to reach to each one, the flexibility of each industrial heritage site can be analysed. The findings confirm that in all adaptive reuse projects of industrial heritage in Iran flexibility receives a very high score. In other words, adaptive reuse practices have been taken place in a case with high rate of flexibility. This can be interpreted as a statement that industrial heritage sites with low scores of flexibilities might be unable to accommodate possible future changes easily.

On the other hand, four aspects of flexibility refer to specific features of a building or site and together they make a comprehensive model of flexibility in adaptive reuse practice in industrial heritage. Through analysing these criteria in case studies, a comprehensive model of flexibility for adaptive reuse practice of industrial heritage sites is obtained (Fig. 5). This model can show the importance of each criterion in the flexibility of industrial heritage sites. Hence, by interpreting this model it is easily understandable that durability of these sites has the most influential impact on their flexibility.

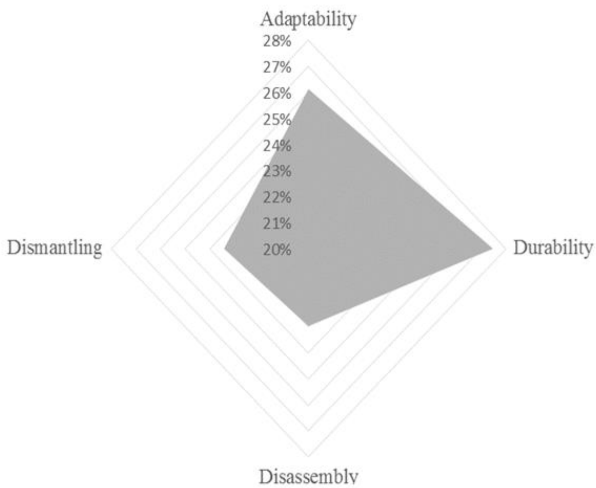

Fig. 5. The model of flexibility in industrial heritage of Iran

Taking all these analyses into account, the main suggestion of this paper is to point out that, in future projects for treating industrial heritage sites or buildings, the analysis of flexibility will be necessary to conduct before starting to plan any strategy for these architectural constructions. Consequently, adaptive reuse practice could be a proper way of encountering sites with satisfying flexibility rate and for sites with low-rate of flexibility other attitude should be applied based on their special conditions.

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References

[1] M.D. García, **A World History of Nineteenth-Century Archaeology: Nationalism, Colonialism, and the Past**, Oxford University Press, 2008.
[2] H. Bazazzadeh, A. Nadolny, K. Attarian, B. Safar ali najar, S. Hashemi safaei, *Promoting Sustainable Development of Cultural Assets by Improving Users' Perception through Space Configuration; Case Study: The Industrial Heritage Site*, **Sustainability, 12**(12), 2020.
[3] H. Bazazzadeh, M. Mahdavinejad, M. Ghomeshi, S. Hashemi safaei, **Requirements for comprehensive management of industrial heritage sites and landscapes**, *The International Conference on Conservation of 20th Century Heritage from Architecture to Landscape*, 2018, Tehran, Iran
[4] * * *, **The Nizhny Tagil Charger of the Industrial Heritage**, TICCIH Press, 2003.
[5] L. Smith, P. Shackel, G. Campbell, **Heritage, Labour, and the Working Classes**, Routledge, 2011.
[6] R. Shipley, S. Utz, M. Parson, *Does Adaptive Reuse Pay? A Study of the Business of Building Renovation in Ontario Canada*, **International Journal of Heritage Studies, 12**(6), 2006, pp. 505-520.
[7] S. Samadzadehyazdi, M. Ansari, M. Mahdavinejad, M. Bemaninan, *Significance of authenticity: Learning from best practice of adaptive reuse in the industrial heritage of Iran*, **International Journal of Architectural Heritage, 14**(3), 2018, pp. 329-344.
[8] H. Bazazzadeh, **Truth of sincerity and authenticity or lie of reconstruction; whom do the visitors of cultural heritage trust?** *The International conference of defining the architectural space*, 2020, Kraków, Poland.
[9] M. Philokyprou, *Adaptation of New University Uses in Old Buildings: The Case of Rehabilitation of Listed Buildings in Limassol Cyprus for University Purposes*, **International Journal of Architectural Heritage, 8**(5)**,** 2014, pp. 758-782.
[10] S. Samadi, E. Noorzai, L.O. Beltran, S. Abbasi, *A computational approach for achieving optimum daylight inside buildings through automated kinetic shading systems*, **Frontiers of Architectural Research, 9**(2), 2020, pp. 335-349.
[11] H. Oevermann, H.A. Mieg, **Industrial Heritage Sites in Transformation: Clash of Discourses**, Taylor & Francis Publisher, 2014.
[12] K. van Assche, M. Duineveld, *The good, the bad and the self-referential: heritage planning and the productivity of difference*, **International Journal of Heritage Studies, 19**(1), 2013, pp. 1-15.
[13] J. Douet, **Industrial Heritage Re-tooled: The TICCIH Guide to Industrial Heritage Conservation**, Routledge Press, 2013.

[14] * * *, **Re-using Redundant Buildings: Case Studies of Good Practice in Urban Regeneration**, Department of the Environment of Great Britain URBED (Urban and Economic Development), H.M.S.O. Publisher, 1987.
[15] D. Wang, **Historical Research**, in Architectural research methods (Edited: L. Groat and D. Wang), Wiley & Sons Publisher, 2013.
[16] A. Forty, **Words and Buildings: A Vocabulary of Modern Architecture**, Thames & Hudson Publication, 2004.
[17] J.N. Habraken, *Design for flexibility*, **Building Research & Information, 36**(3), 2008, pp. 290-296.
[18] T. Schneider, J. Till, **Flexible Housing**, Architectural Press, 2007.
[19] E.S. Bernardes, M.D. Hanna, *A theoretical review of flexibility, agility and responsiveness in the operations management literature: Toward a conceptual definition of customer responsiveness*, **International Journal of Operations & Production Management, 29**(1), 2009, pp. 30-53.
[20] S. Suchi, R. Drogemuller, T. Kleinschmidt, **Flexible Airport Terminal Design: Towards A Framework**, *IIE Asian Conference*, Singapore 2012.
[21] S. Groak, **The Idea of Building: Thought and Action in the Design and Production of Buildings**, Routledge Press, 1992.
[22] Google Ngram Viewer, **The Usage of the Terms Sustainable, Flexible and Adaptable Architecture Over Time**, Google, 2013.
[23] D.M. Zelenovic, *Flexibility; a condition for effective production systems*, **International Journal of Production Research, 20**(3), 1982, pp. 319-337.
[24] L. Trigeorgis, S.P. Mason, *Valuing Managerial Flexibility*, **Midland Corporate Finance Journal, 5**(1), 1987, pp. 14–21.
[25] J.H. Saleh, D.E. Hastings, D.J. Newman, **Extracting the Essence of Flexibility in System Design**, *Proceedings Third NASA/DoD Workshop on Evolvable Hardware (EH)*, IEEE Publication, 2001.
[26] L. Araujo, M. Spring, **Manufacturing Flexibility and Industrial Networks**, *18th IMP Conference*, IMP Publication, 2003.
[27] A. Ross, Adam, M. D.H. Rhodes, D.E. Hastings, *Defining changeability: Reconciling flexibility, adaptability, scalability, modifiability, and robustness for maintaining system lifecycle value*, **Systems Engineering, 11**(3), 2008, pp. 246-262.
[28] G.S. Shabha, *Flexibility and the Design for Change in School Buildings*, **Architectural Science Review, 36**(2), 1993, pp. 87-96.
[29] D.M. Gann, J. Barlow, *Flexibility in building use: the technical feasibility of converting redundant offices into flats*, **Construction Management and Economics, 14**(1), 1996, pp. 55-66.
[30] A. Friedman, D. Krawitz, *The Next Home: Affordability through Flexibility and Choice*, **Housing and Society, 25**(1), 1998, pp. 103-116.
[31] S. Kendall, *Open Building: An Approach to Sustainable Architecture*, **Journal of Urban Technology, 6**(3), 1999, pp. 1-16.
[32] N. Sadafi, M.F.M. Zain, M. Jamil, *Design criteria for increasing building flexibility; Dynamics and prospects*, **Environmental Engineering and Management Journal, 13**(2), 2014, pp. 407-417.
[33] H. Estaji, *A Review of Flexibility and Adaptability in Housing Design*, **International Journal of Contemporary Architecture (The New ARCH), 4**(2), 2017, pp. 37-49.
[34] E.K. Morlok, D.J. Chang, *Measuring capacity flexibility of a transportation system*, **Transportation Research, Part A: Policy and Practice, 38**(6), 2004, pp. 405-420.
[35] P. Taneja, H. Ligterngen, W.E. Walker, *Flexibility in port planning and design*, **European Journal of Transport and Infrastructure Research, 12**(1), 2012, pp. 66-88.

[36] K.M. Nelson, H.J. Nelson, M. Ghods, **Technology Flexibility: Conceptualization, Validation, and Measurement**, *Proceedings of the Thirtieth Hawaii International Conference on System Sciences*, IEEE Publication, 1997.

[37] T. Esin, N. Cosgun, *A study conducted to reduce construction waste generation in Turkey*, **Building and Environment, 42**(4), 2007, pp. 1667-1674.

[38] A. Omran, M. Gavrilescu, *Municipal solid waste management in developing countries: a perspective on Vietnam*, **Environmental Engineering and Management Journal, 7**(4), 2008, pp. 469-478.

[39] R. Bon, K. Hutchinson, *Sustainable construction: some economic challenges*, **Building Research & Information, 28**(5), 2000, pp. 310-314.

[40] S. Moaffatt, P. Russel, *Assessing Buildings for Adaptability, Annex 31; Energy-Related Environmental Impact of Buildings*, **International Energy Agency (IEA)**, 2001.

[41] R.P. Geraedts, **Design for Change; Flexibility Key Performance Indicators**, *1st International Conference on Industrialised, Integrated, Intelligent Construction (13CON), 2008*, Leicestershire, UK.

[42] R.P. Geraedts, T.R. Hilde, H.H. Marleen, E. Van Rijin, **Adaptive Capacity of Buildings: A Determination Method to Promote Flexible and Sustainable Construction**, *International Union of Architects World Congress UIA*, 2014, Durban South Africa.

[43] T. Schneider, J. Till, **Flexible Housing**, Architectural Press, 2007.

[44] J. Douglas, **Building Adaptation**, Butterworth-Heinemann Publication, 2002.

[45] R. Schmidt, T. Eguchi, S. Austin, and A. Gibb, **What is the Meaning of Adaptability in the Building Industry**, *16th International Conference of Open and Sustainable Building (O & SB)*, 2010, Bilbao, Spain.

[46] R.B. Richard, **Individualisation & Industrialisation**, *International Conference on Adaptable Building Structures*, 2006, Eindhoven, Netherlands.

[47] B. Leupen, R. Heijne, J. van Zwol, **Time-based Architecture**, 10 Publishers, 2005.

[48] * * *, **Design Guidelines for Sustainable Housing and Livable Neighbourhoods**, South Australian Housing Trust, Government of South Australia, 2017.

[49] R.B. Richard, **Industrialized, Flexible and Demountable Building Systems: Quality, Economy and Sustainability**, *International Symposium of Advancement of Construction Management and Real Estate*, 2006, Beijing, China.

[50] P. Crowther, **Design for Disassembly; Themes and Principles**, Queensland University of Technology Press, 2005.

[51] C.Morgan, F. Stevenson, **Design and Detailing for Deconstruction**, Scottish Ecological Design Association, 2005.

[52] C. Thormark, *Recycling Potential and Design for Disassembly in Buildings*, **PhD Thesis**, Lund University, Department of Construction and Architecture, 2001.

[53] M.D. Webster, D.T. Costello, **Designing Structural Systems for Deconstruction: How to Extend a New Building's Useful Life and Prevent it From Going to Waste When the End Finally Comes**, *Greenbuild conference*, 2005, Atlanta, USA.

[54] H. Bressers, Hans, T. de Bruijn, L. Franco, K. Lulofs, Y. Xue, *Voluntary agreements as a way to stimulate industrial environmental management and their conditions for success*, **Environmental Engineering and Management Journal, 12**(8), 2013.

[55] C. Landorf, *A Framework for Sustainable Heritage Management: A Study of UK Industrial Heritage Sites*, **International Journal of Heritage Studies, 15**(6), 2009, pp. 494-510.

[56] D.S. Macozoma, **Understanding the Concept of Flexibility in Design for Deconstruction**, *CIB Task Group 39 – Deconstruction Meeting*, 2002, Karlsruhe, Germany.

[57] M.A. Keymer, *Design strategies for new and renovation construction that increase the capacity of buildings to accommodate change*, **Master Thesis**, Massachusetts Institute of Technology (MIT), Department of Civil and Environmental Engineering, 2000.

[58] E.S. Slaughter, *Design strategies to increase building flexibility*, **Building Research & Information, 29**(3), 2001, pp. 208-217.
[59] R.P. Geraedts, **Cost and Benefits of Flexibility**, *CIB World Building Congress: Performance in Product and Practice*, 2001, Wellington, New Zealand.
[60] A.R. Chini, **Anticipating and Responding to Deconstruction through Building Design**, In Design for Deconstruction and Material Reuse, (Edited: A.R. Chini and S. Balachandran), CIB Publication University of Karlsruhe Germany, 2002.
[61] P. Sassi, Defining closed-loop material cycle construction, **Building Research & Information, 36**(5), 2008, pp. 509-519.
[62] J. Charytonowicz, *Consumption and recycling in the economic design of architecture*, ***4th International Conference on Universal Access in Human-Computer Interaction*** *(UAHCI)*, Beijing, China2007.
[63] J.W. Hurley, **Design for Deconstruction- Tools and Practices**, *CIB TG 39 annual meeting*, 2002, Karlsruhe, Germany.
[64] B. Guy, **Building Deconstruction Assessment Tool, Deconstruction and Materials Reuse: Technology, Economic, and Policy**, CIB Publication University of Karlsruhe Germany, 2001.
[65] R.P. Geraedts, **Upgrading the Flexibility of Buildings**, *CIB World Building Congress: Performance in Product and Practice*, 2001, Wellington, New Zealand.
[66] E. Durmisevic, *Transformable building structures; Design for disassembly as a way to introduce sustainable engineering to building design and construction*, **PhD Thesis**, Delft University of Technology, 2006.
[67] S.L. Fletcher, O. Popovic, R. Plank, **Designing for Future Reuse and Recycling**, Deconstruction–Closing the Loop, 2000, Watford, UK.
[68] S. Cantacuzino, **New Uses for Old Buildings**, Architectural Press, 1975.
[69] S. Cantacuzino, **Re-architecture: Old Buildings/New Uses**, Abbeville Press, 1989.
[70] P. Eley, J. Worthington, **Industrial Rehabilitation: The Use of Redundant Buildings for Small Enterprises**, Architectural Press, 1984.
[71] P. Cunnington, **Change of use: The Reuse of Old Buildings**, Alphabooks, 1988.
[72] C.A. Brebbia, **Structural Studies, Repairs and Maintenance of Heritage Architecture**, WIT Press, 2011.
[73] H. Razavivandfard, A. Mehan, *Adaptive reuse of abondoned buildings for refugees: lessons from European context*, **Suspended Living in Temporary Space: Emergencies in the Mediterranean Region**, LetteraVentidue Edizioni, 2018.
[74] G. Howard Snyder, *Sustainability through adaptive reuse: the reuse of industrial buildings*, **Master Thesis**, University of Cincinnati, Department of Architecture, 2005.
[75] S. Brand, **How Buildings Learn: What Happens After They're Built**, Penguin Publishing Group, 1995.
[76] H.S. Yang, *A Study on Preservation, Restoration and Reuse of the Industrial Heritage in Taiwan: The Case of Taichung Creative Cultural Park*, **XVth International Congress of the International Committee for the Conservation of the Industrial Heritage**, Taipei, 2012.
[77] * * *, **17th General Assembly of ICOMOS**. Edited by ICOMOS Press, 2011.
[78] M. Falser, **Industrial Heritage Analysis**, UNESCO World Heritage Center, 2001.
[79] P.B Del pozo, P.A. González, *Industrial Heritage and Place Identity in Spain: From Monuments to Landscapes*, **Geographical Review, 102**(4), 2012, pp. 446-464.
[80] M.P. Repellino, L. Martini, A. Mehan, *Growing Environment Culture through Urban Design Processes*, **Nanfang Jianzhu, 2**(2), 2016, pp. 67-73.
[81] G. Swensen, *Integration of Historic Fabric in New Urban Development – a Norwegian Case-study*, **Landscape and Urban Planning, 107**, 2012, pp. 380-388
[82] I. Strange, D. Whitney, *the changing roles and purposes of heritage conservation in the UK*, **Planning Practice and Research, 18**(2), 2003, pp. 219-229.

[83] G. Cullen, **The Concise Townscape**, Van Nostrand Reinhold, 1961.
[84] E.H.K. Yung, Q. Zhang, E.H.W. Chan, *Underlying social factors for evaluating heritage conservation in urban renewal districts*, **Habitat International, 66**, 2017, pp. 135-148.
[85] K. Attarian, B. Safar ali najar, *Vernacular and historic underground urban facilities and sustainability of cities case study*, **Journal of Cultural Heritage Management and Sustainable Development, 19**(1), 2018, pp. 2-23.
[86] M. Mohammadjavad, M. Didehban, H. Bazazzadeh, *Contemporary architectural heritage and industrial identity in historic districts, case study: Dezful*, **Journal of Studies on Iranian-Islamic City, 6**(22), 2016, pp. 41-50.
[87] H. Bazazzadeh, M. Ghomeshi, *The White Bridge of Ahwaz*, **TICCIH Bulletin, 81**, 2018, pp. 18-19.
[88] K. Stefanski, P. Gryglewski, Y. Ivashko, A. Dmytrenko, O. Ivashko, *Revitalization Specifics of Industrial Enterprises Made of Brick and Concrete. Examples of Lodz, Kyiv and Poltava*, **International Journal of Conservation Science, 11**(3), 2020, pp. 715-730.
[89] V. Comite, J.S. Pozo-Antonio, C. Cardell, T. Rivas, L. Randazzo, M.F. La Russa, P. Fermo, *Environmental Impact Assessment on the Monza Cathedral (Italy): A Multi-Analytical Approach*, **International Journal of Conservation Science, 11**(Special Issue: 1), 2020, pp. 291-304.
[90] A. Mostadi, R.W. Biara, *Sustainable Development of Brownfield Site for a New Landscape Perception of an Industrial Heritage in the City of Kenadsa*, **International Journal of Conservation Science, 10**(1), 2019, pp. 165-176.
[91] P. Spiridon, I. Sandu, *Conservation of cultural heritage: from participation to collaboration*, **ENCATC Journal of Cultural Management and Policy, 5**(1), 2015, pp. 43-52.
[92] I.C.A. Sandu, P. Spiridon, I. Sandu, *Current Studies and Approaches in the Field of Cultural Heritage Conservation Science. Harmonising the Terminology in an Interdisciplinary Context*, **International Journal of Conservation Science, 7(**3), 2016, pp. 591-606.
[93] O. Florescu, I.C.A. Sandu, P. Spiridon-Ursu, I. Sandu, *Integrative Participatory Conservation of Museum Artefacts. Theoretical and Practical Aspects*, **International Journal of Conservation Science, 11(**1), 2020, pp. 109-116.

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