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Assessing user's satisfaction in innovation centers with industrial heritage renovation

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ABSTRACT

BACKGROUND AND OBJECTIVES: Adaptive reuse of heritage buildings is important because of their impact on preserving the city's identity and urban integrity, as well as their hidden capabilities and values. In recent years, one of the adaptive reuse projects in existing factories around the world and also in Iran is transforming them into innovation centers. Thus, it is necessary to investigate the effective indicators of designing innovation centers and adapting the industrial heritage buildings to these criteria. This study aims to investigate and prioritize the criteria and indicators of designing innovation centers with industrial heritage renovation.
METHODS: The current study is performed in two phases. First, the related literature was studied and criteria regarding industrial heritage and innovation centers were distinguished. In the next phase, post-occupancy evaluation of two cases of innovation centers in Tehran and Mashhad (Azadi innovation factory and Mashhad innovation factory) was carried out and the results were gained by applying structural equation modeling method using SmartPLS software. Thus, users' satisfaction level of these criteria and the importance of each criterion from the users' point of view were investigated.
FINDINGS: The results revealed that, for designing innovation centers in industrial heritage sites, four main criteria such as environment, technology and energy, aesthetics and socio-cultural could be discussed. According to the presented structural equation modeling, according to users' opinion, environment criteria with Path coefficients of 0.4 in both cases is the most important factor while technology criteria with Path coefficients of 0.3 ranks after it. The factor loadings show that attention should be paid to the appropriate dimensions of work spaces (0.8), flexible and appropriate furniture (0.7-0.9), and providing service areas (0.8). Also, creating a sense of place and increasing productivity and improving social interactions were very important from the users' point of view while designing adaptively reused heritage as innovation centers.
CONCLUSION: For designing innovation centers the environment criteria are more important in users' opinion and more attention should be paid to greenery, space and mass and access to the complex. The environmental comfort factors for users are also of high importance and the users' satisfaction level reveals that in these two cases users are almost satisfied with the design.

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INTRODUCTION

In the second half of the 20th century, after the industrial era, significant changes were made in urban design. Many industrial complexes in the core of the cities lost their use and were abandoned (Rezaei Ghahroodi and Mahdavinejad, 2019). For the first time in history, the need to preserve the values of heritage buildings was noticed after the destruction of several industrial buildings in England (Sulimowska-Ociepka, 2021). The explanation of heritage values begins with the Athens Charter, which is the first global document establishing fundamental guidelines for a code of practice for conservation and the issue of international charters after it (Chatzi Rodopoulou 2023). After revising the principles of Athens Charter, the Venice Charter was proposed in 1964 (ICOMOS, 1964), and after that, the Nizhny Tagil Global Charter was issued in 2003 (TICCIH, 2003). In this regard, in 2011, a protocol was approved to develop the principles of heritage protection under the title of Dublin principles (ICOMOS-TICCIH, 2011). Industrial heritage should be preserved since they have tangible and intangible values (Nejadebrahimi *et al.*, 2014) and in other words, social, economic, cultural, aesthetic, original and special values (Hanachi and Khani, 2021). As the city's infrastructure grew over time, many industrial zones were built, but some of them are not fully operational now. This caused the quality of life to deteriarate: there were more slums and health problems, and the social and economic situation declined (Potseshkovskaya and Soroka 2021). Studies about industrial heritage show that they are the result of interaction between culture and industry and contain valuable information about science and technology of their time. Industrial heritage forms part of the identity and memories of cities. Creating memories is a way of preserving the past in the present or preserving the present in the past, so it is needed to reuse and adapt these buildings to the current uses required in cities (Bahramipanah, 2022; Ghanbari, 2018; Shahhosseini and Moulaii, 2019). The authenticity, environmental values, urban image and vision for urban development are the other aspects that emphasize on importance of preserving industrial heritage for urban integrity (Oevermann, 2015). Local community's feeling towards heritage is essential for their regeneration and if the heritage sites are abandoned, they can cause negative memories. Vice versa, reusing the heritage buildings can increase social integrity and strengthen local identity (Martinovic and Ifko, 2018). Besides protection of industrial sites for future generation, they bring a new life to the city environment (Gharaati *et al.*, 2023). Thus, it is vital to comprehend how industrial heritage is locally used and understood for its preservation (Galaz-Mandakovic and Rivera, 2023). According to Leus cited in Ranjkesh and Fadaei Nezhad Bahramjerdi, (2020), preservation of industrial heritage is only possible through "adaptive reuse". By adaptive reuse and by creating a new usage, the industrial heritage buildings are modernized for contemporary use. Adaptive reuse is a method to adjust the new use to the abandoned building in four aspects such as function, architecture, structure and infrastructure, which is also in line with sustainable development, from an environmental point of view (Heidari *et al.*, 2019; Bahramipanah, 2022). Some suitable reuses for industrial heritage include garden nurseries, markets, tertiary education, arts and creative industries, and new business incubators (Clark, 2013). In recent years, more attention has been paid to innovation centers in Iran and the need to support start-ups. Innovation centers are referred as science and technology park or innovation center or incubator. Incubators are centers that help start-ups and new innovative companies to increase success and reduce the risk of failure (Dupal *et al.*, 2017). Creating innovation centers is one of the methods to preserve industrial heritage during the process of reuse, which has been implemented in recent years. Due to the formation of a number of innovation centers in Iran and reuse of industrial heritage as innovation centers in several cities, it is necessary to examine the criteria required in the adaptive reuse of heritage in order to design innovation centers in accordance with the users' needs.

Research background

Industrial heritage and adapting heritage use

Heritage can be considered as a memory of the past that people live with it now, and then leave it to the next generations to learn from and enjoy it (Jopela, 2011). The International Committee for the Conservation of the Industrial Heritage (TICCIH) in The Nizhny Tagil Charter for the industrial heritage has defined Industrial heritage as "The remains of industrial culture which are of historical, technological,

social, architectural or scientific value. These remains consist of buildings and machinery, workshops, mills and factories, mines and sites for processing and refining, warehouses and stores, places where energy is generated, transmitted and used, transport and all its infrastructure, as well as places used for social activities related to industry such as housing, religious worship or education" (TICCIH, 2003 cited in Clark, 2013; Sulimowska-Ociepka, 2021). Industrial heritage sites are an important part of the landscape and built environment around us. These landscapes illustrate the interplay between humans and machines, and also between nature and architecture (Meng *et al.*, 2023). They establish tangible and intangible connections with our past and have the potential to play an important role in cities and suburbs (Clark, 2013), they can even affect movements of urban citizens (Bazazzadeh *et al.*, 2022). There are different theories regarding the value of heritage protection. In Cesare Brandi's classification, the three main aspects of place, time and authenticity are the basis of the value evaluation framework. The parameter of place is divided into six sub-components including interventions, social, political, economic, functional and structural. And the time parameter is divided into two sub-components of identity and value. The authenticity parameter is divided into nine subcomponents such as original, natural, exceptional, impressive, referential, technical, artistic, practical, and rare (Mahdavinejad *et al.*, 2017). In another category, heritage values are classified in five aspects including historical, technological, economic, educational and psychological values (Jie, 2009). One way to preserve these values is the adaptive reuse of heritage (Alavi et al., 2021). Adaptive reuse includes changing the use of existing structures or buildings based on new needs of users aiming to achieve economic, social and environmental sustainability with an emphasis on saving material, reducing costs and preserving the inherent values of heritage (Ferretti *et al.*, 2014). In research about adaptive reuses in Australia, the criteria including the age of the building and its conditions, height, depth, building envelope and cladding, structure, facilities, interior design, flexibility for various uses, type of construction, location, values, dimensions, Accessibility, proactive legislation, acoustic isolation, user demands and site orientation are reviewed (Wilkinson *et al*., 2009). To achieve a framework for sustainable heritage management industrial heritage sites in England were studied. Research shows that for sustainable heritage management, while analyzing the situation, strategic orientation, holistic planning and long-term sustainability perspective, the active participation of stakeholders and their values should also be considered (Landorf, 2009). In adaptive reuse capabilities in a research information such as identity, location, context, use, ownership, building features, architectural details, and heritage materials were examined through record cards, image collections, and building dimensions (Fuentes, 2010). Another research about the silos of Spain, investigated the impact of comparative use of these buildings in their context and the impact on the landscape of the surrounding urban context (creating an urban sign or urban public space) by examining the primary information about case examples (sites and images) (Garrido-Cifuentes *et al.*, 2017). In a study on the comparative use of grain silos in Italy, based on the multi-criteria decision analysis method, after reviewing the information of the existing situation, the new use was determined by considering the number of changes in levels, openings, mass and view (Giuliani *et al.*, 2018). Reviewing 25 cases of Iran's industrial heritage shows flexibility as an important feature in adaptive use. This feature has four criteria including "adaptability", "dismantle and reuse of materials", "assembly and disassembly" and "durability" (Bazazzadeh *et al.*, 2021). Based on the value of heritage and functional building service life model (building functional cycle), users' behavior in the urban space and choosing routes were investigated using DepthmapX software. Also, parameters such as facade dimensions and pedestrian access and facade alignments and building height and visibility and permeability were investigated (Pizarro-Reyes *et al.*, 2022). Esmaeilian Toussi and Etessam, (2019) studied the textile factories of Isfahan and Yazd using the combined method of typology and analytic form. In this research, the sub-criteria of the cases have been examined by describing the interpretative-historical characteristics. Then, based on the physical characteristics, the physical-spatial, semantic, and physical parts, the case samples were parameterized and the data was analyzed through inductive and analogical reasoning. In a research on change in function and green application of Ray cement industrial complex, the importance of using

industrial heritage capacities for green adaptive reuse with the aim of productivity, reducing consumption, and recycling had been discussed (Bahramipanah, 2022). Another research on improving the energy performance in historical buildings shows that interventional and non-interventional methods are ways of protecting the heritage. These methods are applied in facade, cooling-heating and lighting systems (Gholami *et al*., 2021). Mahdavinejad *et al.,* (2016) investigated the factors of the formation of spatial identity such as memories, orientation, spatial order and figure and appearance and individual identity in the historical area of Dezful city. The criteria discussed in mentioned researches are summarized in Fig. 1.

Innovation Center

Work spaces are somewhat different from each other according to the type of work and activities performed in them. Due to the changing nature of these spaces, there is no clear distinction between them. Accelerators, incubators, co-working spaces, pilots, startup spaces, and urban innovation centers are types of innovative workspaces. One of the parts of every innovation center is the co-working space. In 2005, the first co-working space started in San Francisco by Brad Newberg (Merkel, 2015; Spinuzzi, 2012). A study about the successful examples of innovation centers in Melbourne, Sheffield and Cardiff, mentions the criteria for an innovation center such as the spaces with different functions and with different dimensions, flexibility of the spaces, easy access to the building for all groups, the use of open plan and suitable natural or artificial lighting (Montgomery, 2007). Another study, suggests that besides easy access to the building and having rooms for concentration, a work space needs to be open 24 hours a day to create a greater sense of belonging (Spinuzzi, 2012). Based on the users' opinion at the design and innovation center of Aalto University, values such as cooperation, openness, interactions, accessibility and sustainability have been considered for a co-working space. To achieve this purpose, criteria such as an inviting lobby, multiple spaces with different functions, flexible spaces and flexible furniture on wheels, relaxing and intimate spaces, decorative and interesting elements, bright colors and cozy corners were mentioned. Using different materials in interior design and a space for displaying prototypes and posters can also fulfill these values (Kojo and Nenonen, 2014). In a study in Wales, the presence of meeting spaces, private offices, and rest spaces, along with flexible spaces, are listed as essential elements for employees' satisfaction, and co-working spaces should have a happy atmosphere and lively social connection. It is also necessary to

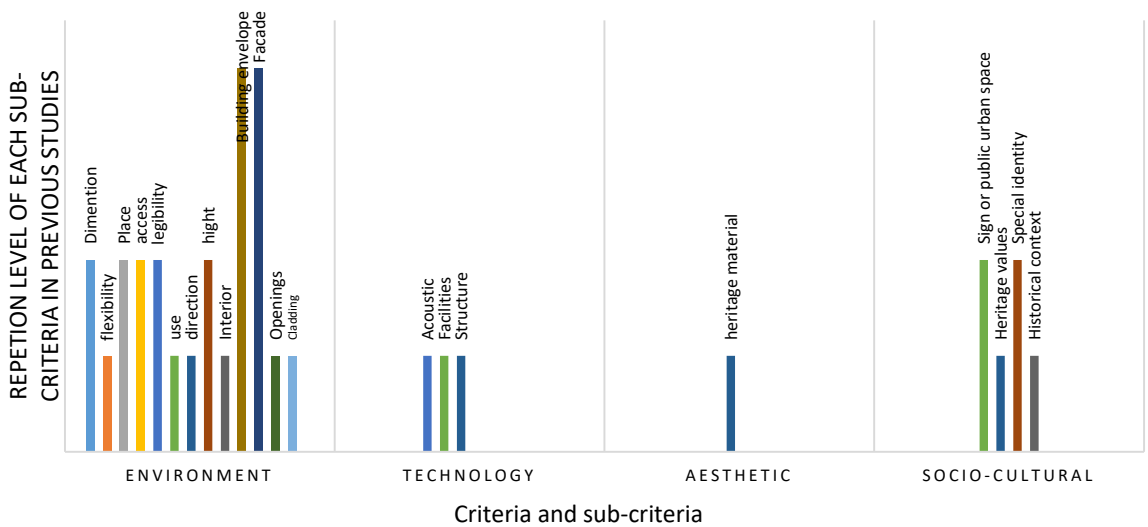


Fig. 1: The components studied in previous research (Giuliani *et al.*, 2018; Garrido-Cifuentes *et al.*, 2017 ; Pizarro-Reyes *et al.*, 2022; Esmaeilian Toussi and Etessam, 2019; Mahdavinejad *et al.*, 2016; Fuentes, 2010; Wilkinson *et al.*, 2009)

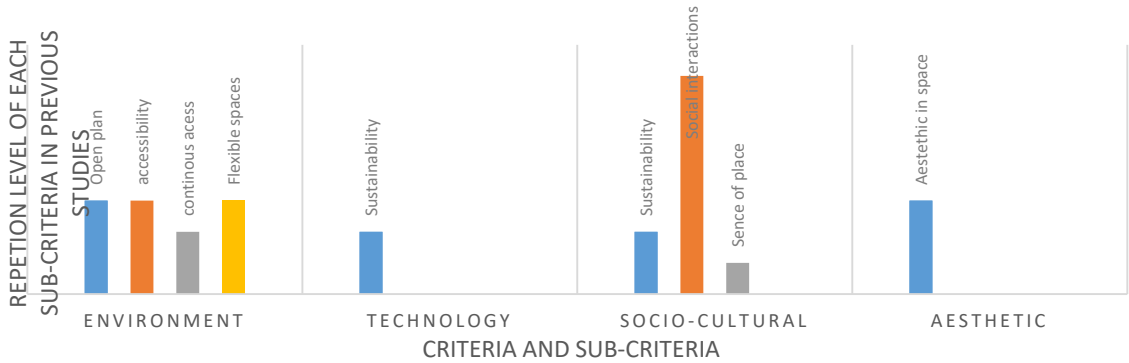


Fig. 2: Characteristics studied in the innovative work spaces based on previous researches (Montgomery, 2007; Spinuzzi, 2012; Kojo and Nenonen, 2014; Merkel, 2015; Fuzi, 2015; Kojo and Nenonen, 2016; Brown, 2017; Micek, 2020)

have spaces that inspire and stimulate creativity (Fuzi, 2015). In the study of co-working spaces in Finland, the typology of these spaces is divided into three categories: public, semi-public and private. Also, the importance of the built space from the access perspective is pointed out (Kojo and Nenonen, 2016). Brown, (2017) states that one of the reasons for motivating people to work in innovation and co-working centers is having an open-plan space with multiple uses, as well as flexibility and aesthetic design, which also increases social interaction. Adjacency and friendly social relations in innovation centers have been found as the reason for strengthening cooperation and achieving innovation, and also open and multi-use spaces as criteria for achieving it (Micek, 2020). Fu *et al.*, (2023) in a research conducted in two platforms served as enterprises discovered a positive relationship between space utilization and social interactions and that making a sense of identity will thrive incubators. In a user experience survey about co-working spaces in Nigeria, more than 50% of the respondent's declared that visual and thermal comfort as well as social and relaxation spaces are very important. The findings also show that various furniture design and accessibility are the important factors for designing co-working spaces (Memud and Tabibi, 2023). Irrespective of user and place, in designing co-working spaces, considering accessibility and half-open layouts is beneficial (Appel-Meulenbroek *et al.*, 2021)

Fig. 2 summarizes the components examined in the mentioned studies about innovation centers.

Post-Occupancy Evaluation (POE) in similar uses

POE is an effective way to find design solutions for productivity and user satisfaction (Motalebi *et al.*, 2021). For more than half a century, post-occupancy evaluation has been used as a method to determine how well a building was designed to meet the needs and goals of its users. One of the tools for POE is preparing a questionnaire that can be classified and implemented by three methods as Building Use Studies (BUS), Design Quality Indicator (DQI) and Overall Liking Score (OLS) (Bordass and Leaman, 2005). Several parameters of POE such as privacy, acoustics, lighting, temperature, ventilation, comfortable furniture, cleanliness, visual comfort are questioned to check the quality of the indoor environment. In post-occupancy evaluation of 20 office buildings in USA, considering factors such as age and gender, the results showed that the quality of air temperature was the most important factor in employees' satisfaction (Choi *et al.*, 2012). Hua *et al.*, (2014) have investigated the effect of various factors such as building facade, thermal comfort, indoor air quality, sound privacy, visual comfort and personal control on users' satisfaction and its effect on the spatial map of users. Another study compared the post-occupancy evaluation of two green office buildings in China to investigate the level of user satisfaction with environmental factors such as acoustics, thermal and visual comfort, and indoor air quality (Pei *et al.*, 2014). Park *et al.*, (2018) in a study that investigated satisfaction in 64 office buildings through post-occupancy evaluation

found that factors such as temperature, space size and quality of windows and temperature control are the most significant factors in satisfaction with thermal quality. A research on the characteristics of co-working spaces, based on the users' preference, states that criteria such as accessibility (by public transport or private car), spatial plan (semi-open plan), having multiple work groups and a sense of intimacy were the priorities of most users (Weijs-Perree *et al.*, 2019). Pastore and Andersen (2019) in a research in Switzerland evaluated post-occupancy of four green office buildings by collecting information about the dimensions, year of construction, number of users and the amount of control over the awnings and windows. The findings state the effect of factors such as temperature, light and air quality on users' satisfaction. In the study of work spaces in seven buildings in Singapore, eighteen parameters were investigated and users were most dissatisfied with parameters such as cleanliness, sound privacy, personal control and temperature (Cheung *et al.*, 2020). Another research examined a green building in Korea and the technologies used in it to evaluate post-occupancy and user satisfaction with components such as parking lots and the possibility of charging electric cars, efficient water supply system, building envelope. Also, use of renewable energy and factors affecting comfort and environmental control such as ventilation, heating and cooling, lighting and awnings were examined (Kim and Kim, 2020). Asojo *et al.* (2021) examined twelve categories of indoor environment quality indicators in a work space in Minnesota. They found that the level of light control, humidity, visibility and technology in the building has a direct relationship with the level of users' satisfaction and the employees are the most dissatisfied with controlling heat, furniture, visual and acoustic privacy and the aesthetics. The impact of adjustable and changing facades on the users' experience and criteria such as acoustics, visual features, aesthetics, air quality, control and heating were examined based on the users' preferences and existing conditions (Koyaz and Ünlü, 2022). Cited in Hassanain and Mahroos, (2023) other POE studies of office buildings also conducted by Deuble and de Dear, (2012), Akashah *et al.*, (2015), Choi and Moon, (2017) and Middlehurst *et al.*, (2018) gathered information on users' satisfaction with indoor environment quality(IEQ) in work spaces. Jailani *et al.*, (2015) conducted a POE to identify the gap between users' preferences and the building's performance and conclusion showed no significance relavance between user's expectations and building's performance (Jailani *et al.*, 2015 cited in Hassanain and Mahroos, 2023).

The main criteria investigated in post-occupancy evaluation in mentioned studies are shown in Fig. 3.

In order to discover criteria of designing innovation centers with industrial renovation, the mentioned factors were analyzed from two perspectives: importance from the users' point of

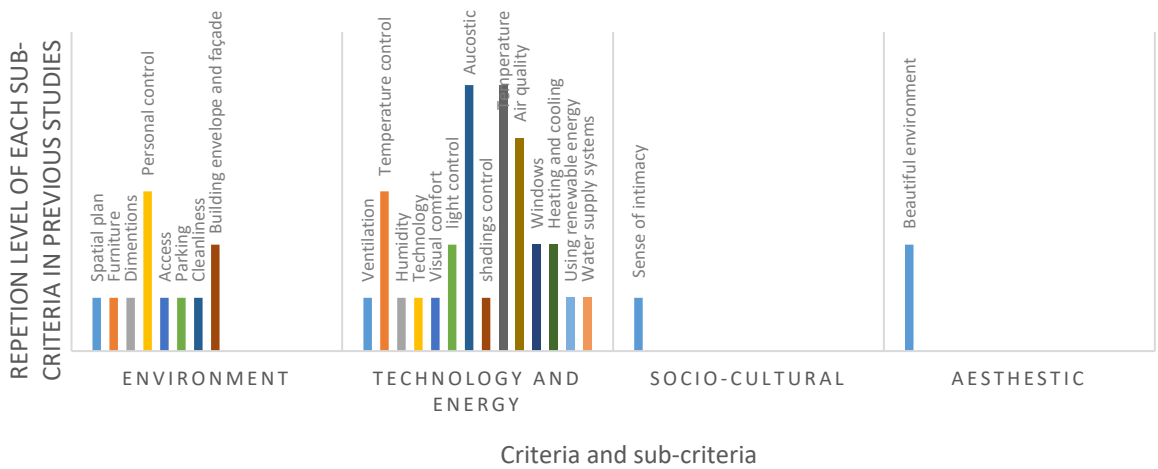


Fig. 3: investigated components of each criteria in POE of work spaces based on previous researches (Koyaz and Ünlü, 2022; Asojo *et al.*, 2021; Cheung *et al.*, 2020; Kim and Kim, 2020; Pastore and Andersen, 2019; Weijs-Perree *et al.*, 2019; *Park et al.*, 2018; *Pei et al.*, 2014; Hua *et al.*, 2014; Choi *et al.*, 2012)

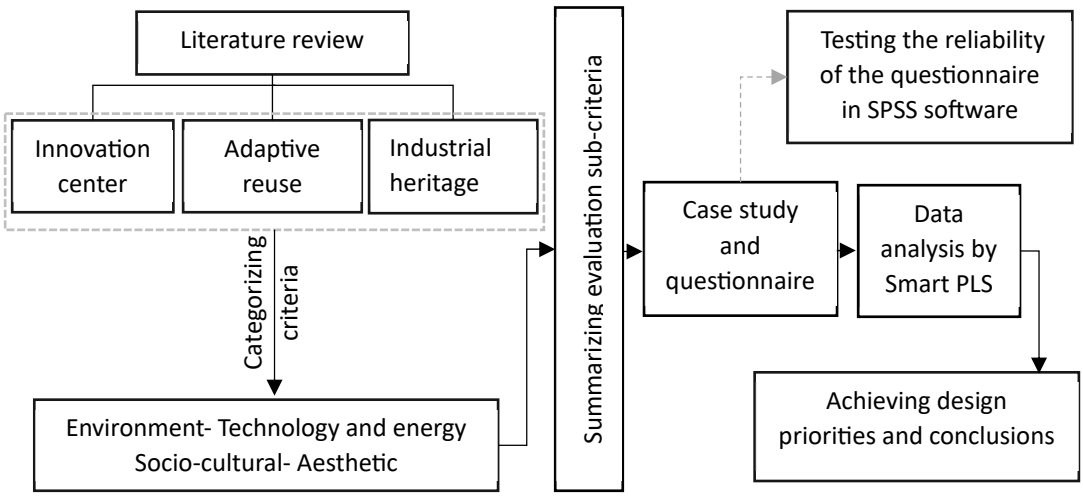


Fig. 4: Theoretical research model by: Authors)

view and the user's satisfaction. Therefore, at first, this research has extracted the effective factors and common cases in innovation centers and industrial heritage by considering the different dimensions of industrial heritage according to the literature review about the three topics of innovation center, industrial heritage and adaptive reuse. In the next step, according to the literature and principles and models studied in Liu *et al.* (2018) research and Nili *et al.* (2017) research according to five Broadbent's criteria, these factors were categorized into four main criteria such as aesthetics, socio-cultural, environment and technology and energy and then the sub-criteria, observed in literature review, were placed under the four criteria. Then, by post-occupancy evaluation, these factors were analyzed in two existing factory cases in terms of importance from the users' point of view and the users' satisfaction, and the Structural Equation Model (SEM) was analyzed in Smart PLS3 software.

The research hypotheses include the following:

· Among the four examined criteria, environment and technology and energy are more important than the other two criteria from the users' point of view.

· Socio-cultural criteria are more important than aesthetic criteria for users.

· Users are most satisfied with environment criteria.

The research questions are as follows:

1. Which design sub-criteria in these four categories has a greater impact on users' satisfaction?

2. Do the environment criteria affect users' satisfaction more than technology?

3. Which of the environment sub-criteria are more important for users?

The process of this research is shown in Fig. 4.

As mentioned in the literature, previous research on industrial heritage were conducted in terms of assessing the buildings characteristics but not for a specific use as work spaces and the articles about innovation centers or offices which observed users' needs were not cases of industrial renovation nor adaptive reuse. Another novelty aspect of the research is that the POE is not only assessing users' satisfaction with the building but also it investigates the users' expectations by asking the importance of factors from users' opinion. So, the importance and level of satisfaction could be compared to find the gap in current designed innovation centers and be considered in future design. Thus, the result of the article shows a new aspect of post occupancy evaluation of heritage buildings which is the users' needs and opinion on how to design innovation centers in these heritage buildings. Two achieve this, the study was conducted in Mashhad and Tehran innovation centers in Iran in 2023.

MATERIALS AND METHODS

Case study

In Iran, innovation as concept of research and

development started with Pasteur Research Institute, which was established for medical research in 1920 (Ansari *et al.*, 2016). In the field of innovation, since 2007, innovation centers have been established in Iran. The first industrial heritages in Iran were built in Qajar period, and reached the peak in Pahlavi period. Till then, more than 270 factories were established, and by 1952, this number reached 347 factories, most of which were located in Tehran (Samadzadehyazdi *et al.*, 2019). Buildings such as Behshahr textile factory, administrative and technical railway buildings in Tehran, Mashhad, Tabriz and other cities, also some factories in Qazvin, Yazd, Isfahan, Rasht, Rey and Qom were built during the Pahlavi era. Among the existing industrial heritage, Ama Electrode Factory (Azadi Innovation center) and Coca-Cola Factory (Mashhad Innovation center) are two examples of industrial heritage remained from the Pahlavi II era, which are adaptively reused innovation centers. Fig. 5 shows the geographic location of the cases.

The reason for selection of these two cases is their former use as factory and construction time with an interval of two years, also their new use as innovation centers during 2016 to 2019. More information about the buildings' attributes is provided in Table1.

After examining the characteristics of the two cases and the commonalities obtained from studies on industrial heritage and POE, the suggested criteria for preparing the questionnaire were divided into the general categories of environmental, technology and energy, socio-cultural, and aesthetic. The criteria and sub-criteria for preparing the questionnaire are shown in Table 2. The online questionnaire was designed based on the five-point Likert scale, for each of the factors, based on two indicators of satisfaction and the importance of the factor from the users' point of view. Then, the relationship of each factor with user satisfaction and the importance of the factor in the design of each case was investigated using structural equation model in Smart PLS3 software.

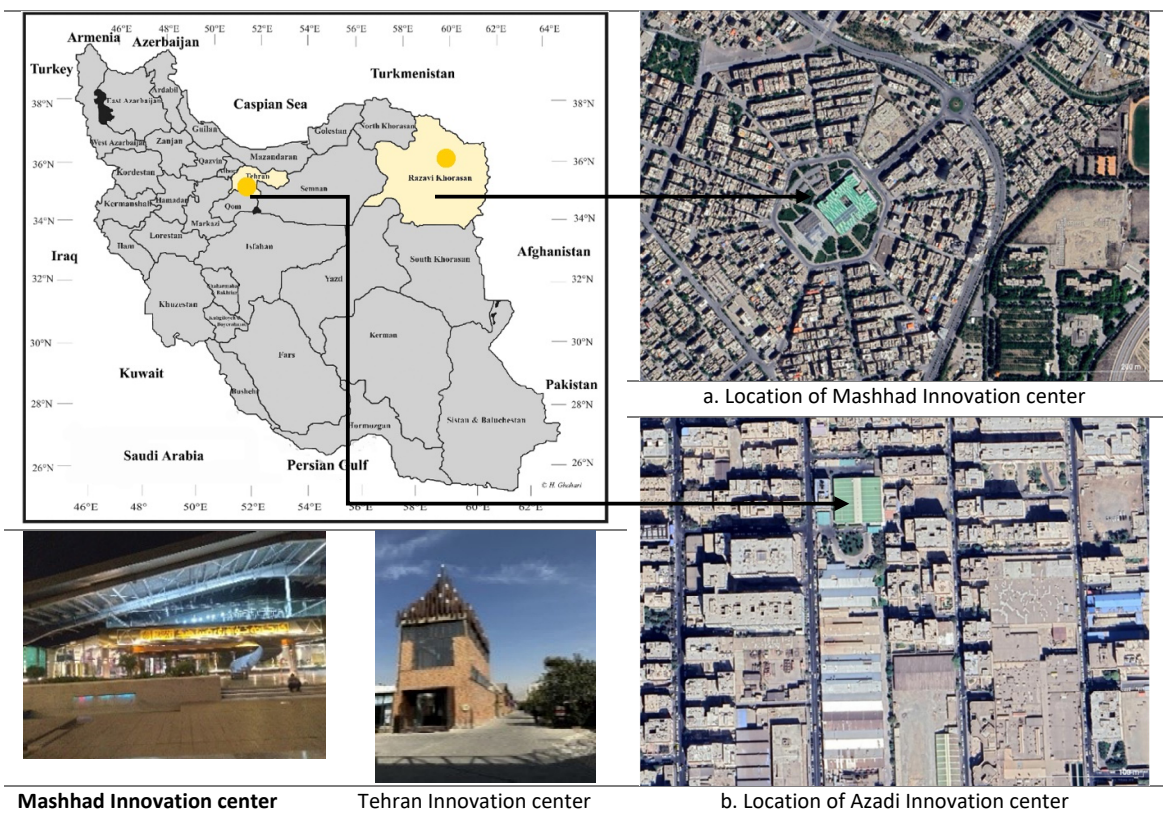
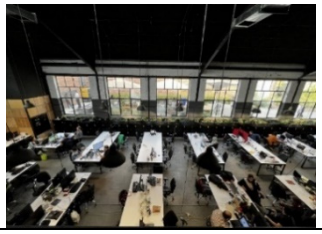


Fig. 5: Geographic location of the case studies

Table 1: Information about innovation centers in Mashhad and Tehran

	Ama Electrode Factory	Coca-cola factory
Location	Tehran, Lashgari Expy	Mashhad, Pajuhesh square, Kosar boulevard, Mashhad
Age	Pahlavi II	Pahlavi II
Ownership	Hamava Company (A branch of Pardis Technology Park)	Mashhad Municipality
Area	18500 square meters	3.7 hectares
Built area	Around12000 square meters	Around 10000 square meters
Previous function	Factory	Factory
Establishment	1960	1958
Architectural space	Ten niches plus the central building and 4500 square meters office space	Two niches with four-part brick and steel arches
Decoration	No decoration except the remained bricks from the old factory	No decoration
Type of adaptive reuse	Tehran innovation center	Mashhad innovation center
Spaces in new function	Accelerator, Innovation Studio, co-working space, Cafe, Botanists Production, Contemporary Architects Center, Sports Club, Tech-shop, Lobby, Conference Hall, export exhibition, management	Dining hall, exhibition hall, classrooms, winter and summer courtyard, two co-working spaces (small and large), office space, spaces for conversation, amphitheater, studio and content production, innovation laboratory, reception, warehouse and safe deposit box, management, Special innovation spaces for children
connection with the urban spaces	Connecting through entrance	Connecting through park and playground
Privacy	Fences	No fence
Interior photo		

Structural equation modeling (SEM), segregates measurement errors from the scores of factors, so it provides a methodology for modeling the latent variables directly. SEM has developed since 1970, and is now widely applied. Multiple indicators for a latent variable in form of factor analysis is the idea for SEM. Several widely used statistical models are covered by SEM methodology (Yuan and Bentler, 2006; Samimi and Nouri, 2023).

Therefore, 60 questionnaires were collected from Mashhad Innovation Factory users and 60 questionnaires from Azadi Innovation Factory users in Tehran. The total number of respondents was 120. The respondents were of different age groups but were mostly between 18 to 25 years old and almost 66.7 percent of them were men. 42.5% of the respondents were working in co-working spaces and the rest were working in private offices, management and other parts of the centers. The presented model based on the four presented criteria for each of two cases was conducted separately from two aspects of satisfaction and importance in Smart PLS3 software. In order to check the reliability of the questionnaire and the presented model, Cronbach's alpha was also checked in SPSS software. Reliability in each of the criteria is acceptable. (Cronbach's alpha is higher than 0.7). Also, the construct cross-validated redundancy and the construct cross validated communality, was checked and the quality of the structural model is acceptable because of the positive values. Also, the results of Bartlett and Kaiser-Meyer-Olkin (KMO) test show appropriate values as shown in Table 3.

Table 2: Classification of criteria and sub-criteria for preparing questionnaire (Nili *et al.*, 2017; ;Liu *et al.*, 2018)

Criteria	Factors	Questions
environment	Greenery	Using greenery in interior and exterior environment
	Mass and space	Legibility of entrance
		Providing parking spaces for cars, motorbikes and bicycles
		Work space flexibility and the multi-functionality of the spaces
		Flexibility and possibility to change the use of service spaces for future development
		Separation of work space in order to provide privacy
		Interior furniture design to provide general order in spaces
		Providing service spaces such as gyms, coffee shops, restaurants and rest areas
		Providing additional spaces (such as group work space, meeting space, space for talking on the phone and communal spaces, conference/video conference room, space for hosting customers, thinking space and study space)
		Suitable dimensions of the work spaces (large and small)
		Appropriate height of work spaces
		Compliance with rules and standards in communication and movement spaces (proper width and height, stairs, ramps, elevators)
	Access	Access to public transportation (metro, bus and taxi)
Technology and energy	Building technology and specialty in structure and facility	Providing comfortable temperature in winter (heating)
		Providing comfortable temperature in summer (cooling)
		Provide adequate ventilation and fresh air
		Providing appropriate relative humidity in spaces
		Providing sound comfort in spaces and controlling annoying sounds from nearby spaces
		Use of suitable natural and artificial light in spaces
		Ability to control light in spaces (such as canopy, shader, curtain, etc.)
		Using modern air purification systems (purifying algae) in order to create fresh air in spaces
		Using new materials and new building systems
	Effect of technology on other contexts	Applying and using new energies (such as solar panels, wind turbines, etc.) in order to reduce the use of fossil fuels
Socio-cultural	Place identity and memories	Designing spaces in order to create a sense of belonging and interest in the work environment
	different aspects of social life	Designing spaces in such a way that social interactions are possible
		Possibility of using the space for other members of the community
	Cultural impact	Monitoring and taking care of spaces and creating a safe place for users
		The effect of designed spaces to increase job productivity
Aesthetics	Artistic value of building such as form, shape, material, color and decoration	Good view and perspective
		Harmony in colors of the spaces and furniture with the use of space
		Using the existing materials in the old factory in order to preserve them

RESULTS AND DISCUSSION

Design and adaptive use of industrial heritage is increasing in the contemporary era, especially in recent years. With respect to the government's support policies for knowledge-based companies and start-ups, the creation of innovation centers in cities, especially in metropolitan cities like Tehran and Mashhad, is increasing. For this reason, in the projects of changing the industrial heritage of factories to innovation centers, it is necessary to examine the design criteria. Therefore, the results of this research, considering the use of the POE method in examining the indicators and criteria of user satisfaction and interest, can be effective in future designs. The first hypothesis: According to the results of the research, the criterion of environment with loadings of 0.47 in Mashhad model and 0.46 in Tehran model and technology and energy with loading of 0.32 and 0.31 in Mashhad and Tehran were the most important from the users' point of view. Therefore, the first hypothesis of the research is confirmed. The second hypothesis: The loadings caused by the aesthetic

Table 3: measures of Bartlett and KMO test

Bartlett and KMO test						
case		criteria	KMO	Approx. Chi-Square	df	Sig.
Mashhad	importance	Technology and energy	0.872	450.803	45	<0.01
		environment	0.932	719.996	78	<0.01
		Socio-cultural	0.788	164.740	10	<0.01
		Aesthetic	0.638	34.588	3	<0.01
	Satisfaction	Technology and energy	0.854	341.713	45	<0.01
		environment	0.813	393.787	78	<0.01
		Socio-cultural	0.810	130.014	10	<0.01
		Aesthetic	0.670	37.387	3	<0.01
Tehran	importance	Technology and energy	0.831	342.977	45	<0.01
		environment	0.901	499.290	78	<0.01
		Socio-cultural	0.817	139.410	10	<0.01
		Aesthetic	0.657	41.461	3	<0.01
	Satisfaction	Technology and energy	0.801	307.707	45	<0.01
		environment	0.862	451.764	78	<0.01
		Socio-cultural	0.793	113.495	10	<0.01
		Aesthetic	0.648	47.834	3	<0.01

Table 4: Path coefficients

Criteria in each case-importance and satisfaction	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics	P Values
Aesthetics -> importance in Tehran factory	0.101	0.106	0.019	5.408	0.000
Socio-cultural -> importance in Tehran factory	0.182	0.181	0.015	11.847	0.000
Technology -> importance in Tehran factory	0.315	0.318	0.021	14.828	0.000
Environment -> Importance in Tehran factory	0.460	0.462	0.019	23.670	0.000
Aesthetics -> satisfaction with Tehran factory	0.132	0.132	0.013	10.294	0.000
Socio-cultural -> satisfaction with Tehran factory	0.205	0.203	0.016	12.583	0.000
Technology -> Satisfaction with Tehran factory	0.282	0.280	0.045	6.314	0.000
Environment -> Satisfaction with Tehran factory	0.481	0.479	0.030	16.192	0.000
Socio-cultural -> importance in Mashhad factory	0.171	0.172	0.009	19.083	0.000
Technology -> importance in Mashhad factory	0.326	0.322	0.016	20.577	0.000
Aesthetics -> importance in Mashhad factory	0.081	0.083	0.011	7.552	0.000
Environment -> Importance in Mashhad factory	0.470	0.474	0.022	21.833	0.000
Socio-cultural -> Satisfaction with Mashhad factory	0.227	0.225	0.019	11.796	0.000
Technology -> Satisfaction with Mashhad factory	0.361	0.375	0.031	11.831	0.000
Aesthetics -> satisfaction with Mashhad factory	0.113	0.112	0.016	6.994	0.000
Environment -> satisfaction with Mashhad factory	0.407	0.410	0.030	13.647	0.000

criterion in Tehran and Mashhad were 0.10 and 0.08, respectively, based on its importance from the users' point of view. While the loadings of the importance of socio-cultural criterion in Tehran and Mashhad were 0.18 and 0.17 respectively. Therefore, socio-cultural criterion was more important than aesthetic criterion for users, and the second hypothesis of the research is also confirmed. The third hypothesis: By examining the level of satisfaction with environmental criterion, according to the evaluated model, it can be stated that the loading of environmental criterion was more than other criteria. Therefore, it can be said that users are more satisfied with the environmental criterion than other criteria. Therefore, the third hypothesis of the research is also true. In Table 4, the positive impact of the criteria and the significance of the relationship between the criteria and satisfaction and importance are shown.

Fig. 6 illustrates the weight of attributes as histogram graphs. The correlation between each pair of variables is demonstrated using heat map matrix in Fig. 7.

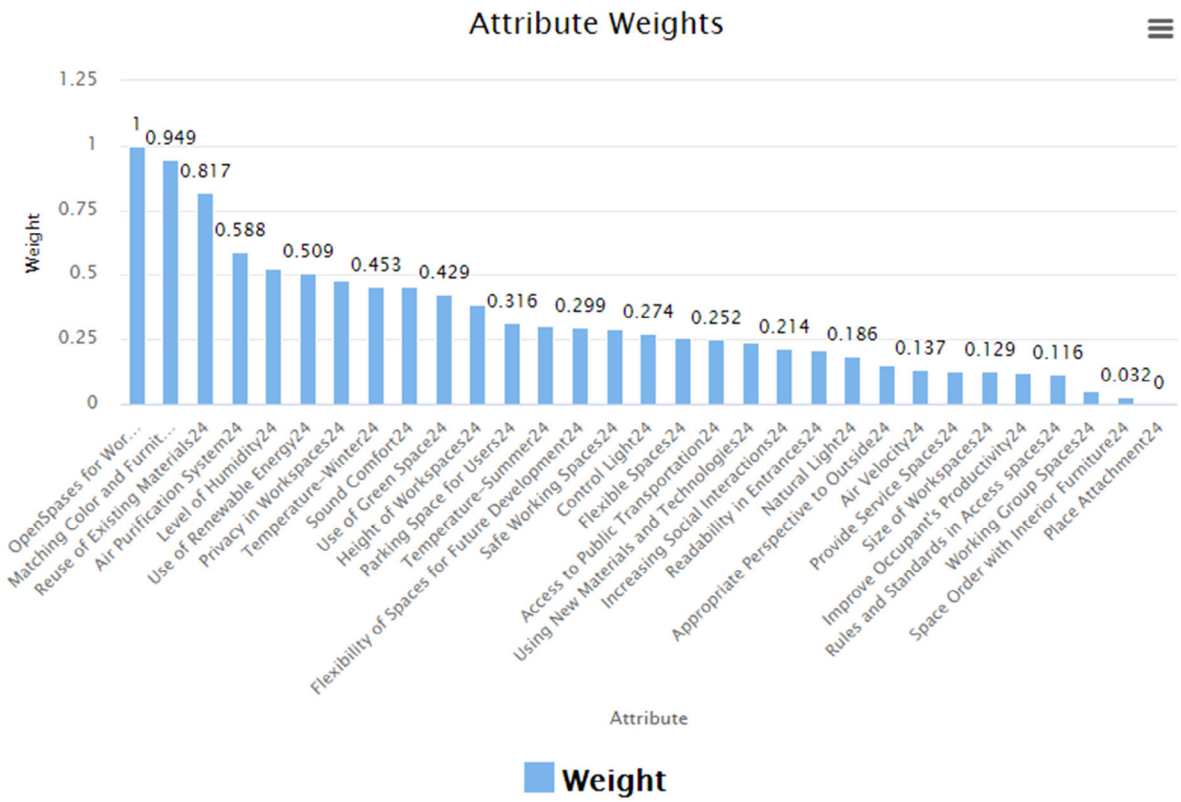


Fig. 6: Weight of attributes

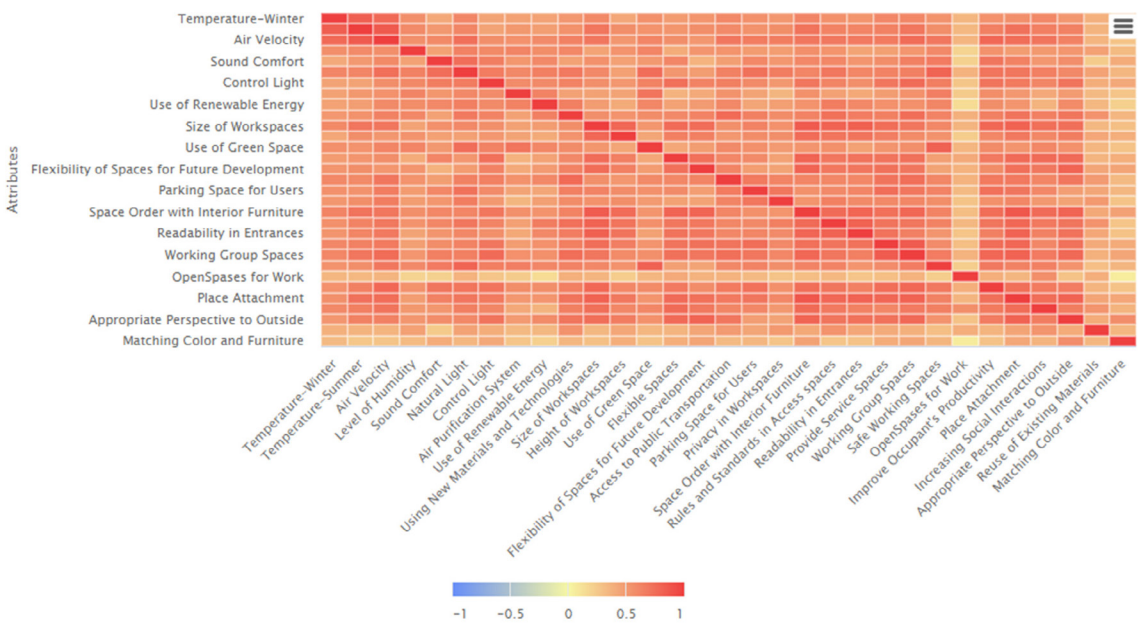


Fig. 7: Data correlation map

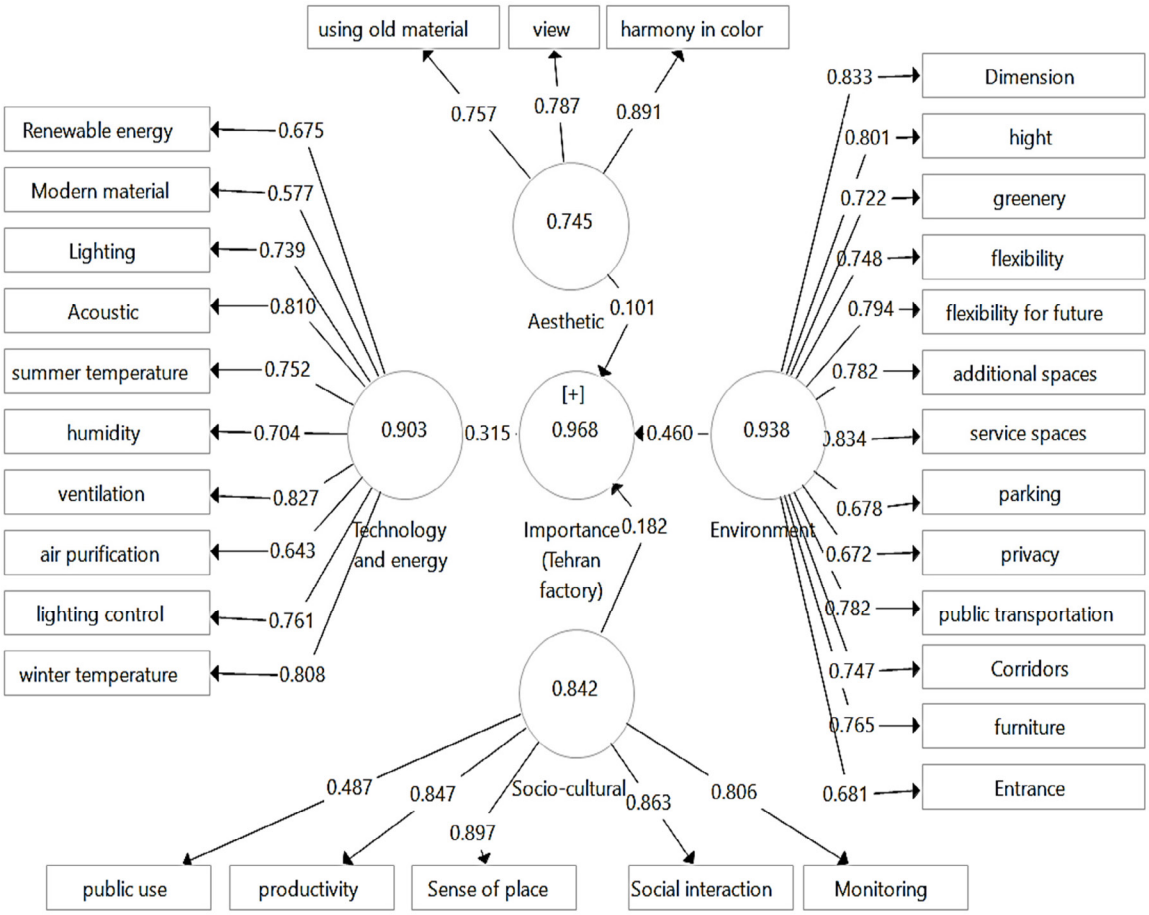


Fig. 8: PLS algorithm for the importance of factors in innovation center in Tehran

In response to the first question of the research, it should be said that in Mashhad Innovation Factory, in terms of environmental criteria, the two sub-criteria of dimensions of working spaces and furniture design for creating order in the spaces have caused the most satisfaction. In Tehran Innovation Factory, in the same criterion, the provision of additional spaces such as group work space, meeting space, space for talking on the phone and collective spaces, conference and video conference room, space for hosting customers, thinking space and space for study has created satisfaction in users. In terms of aesthetics, harmony in colors of the spaces and furniture with the use of space in Tehran Innovation Factory, and the perspective and view in Mashhad Innovation Factory have caused the most satisfaction. In Mashhad, the effect of spaces designed to increase job productivity and in Tehran, the design of spaces to establish social interactions, have caused the greatest satisfaction from the socio-cultural criterion. This is in line with research by Weijs-Perree *et al.,* (2019). In relation to the technology and energy criterion in Tehran, the provision of adequate ventilation has been found to be more satisfactory. Conversely, in Mashhad, the provision of appropriate relative humidity has been deemed more successful. This observation aligns with the researches of Cheung *et al.*,)2020(, Park *et al.*,)2018(and Asojo *et al.*,)2021(. In response to the second question of the research, while examining the factor loadings of the technology and environment criteria, it can be stated that in Mashhad Innovation Factory, overall satisfaction with the environmental component is more than technology and energy criterion, but in three sub-criteria (access, provision

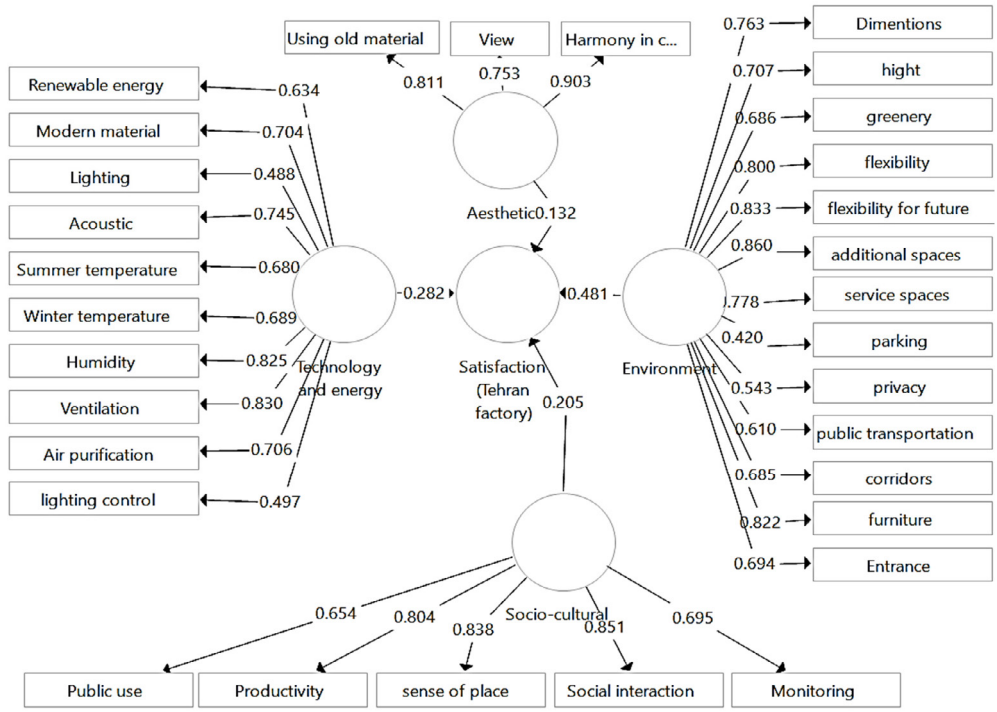


Fig. 9: PLS algorithm for the satisfaction with the factors in innovation center in Tehran

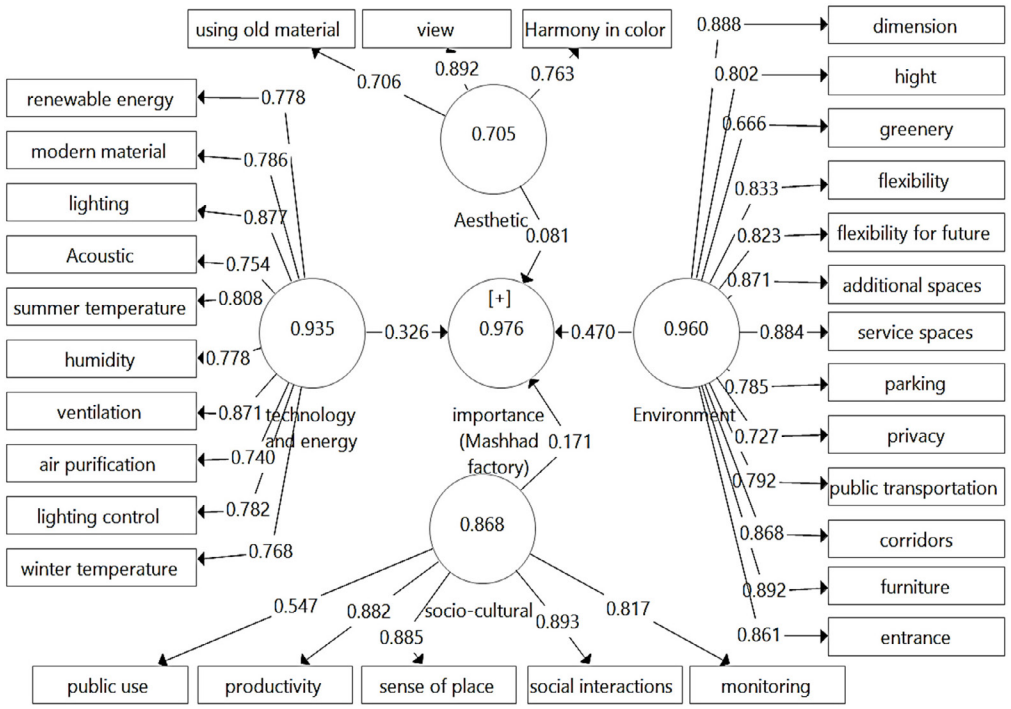


Fig. 10: PLS algorithm for the importance of factors in innovation center in Mashhad

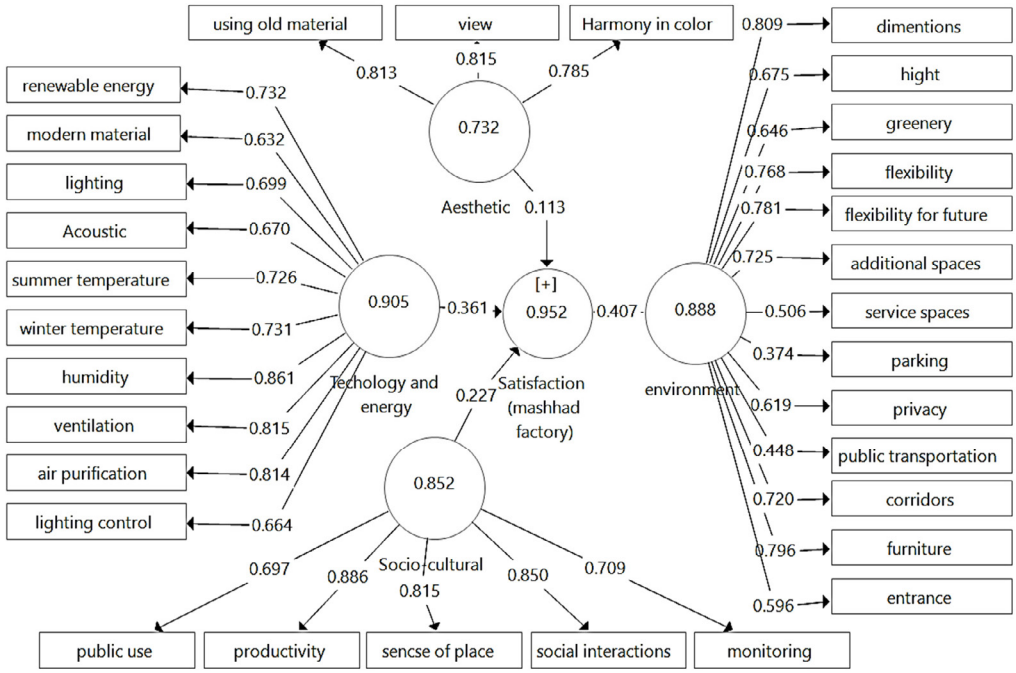


Fig. 11: PLS algorithm for the satisfaction with the factors in innovation center in Mashhad

of parking and service spaces) factor loadings are less than the other sub-criteria. Based on the objective assessment and talking with the users of Mashhad Innovation Factory, one of the main problems of the users was the lack of service areas such as restaurants or coffee shops and the weakness of additional services. Also, the distance to the metro station and the lack of parking space for the members of the center indicates the relative level of dissatisfaction with the three mentioned factors. In Tehran, the factor loading of all components is higher than 0.50, except for the factor of providing parking space (0.42). According to the factor loadings and the coefficients of the two criteria, in general, satisfaction with the factors of the environmental criterion is more than that of the technology criterion. The insufficiency of available parking facilities for patrons of center constitutes a conspicuous factor contribution to their discontentment. In the environmental criterion, dimensions of work spaces, interior furniture design and provision of service spaces have been more important from the point of view of the users, which is also in line with Asojo *et al.*, (2021). The results of the algorithm are briefly shown in Figs. 8 to11.

CONCLUSION

Industrial heritages have various values and form a part of the identity and common memories of citizens, so the adaptive reuse of these buildings to the current uses is important. By using post-occupancy evaluation, in Mashhad and Tehran innovation centers, criteria for future design and important indicators can be achieved to be used in future. According to the findings of the research, the need for service spaces in innovation centers to facilitate the activities of companies and start-ups should be noticed more in future designs. Also, flexibility for future developments is one of the factors that requires more attention for adaptive change of the industrial heritage to innovation centers. Considering the capabilities of the structure and the possibility of having large spaces in the factories, it is possible to build flexible spaces for the convenient moving and changing them for future uses. Using wheeled furniture is another practical recommended method of flexibility that has been applied in Mashhad and as users stated their satisfaction it is proved to be a desirable method. Also, factors such as the use of renewable energies and modern air

purification systems are important according to the users' opinion, but they have been less noticed in the existing cases except few microalgae purifiers used in Mashhad center. Furthermore, the opinion of users regarding dissatisfaction with green space in Tehran innovation center shows the importance of dealing with green space and its impact on increasing productivity in the workplace. So, by creating more green spaces and adding more plants preferred by users in indoor environment besides improving indoor environmental quality a sense of belonging to the working environment could be improved. Also, the sound comfort is important in working environments and co-working spaces. In Azadi Innovation Factory, due to having larger spaces and larger shared co-working spaces, despite the use of sound insulation and hemp furniture, which reduce the echo of sound, the level of satisfaction is evaluated less than Mashhad center. Therefore, paying attention to the separation of spaces and sound control in shared work spaces especially in large areas is one of the effective factors in design. According to the analyzed data, surveillance and control is one of the important factors in social criterion based on users' opinion. Therefore, as discussed in the previous studies, control on windows and transparency is a key factor for designing co-working spaces to have more surveillance. Using transparent separators is also another way.

As the findings of the research shows, creating a sense of place is ranked as one of the highest socio-cultural sub-criteria which opens a novel aspect towards innovation center design with adaptive reuse. To create a suitable work space as well as creating a sense of place to both heritage building and the new designed place is important. Thus, further research could be done on technics of creating a sense of place and belonging in working spaces of innovation centers. The sense of belonging and creating collective memories in cities is created by recognizing the cultural, individual and social values of the citizens of each city. Another important factor from the users' point of view in these industrial heritage buildings (innovation centers) is the possibility of creating social interactions. According to the analyzed data, users were satisfied with this sub-criterion (possibility of improving social interactions) and the results shows that working in the designed environment and co-working spaces helps the individuals to communicate more with other companies. The links between the buildings mass and the semi-open and open spaces help improve these interactions. Although previous articles on POE of working spaces were mostly conducted on environmental factors and indoor quality except few cases that mention social interactions in co-working spaces, current research investigates satisfaction of users about social interactions and productivity which has been ranked as important sub-criteria of designing innovation centers from users' point of view which is also in line with previous research. Thus, one of the topics for future research can be how to design and use buildings adaptively to improve productivity. Also the design factors for improving social interactions in working spaces is another future topic for POE. This research was done only in two available cases in Iran which were in Mashhad and Tehran cities due to the limitations of cost and time for publishing the questionnaire in other cities or other countries. So future research could be done in different places and different age groups. The results may vary in some factors as the social and cultural norms differ in other locations. Another limitation of the research was access to the innovation center and the people who work there due to the secret aspects of innovative ideas and control over the area. Therefore, the number of filled out questionnaires were limited to 120 totally. It is suggested that future researchers conduct a greater number of questionnaires.

AUTHOR CONTRIBUTIONS

S. Madani performed the literature review, questionnaire and data gathering, analyzed and interpreted the data, prepared the manuscript text, and manuscript edition. H. Kamelnia helped in the literature review and questionnaire preparation. A. Ghalenovi helped in questionnaire preparation and data analysis and manuscript edition.

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CONFLICT OF INTEREST

The authors declare no potential conflict of

interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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PUBLISHER'S NOTE

ABBREVIATIONS

IEQ	Indoor Environment quality
BUS	Building Use Studies
DQI	Design Quality Indicator
OLS	Overall Liking Score
POE	Post Occupancy Evaluation
SEM	Structural Equation Modeling
TICCIH	International Committee for the Conservation of the industrial Heritage

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