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INNOVATIVE DESIGN TYPOLOGY FOR ADAPTIVE REUSE OF OLD BUILDINGS IN PUBLIC SPACES

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Abstract

The aim of this paper is intended to challenge traditional approaches to classifying innovative design by clarifying its typology through evidence from the adaptive reuse of old buildings in the public space. Using both theoretical and empirical approaches, this study summarizes the characteristics of old-building renewal and reuse and builds a foundation for further research on the theoretical evaluation of innovative design. In the theoretical part, we examine 24 examples from seven categories of the innovative design according to adaptSTAR model, which are grouped into four types: function, aesthetics, technology, and location. Then, we explore the relationships between those four types and the geographical regions they are situated in. For the empirical part, we administer questionnaires to verify the results obtained in the theoretical analysis. The results suggest that the most important element of innovative design for the adaptive reuse of old buildings is technological innovation, which is found to have an effect on higher creativity.

Keywords: Adaptive reuse, Creativity, Innovative design, Old building typology, Sustainability.

1. Introduction

The adaptive reuse of old buildings has been a hot topic in the field of architectural design. The definition of adaptive reuse is the renovation and reuse of structures existing previously for new usages. Adaptive reuse is a process that transforms an obsolete or ineffective project into a new one that can be used for a different aim [1]. It is defined as an important modification to an existing building function when the former function has become disused [2]. Working with historic structures is more environmentally sustainable and cost-effective than constructing new buildings, and many believe the best designs occur at the intersection of old and new [3]. From a functional perspective, old buildings have often outlived their purposes, but in terms of architecture and cultural history, they represent an asset, which is increasingly being recognized and utilized in both publicly and privately financed urban renewal projects [4]. In developed countries, there are many examples of abandoned buildings (such as factories and warehouses) being converted into useful alternative spaces such as commercial, recreational, and residential buildings.

As explained by Sarkar and Chakrabarti [5], innovative design is defined as a practical process by which, the designer uses his or her ability to generate some novel and valuable ideas, solutions, or products. The essence of innovative design in architecture is reconfiguring an established system which links together existing elements in a new way [6]. The innovative design of space could efficiently work as a place identity generator [7]. According to Douglas [2] and Gregory [8], the significance of this trend is that extending the lifespan of existing buildings supports the core concepts of sustainability by reducing materials, transport, pollution and energy consumption.

Many cases, however, are based solely on an individual's motivation to discover his or her own innovative design ideas, which are transformed by functional and aesthetic requirements in completing the dialogue during the process of adaptive reuse. Most research on design innovation has focused on such individual innovation [9]. Few of the successful cases of old-building renewal have been comprehensively classified from the perspective of innovative design. The adaptive reused old buildings present a true challenge to architects and designers to find innovative solutions [1].

A new observation tool named adaptSTAR is used as a guideline, which offers a holistic and unified design standard compatible for assessing the adaptive reuse of old buildings. The criteria can be identified in seven categories according to physical, economic, functional, technological, social, legal and contextual parts [10].

Therefore, this study first selects randomly 24 successful cases (Abbreviations in page 2) of adaptive reuse buildings representing the "reconstruction of existing public space" by the discussion with the scholars and designers. From the perspective of adaptSTAR model, these are classified into seven categories of innovative design, which above mentioned. Second, we redefine the seven categories and induce them into four types of innovative design (function, aesthetic, technology, and location) related to the geographical region. We administer questionnaires from 40 participants with the backgrounds in architecture and interior design according to creativity criterion to verify this induction and discover higher innovation type in the design process for adaptive reuse of old-building. Finally, we conclude that technological

innovation has the higher creativity in adaptive reuse of old-buildings design in public space as shown in Fig. 1.

The purposes of this paper are shown as following: First, we inductively classify the types of the innovative design according to the criterion of adaptSTAR model in adaptive reuse of old buildings with examples to present a basic summary from existing buildings in public spaces. Second, we explore the important types affecting innovative design via questionnaires to establish a foundation for the theoretical evaluation of innovative design in the adaptive reuse of old buildings.

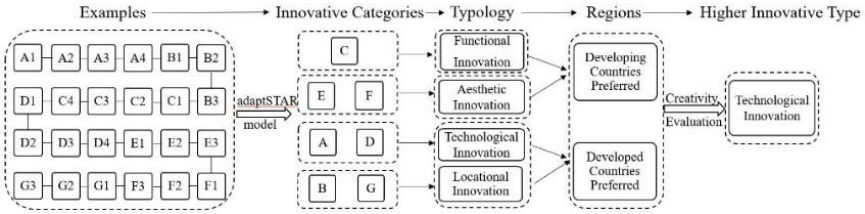

Fig. 1. Framework for adaptive reuse of old-building in an innovative-design typology.

2. Examples of Innovative Design

Many studies have investigated the characteristics of design thought processes in terms of innovation [11] and there are some excellent examples of creative designs in old building renewal. The adaptSTAR model is an extension to the existing sustainability tools used to measure a building's adaptability, which may produce future successful adaptive reuse of buildings [12].

As stated by Conejos et al. [10], based on adaptSTAR model, we choose 24 from over 100 cases of renewed old buildings in the public space in terms of seven representative types - physical (long life), economic (location), functional (loose fit), technological (low energy), social (sense of place), legal (quality standard) and contextual (politic) innovation. Although many have outstanding architectural and historical features, high-quality original materials, and great locations with excellent facilities, these cases have individual innovative features to create a revitalized character in its own distinct way as shown in Fig. 2.

Fig. 2. 24 selected case studies: A1. Baltic Centre for Contemporary Art, UK, A2. Old Breton Barn converted into an Artist Studio, France, A3. Wall cloud, Japan, A4. Allez UP rock climbing gym, Canada, B1. PCH International Innovation Hub, USA., B2. Musee d'Orsay, France, B3. House of Vans London, UK., C1. Town Folktales, China, C2. Impact Hub Belgrade, Serbia, C3. Library, museum and community center 'De Petrus', Netherland, C4. Wooden structure at Launchlabs, Switzerland, D1. Parliament building, German, D2. Green Building, USA., D3. Rainbow, Vietnam, D4. Garvergarden, Denmark; E1. Arquipelago Contemporary Arts Centre, Portugal, E2. Zeitz Museum of Contemporary Art Africa, South Africa, E3. MALHA Architecture, Brazil, F1. Centre for Individuals with Disabilities, Spain, F2. Professional Cooking School in Ancient Slaughterhouse, Spain, F3. Box in the Box, Spain, G1. Guggenheim Museum, USA., G2. Glass Pyramid at the Louvre Museum, France, G3. O-office, China.

A. Physical innovation

The criterion for physical innovation includes four elements: Structural Integrity - structural design of the building to fit to future uses and loads; Material Durability - developed innovatively long-lasting materials in space during the building cycle; Workmanship - used craftsmanship of structure, which different to traditional way, Design Complexity -various geometries relevant to the building's design and creativity [10]. The followings focused on these aspects respectively.

A1. Baltic Centre for Contemporary Art, UK

Structural innovation concerns finding solutions to structural problems [13]. Baltic Centre for Contemporary Art, located in the UK, was originally a flour mill that was transformed in 2002. The most difficult aspect of its transformation involved its structure. A new floor was required to ensure the internal connectivity of the two main facades of the original flour mill. A certain degree of innovation was needed in the new structure to avoid destroying the original building. Aside from the newly added floors, the viewing platform and entrance hall allow the museum to have flexible exhibition and performance spaces to meet future uses.

A2. Old Breton Barn converted into an Artist Studio, France

In order to meet new uses, the art studio totally cleared the previous functions in 2014. To refurbish the interior space, a concrete floor had to be made. It was finished by the sealing of air gaps and the insolation of the walls by throwing lime and finally new water and electricity networks. After the timber frames being strengthened, a coat of insulating material has been set [14]. In this space, it was used creatively a new concrete material to get the long-time durability.

A3. Wall Cloud, Japan

This building was reused in 2014. Due to the attic part of the former discotheque on the second floor had a low ceiling, designer felt like creating an open space with floating walls and pillars. The beams and other elements were reconsidered as different spatial components, and were rebuilt in the space. The ceilings were eliminated, and the beams now surround the space as floating walls, while lights are used to enhance the sense of drifting. The oppressive attic-like space of a symbol of the past was transformed like a wall cloud and renewed as an impressive space because of craftsmanship of structure.

A4. Allez UP Rock Climbing Gym, Canada

This building was transformed from an abandoned silo into a rock-climbing gym in 2013, which was a special way to maximize various geometries in design creativity. The climbing wall formations actually resemble sugar cliffs, reminding visitors of the original function of the Redpath silos. These geometrical climbing walls offer various routes for different levels of climbers. The multi-coloured climbing-holds speckled across the walls add to the dynamic charm of this distinctive interior space [14].

B. Economic innovation

The criterion for economic innovation more concentrates on location, it involves three aspects: Market Proximity-distance to major city, CBD, etc.; Site Access-proximity or link to access roads; Planning Constraints-utilize restricted site condition to convert into beneficial elements in space [10]. The cases in these aspects are demonstrated below:

B1. PCH International Innovation Hub, USA

PCH International Innovation Hub was adaptively renovated from a warehouse in 2014. The location was convenient to downtown, where was visible from highway, the on-ramp to Silicon Valley, and in close proximity to many of the city's creative makers, mover, and shakers. This project was designed and constructed to achieve LEED ID+C Gold Certification.

B2. Musee d'Orsay, France

This museum was renewed from an abandoned train station in 1986, which was located on the left bank of the Seine, near Louvre Museum and Tuileries Gardens. Because its original function was a station, this museum has a unique location and people can easily arrive both in land and water transportation. The site reflects the convenience of the accessing.

B3. House of Vans London, UK

The new uses from Vans was to provide a cultural hub for skateboarding, art, film and music. Utilizing the previous tunnels, the site was delineated into the four main functions in 2014, so that each was housed within a specific tunnel. Such as a tunnel for skateboarding - a skate park for all levels of skateboarding ability, in particular a skateboarder samples the environment who is about to ride. The overall aim was to use the previous site constraint for a new creative space [14].

C. Functional innovation

Most old-building renewals involve a functional transformation due to the requirements of the new situation. Here, functional innovation refers to four elements in details: Flexibility-space capability to change according to newly requirements, plug and play elements, etc.; Disassembly-options for reuse, recycle, demountable systems, modularity, etc.; spatial flow-mobility, open plan, fluid and continuous; Convertibility-divisibility, elasticity, multi-functionality [10].

C1. Town Folktales, China

This was transformed from a movable-type printing plant into a public activity centre in 2017, where including dining space, reading space, all of which, helps provide high-end service for customers. The wooden steps in book bar area, along with the movable display shelves, can be combined and arranged freely and ideally to fulfil different functions, which was an exemplification of flexibility of space.

C2. Impact Hub Belgrade, Serbia

This is a renovation of the Events Hall in the former house of the headquarters in 2014. Within the project, a special working desk was designed with functional, economical and suitable idea. The original design offers a folding table with minimum sizes, easy to store and transport. According to the users' needs, trapezoidal shaped workspace becomes a module for a great number of different combinations. Users freely gathered the desks together for different needs. The intention was to enable users to be more focused on each other by using the modularity of desks.

C3. Library, Museum and Community Center 'De Petrus', Netherland

An extensive renovation the church, was reused into a public centre in 2018, containing a library, a museum but also a bar and shops. All functions were blended into a large open space to the public. The most striking feature was the mezzanine floor. This unique element gave the church a new look fitting for its new function. Because the church floor can be used in a highly flexible way, it provides space for events on all scales as well as function as a library. Meanwhile, the bookshelves are placed on a rail system so they could be moved to the aisles of the church. All of these are the good examples of spatial flow.

C4. Wooden structure at Launchlabs, Switzerland

The main assembly hall of the former machine factory in Basel, Switzerland, has been served as a convertible and multifunctional working environment since 2014. The goal was to create a space, adaptable to various uses, offering countless possibilities – co-working, regular office workstations, areas for informal and cultural activities,

workshops – all while still being able to host bigger events. The main intervention consist in the insertion of an autonomous wooden installation. In order to preserve a maximum of elasticity on the ground floor, most of the construction was lifted and suspended on wooden beams [14].

D. Technological innovation

Technological innovation focuses on low energy, mainly refers to introducing energy-saving technologies to gain sustainable low-carbon emissions. Based on studies by Conejos et al. [10], it includes: Solar Access-use of solar power by measuring for summer and winter sun to energy-saving; Building Control Systems-stormwater collection system, which control water operations and performance systems to achieve efficiency; Natural Lighting and Ventilation- -inclusion for natural daylight, efficient lighting systems, and optimise airflow, quality fresh air, etc.; Reuse and recycle items - through the reuse and recycle of waste items to achieve energy efficient. The corresponding cases was shown below.

D1. Parliament building, German

The German parliament building was modernized in the 1990s, taking into account ecological issues. In terms of energy efficiency, the building's heating and energy systems employ solar technology, mechanical ventilation, the use of strata for cold and heat storage, thermal power plants, heat power generation from waste, and renewable materials. In particular, the vault of the building incorporates energy-saving technology.

D2. Green Building, USA

Based on the relationship between design and sustainability, this studio used a 115-year-old previous dry goods store to create a commercial space in 2008, which employs sustainable technologies like the stormwater collection system. For example, stormwater is either absorbed by the green roof, collected in three large rain barrels, or directed into a rain garden, where the toxins are eliminated by plant material before re-entering the groundwater system [14]. It represents the water-efficiency.

D3. Rainbow, Vietnam

The contribution of the project was dealt with ventilation and natural lighting efficiently in 2015. Solar energy is transformed into electricity for lighting facilities and heating water for daily use. A collection and reuse of various old and broken construction materials such as scaffolding steel pipes, sheet metals, bricks, ashlars, bathroom ware, tables and chairs. It is a multifunctional project include health station, art performance theatre, refreshment tent, etc.

D4. Garvergarden, Denmark

Many Danish towns have examples of abandoned commercial or industrial buildings. A former shoe factory, the Garvergarden in Vestergade was converted into a new building. According to Tornqvist [4], the containing common areas and restaurant structure was built using recycled materials from other demolished buildings, including recycled cement, wood, slate, and brick. Reusing existing material stock - especially as

a result of performance upgrades - has been regarded as having a positive impact on the sustainability of the built environment [15-18].

E. Social innovation

Innovation for social aspect mainly refers to sense of place, including the following three elements: Image/Identity-social and cultural attributes, values, etc.; Aesthetics-architectural beauty, good appearance, proportion; Amenity-provides comfort and convenience facilities [10].

E1. Arquipelago Contemporary Arts Centre, Portugal

In 2014, an old tobacco warehouse was transformed into the Arquipelago Contemporary Arts Centre, which was located in Ribeira Grande, Portugal. The new building adds meaning to the social and cultural context of the place where it is built, represents the social and cultural identity of a specific place. The building achieves its identity by the quiet variation between the pre-existence and the two new buildings. As explained by Jouer [19], certain sustainable design effects were observed as well.

E2. Zeitz Museum of Contemporary Art Africa, South Africa

The silo, disused since 1990, stands as a monument to the industrial past of Cape Town, once the tallest building in South Africa, given new life by the transformation in 2017. The galleries and the atrium space at the centre of the museum have been carved from the silos' dense cellular structure of forty-two tubes that pack the building. This form of reconstruction was d and creative，which combines the 100 years old concrete structure with modern glass building, making the interior of the building creative and achieving aesthetic innovation.

E3. MALHA Architecture，Brazil

A warehouse space was chosen and was built to be an innovative platform for the fashion commercial space (a photographic studio, a sewing studio, natural food restaurant and so on) in 2016. The using of containers as the main constructive factor was built up throughout the hangar, as well as a quick and clean construction. Some pallets have been spread throughout the space, serving as seating, and small plant beds have been set up, which combined with sofas, benches, and tables, create comfortable and convenient facilities that mixes the ambiance of a house with that of a public space.

F. Legal innovation

Legal innovation concentrates on a quality standard, mainly refers to three elements: Disability Concern - provision for disability easement, facilities, etc.; IEQ safety and security - provisions for non-hazardous materials, natural fabrics, etc.; Comfort -hygiene and clean environment, etc. [10]. The relevant cases are the followings:

F1. Centre for Individuals with Disabilities, Spain

Based on a study by Xiao [20], one of the important methods to make old building energetic is an expansion. This is an expansion project, which adopts the stimulation and cares for disabilities by using the symbolic meaning of colour and

the arrangement of space. For example, façade and roof are covered with red zinc coated sheet, which is a symbol that makes them visible; it provides a courtyard to capture sunlight and allows disabled people to stay there in summer. Therefore, this project encourages the users to communicate with others from the perspective of visual to be considerate for the users.

F2. Professional Cooking School in Ancient Slaughterhouse, Spain

The project proposes building this space through a new ceramic roof that limits the new construction and consolidates the original building. The Professional Cooking School used this idea of the moulded ceramic plane to draw its geometry in 2011. This roof lends unity to the built complication and indicates the traditional construction of the place, ceramic roofs and whitewashed walls [14]. This non-hazardous new materials benefit for enhancing the Indoor Environment Quality.

F3. Box in the Box, Spain

In 2017, the project entailed the renovation of a warehouse located in Madrid and its conversion into a building that provides spaces for a cultural organization and sporting activities for young people. The use of clean lines and neutral-toned materials gave the spaces a homogeneous-looking. The white palette of translucent, transparent and opaque walls and grey continuous polished-concrete floors were utilized in the space, which reflexes a hygiene and clean environment.

G. Contextual innovation

Contextual innovation refers to political sides. Here relates with two elements: one is adjacent buildings-adjacent enclosures, vertical and visual obstacles, which include the harmonious and contrastive relationship between new and old in architectural environments; the other is community interest/participation-stakeholder relationship and support [10].

G1. Guggenheim Museum, USA

Following the addition of a ten-floor tower of simple buildings in the 1990s, the Guggenheim Museum is a gallery of vertical traffic space. Traffic is assisted by the spiral ramp, and it follows a simple grid line with the design elements of the facade. A square box became a "green leaf building." A conch-shaped body with a simple background makes the Guggenheim appear as a sculpture. With both new and old elements, this building stands harmoniously with its environment and can be considered a model for keeping the faith and understanding context.

G2. Glass Pyramid at Louvre Museum, France

Regarding this controversial example [21], architect I. M. Pei commented that it contains vast contrast and a little harmony. Contrasting with the surrounding buildings of the Louvre, the delicate glass pyramid creates a special artistic effect that can be characterized as contrasting bright and dark, light and heavy.

G3. O-office, China

It was a refurbishment project in 2017. Designers are known for exploring what architecture can do within the contemporary Chinese context. They transformed an

abandoned Shenzhen factory into a dynamic cultural and community centre, where get the support of participation. Through the innovative use of space and material, they intended to "reweave" the urban fabric to revive urban life.

3. Analysis and Discussion

3.1. Similarities

We can identify some similarities in the innovative design cases described above.

3.1.1. Change of original function

Except for the original architectural skin elements, in these 24 cases, only C2, D1, D3 and F1 retain their original function while the rest do not. The majority of internal functions and spaces were completely transformed, losing their original function in the reconstruction. Some elements such as masonry walls, pipes, chimneys and machine tool equipment were transformed in the ways that differed from their original use.

In these 20 cases of functional changes, three transformation directions are identified - artistic creation (art centre, studio) including A2 and E1 (2 of 20), accounting for 10%; leisure and cultural display (art galleries, museums) such as A1, A3, A4, B1, B2, B3, C1, C3, C4, E2, F2, F3, G1, G2 and G3 (15 of 20), accounting for 75%, and commercial entertainment (shopping centres, hotels) like D2, D4 and E3 (3 of 20), accounting for 15%.

Table 1 shows these three directions of functional changes in the adaptive reuse of old buildings in details. Hence, we may conclude the leisure and cultural display was the mainstream in the transformation directions.

Table 1. Directions of functional change.

Type	Example	Original function	Current function	Proportion
Artistic creation	A2	Barn	Artist studio	
	E1	Warehouse	Arts centre	10%
Leisure and cultural display	A1	Flour mill	Art museum	
	A3	Discotheque	Office	
	A4	Silos	Rock-climbing gym	
	B1	Warehouse	Innovation hub	
	B2	Train station	Museum	
	B3	Tunnel	Cultural hub	75%
	C1	Printing plant	Activity centre	
	C3	Church	Multifunctional centre	
	C4	Machine factory	Office	
	E2	Silo	Art museum	
	F2	Slaughterhouse	Cooking school	
	F3	Warehouse	Cultural and sporting space	
	G1	Office building	Art museum	
	G2	Square	Art museum	
	G3	Factory	Cultural centre	
Commercial entertainment	D2	Dry goods store	Commercial space	15%
	D4	Shoe factory	Restaurant	
	E3	Warehouse	Commercial space	

3.1.2. Change of users and their psychology

Owners and users are the subjects behind the space, and they play important roles. Such changes have led to functional changes. The original owners of factories and warehouses were farmers and workers. However, now the owners represent an emerging public (based on class and education) that includes the petit bourgeoisie, white-collar professionals, freelancers, SOHO residents, and so forth. Meanwhile, abandoned factories have mostly been transformed into leisure and cultural displays. The spaces changed from noisy, dull, broken places from the past into relaxed, creative, and stylish environments. Such a change leads to a change in the psychology of users, from negative emotional responses to positive high-end experiences. This indicates that old buildings are more sustainable for long life cycles and for people's higher spiritual pursuits.

3.1.3. Change of development trend

The new purposes of these buildings reflect the shift away from heavy industry. These buildings are located relatively close to the classical urban centres from which, they derive their visitors. However, the changes in the use of the buildings or more generally, their adaptation to economic needs reflect trends in urban development with the changes in industrial structures and urban functions namely, from the industrial age to the information age. For example, B1, C1, F3 and G3 are the conversion of factories to leisure pursuits and they are indicative of the expansion of the leisure economy.

3.2. Differences

At the same time, we also observe some differences.

3.2.1. From perspective of innovative design typology

Haishan [22] suggested that the criterion of design innovation in adaptive reuse of old buildings toward an ecological background should consider function, along with aesthetics, technology, and location.

According to Runco and Pritzker [23], the function reflects the use of the building. Functionalism emphasizes purpose, practical utility, and applicability. The new features of old buildings need to meet the needs of human health and comfort within this dual goal [22]. However, it seems that functional change makes the majority of these cases. Therefore, functional innovation is given as a type (C).

Aesthetic and technology are two basic attributes of architecture [24]. Aesthetic decisions are made with respect to beauty, proportion, concinnity, etc. [23]. Comfortable interior environment benefits to enhance the quality of aesthetic requirement. The sub-factors of aesthetic appeal include hygiene and high indoor environment quality [25]. Therefore, aesthetic innovation at the formal level includes social innovation (E) and legal innovation (F).

Technology influences the innovation of interior design through the development of structure, construction and so forth [13]. Crysler et al. [26] suggested regarding the technological innovation, that perhaps in 15 years, there will be new sustainable materials that can optimize the various subcomponents of buildings. Kebir et al. [27] also claimed that it seems to crystallize around materials,

equipment (heating, lighting) and information technology systems. Various renewable energy has effected on technological innovation [28]. Hence, technological innovation belonging to the content level includes physical innovation (A) and low energy innovation (D).

The location should think about the site of the present condition and contextual background [29]. Present location refers to the basic condition of the site, which was represented by type B, belonging to the external level. Meanwhile, old buildings record the development of urban civilization and exhibit urban development history. It is better to maintain a high degree of integration in context, which is also an innovation. It belongs to the internal level of emotional identity, which is represented by type G. That is why the economic innovation (B) and contextual innovation (G) belong to this category.

Of these 24 selected cases, functional innovation C, includes C1, C2, C3 and C4 (4 out of 24) accounted for 16.7%. There were six cases (E1 - E3, F1 - F3) affecting aesthetic innovation (6 of 24), accounting for 25%. Similarly, eight cases (A1, - A4, D1, D2 - D4) affected technological innovation (8 of 24), accounting for 33.3%, and six cases (B1, - B3, G1 - G3) focused on location innovation (6 of the 24), accounting for 25%. Table 2 summarizes the innovative design typology in four types.

Table 2. Innovative design typology in adaptive reuse of old buildings.

Innovation type	Case	Time	Region	Way
Functional innovation	C1	2017	China	Tradition
	C2	2014	Serbia	Tradition
	C3	2018	Netherland	Tradition
	C4	2014	Switzerland	Tradition
Aesthetic innovation	E1	2014	Portugal	Ecology
	E2	2017	South Africa	Tradition
	E3	2016	Brazil	Tradition
	F1	2011	Spain	Tradition
	F2	2011	Spain	Ecology
	F3	2017	Spain	Tradition
Technological innovation	A1	2002	UK	Tradition
	A2	2014	France	Ecology
	A3	2014	Japan	Tradition
	A4	2013	Canada	Tradition
	D1	1992	German	Ecology
	D2	2008	USA	Ecology
	D3	2015	Vietnam	Ecology
	D4	1990s	Denmark	Ecology
Location innovation	B1	2014	USA	Ecology
	B2	1986	France	Tradition
	B3	2014	UK	Tradition
	G1	2008	USA	Tradition
	G2	1989	France	Tradition
	G3	2017	China	Tradition

The knowledge innovation lies in the central place in the sustainable competitive environment [30]. With reference to the knowledge innovation model, we try to find an innovation model among these four types. In order to achieve the goal of authentic functional innovation, we suggest that designers (individual

knowledge as a single or collective knowledge as a group) should combine aesthetic and technological innovation with explicit knowledge, synthesize locational innovation with tacit knowledge, and convert various factors into a new space through tacit expression，then get the innovative effect. The movement through the four modes runs again and forms a spiral as shown in Fig. 3.

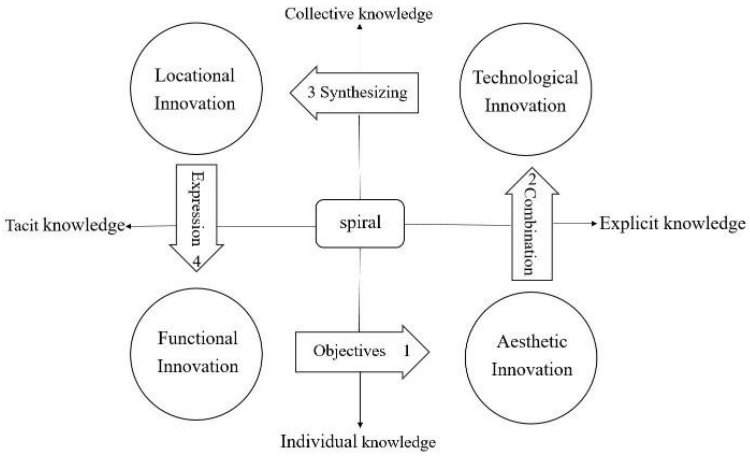

Fig. 3. Innovation model of the four types.

3.2.2. From the perspective of geographical regions

Adaptive reuse of old building got underway in the early 1960s and 1970s. In terms of the aspects of time and region, it has developed significantly since the 1980s. From the Table 2, we found that in these 24 cases, the United States and some developed European countries (18 of the 24) are actively engaged in exploration and practice, accounting for 75%, with outstanding performances. Meanwhile, developing countries such as China, Serbia (6 of the 24) account for 25%.

We select two type cases study equally and randomly according to the geographical regions. There are 5 developed countries (USA, France, UK, German, Spain), which are represented by B1, A2, A1, D1, F1 and 5 developing countries (China, Serbia, South Africa, Brazil, Vietnam), which are represented by G3, C2, E2, E3, D3.

From the ten chosen cases, 2 cases (A1, A2) are in type A, named after 2A, the same as 1B, 1C, 2D, 2E, 1F, 1G. Because technological innovation is summarized by A and D, which are total 4 cases (2A and 2D); Aesthetic Innovation is summarized by E and F, which are 3 cases (2E and 1F); Locational Innovation is summarized by B and G, which are 2 cases (1B and1G); Functional Innovation is summarized by C, which is 1 case (1C). We can see that technological innovation is the major innovation possessing diverse forms.

In this 4 cases in technological innovation, A1, A2, D1 and D3 which represent 3 developed countries (UK, France, German) and 1 developing country (Vietnam). Therefore, we can see that in the renewal of old buildings through innovative design, developed countries place more emphasis on technological innovation, which is an internal design pursuit and developing country strives on positive practice.

The 3 cases in aesthetic innovation (E2, E3, and F1) are presented by South Africa, Brazil and Spain. It means 2 developing countries preferred this type. 1 case C2 means functional innovation that is also represented by a developing country. Meanwhile, in the whole cases, developing countries (China, Serbia, South Africa, and Brazil) are represented by C1, C2, E2 and E3, which belong to function and aesthetics concerning the external mode of innovation. Thus, there is room for growth in the rest of innovation.

In the chosen 2 cases in locational innovation, B1 is a developed country and G3 is developing country, which is the same in number. Therefore, B and G are typical in the locational innovation in whole cases. Five cases (B1, B2, B3, G1 and G2) are developed countries and 1 case (G3) is a developing country. Therefore, most developed countries prefer locational innovation.

In one word, developed countries prefer technological and locational innovation, while developing countries like aesthetics and functional innovation.

In addition, there are two perspectives on transformation. Traditional transformation involves using traditional techniques and materials to change a building's structure, appearance, and indoor environment to meet users' needs, emphasizing the shape of the change. Ecological transformation refers to applying ecological technology and materials to the original building environment, including function and resource utilization, emphasizing quality changes. Seen from Table 2, we find that traditional transformation (16 out of 24) account for 66.7%, while ecological transformation (8 of the 24) account for 33.3%. Hence, ecological transformation needs improvement in the future.

4. Reflection

We use questionnaires to obtain views from 40 respondents regarding which, are the higher innovative design types in the adaptive reuse of old buildings and to verify the technological innovation that is the major innovations possessing diverse forms.

4.1. Method

Questionnaires are conducted through semi-structured interviews and online surveys in PowerPoint using two colourful pictures and text with the typical characteristics to guarantee each case with the same condition. Designers and teachers with backgrounds in architecture and interior design are invited to participate, who also have the foundation and judgement of art design.

4.2. Evaluation of creativity

In the field of creativity studies, it is generally acknowledged that there are two major components of creativity. The first is a novelty and the second is value or usefulness [23]. Based on Finke et al. [31], similarly, the method of these design results are evaluated from the two viewpoints of practicality (the idea for achievability and feasibility) and originality (the idea for innovation and novelty), on a five-point scale (1: low and 5: high). The aim is to discover, which example scores the highest in terms of creativity. Accordingly, the type of innovation it represents has the highest impact. Due to this, 24 cases are classified into seven categories, four types have three examples, three types have four examples, so participants synthesize each example and score in one type.

4.3. Analysis

Table 3 shows the average rate for each innovation type by seven categories in practicality, originality and order of high creativity. To judge the scores clearly, we used a scatter chart in Fig. 4. The abscissa indicates practicality, and the ordinate indicates originality.

Table 3. Creativity evaluation.

Innovation type	Functional innovation	Aesthetic innovation		Technological innovation		Location innovation	
Example	C	E	F	A	D	B	G
Practicality	3.95	4.08	3.73	3.98	4.13	4.00	3.93
Originality	3.70	3.95	3.75	4.00	4.08	4.03	3.82
Order of high creativity	7	4	6	3	1	2	5

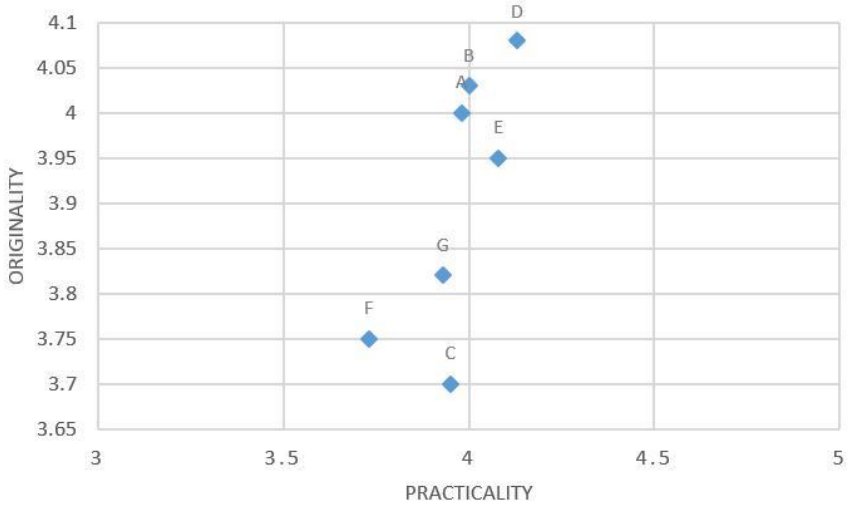

Fig. 4. Creativity evaluation for eight examples.

According to the creativity criterion, originality is high in the order of category D, B, A, E, G, F and C. As explained by Runco and Jaeger [32], the originality is the most vital one for creativity. It is said that creativity evaluation is also high in this order. Obtaining the results as shown, we choose the top three, D (4.08), B (4.03), and A (4.00). At the same time D (4.13), E (4.08), and B (4.00) are high in practicality. Moreover, in the conversation with the participants, half of the respondents (22 of the 40) say that the technological type is more important about the innovative design.

As a result, D and B, which represent the technological and contextual types of innovative design, may influence higher creativity in the adaptive reuse of old buildings preferred by developed countries. The result is in line with the one in 3.2.2.

4.4. Results and Discussion

4.4.1. Results

According to the questionnaire, nearly half of respondents (19 of 40) believe that D has the highest originality with 5 points; they insist the parliamentary plenary hall uses technical means of the top-hanging funnel-shaped pillar. The "funnel" is inlaid with mirrors all around. The sun refracts into the parliamentary hall, thereby it reduces energy consumption for lighting.

Over half participants (22 of the 40) consider that D is the most practical with 5 points because the designers installed a removable aluminium network within the glass dome. A computer automatically adjusts the position according to the movement of the sun.

Therefore, the total score of D is the highest with 4.08 in originality and 4.13 in practicality. From this result, we find that technology innovation (D) is more likely affect the creativity. The emergence of novel technologies has often held a central place in the creative design [33].

4.4.2. Discussion

The results indicate that the most important element of innovative design for the adaptive reuse of old buildings is technological innovation, which is found to have an effect on higher creativity. The predominant point of view about the sustainable future of the art buildings is to utilize energy efficient design [1]. The most typical case with D1 building is an example of green architecture by using technological means to achieve energy conservation, reflecting the building's sustainability.

Hence, technological innovation is more representative of innovative design. It shows the higher creativity and sustainability awareness is the main direction, which is also consistent with the previous analysis in 3.2.2. Without excellent service equipment, such as energy-saving system, it is difficult to make a vital breakthrough in innovation [34].

5. Conclusions

In this paper, we examine two results. First, the typology of innovative design for the adaptive reuse of old buildings in public spaces is clarified from 24 representative examples. Then, by analysing their similarities and differences, we synthesize them into four types of innovative design: functional, aesthetic, technological and locational innovation. Meanwhile, we find that different countries have different preferences regarding innovation types.

Developed countries focus more on technological and locational innovation while developing countries emphasize aesthetic and functional innovation. Second, we learn through the questionnaire that technological innovation leads to higher creativity, which is in line with the previous analysis in 3.2.2. By analysing the representative examples D1, we infer that the main trend is sustainability through technological innovation.

In future studies, we will focus on the theoretical evaluation of innovative design in the adaptive reuse of old buildings in residential spaces.

Abbreviations

A	Physical innovation
A1	Baltic Centre for Contemporary Art, UK
A2	An Old Breton Barn Converted into an Artist Studio, France
A3	Wall Cloud, Japan
A4	Allez UP Rock Climbing Gym; Montreal, Canada
B	Economic innovation
B1	PCH International Innovation Hub, USA
B2	Musée d'Orsay, France
B3	House of Vans London, UK
C	Functional innovation
C1	Town Folktales, China
C2	Impact Hub Belgrade, Serbia
C3	Library, Museum and Community Centre 'De Petrus', Netherland
C4	Wooden Structure at Launchlabs, Switzerland
D	Technological innovation
D1	Parliament Building, German
D2	The Green Building, USA
D3	Rainbow, Vietnam
D4	Garvergarden, Denmark
E	Social innovation
E1	Arquipélago Contemporary Arts Centre, Portugal
E2	Zeitz Museum of Contemporary Art Africa, South Africa
E3	MALHA Architecture, Brazil
F	Legal innovation
F1	Centre for Individuals with Disabilities, Spain
F2	Professional Cooking School at Ancient Slaughterhouse, Spain
F3	Box in the Box, Spain
G	Contextual innovation
G1	Guggenheim Museum, USA
G2	Glass Pyramid at Louvre Museum, France
G3	O-office, China

References

1. Department of the Environment and Heritage. (2004). Adaptive reuse. Preserving our past, building our future. Australian Government.
2. Douglas, J. (2006). *Building adaptation (*2nd ed*)*. Oxford, United Kingdom: Butterworth-Heinemann.
3. Bollack, F.A. (2013). *Old buildings, new forms: New directions in architectural transformations*. New York: The Monacelli Press.
4. Tornqvist, P. (1992). *Urban renewal and housing improvement in Denmark.* Copenhagen: Royal Danish Ministry of Housing and Building, National Building and Housing Agency.
5. Sarkar, P.; and Chakrabarti, A. (2011). Assessing design creativity. *Design Studies*, 32(4), 348-383.
6. Henderson, R.M.; and Clark, K.B. (1990). Architectural innovation: The reconfiguration of existing product technologies and the failure of established

firms. *Administrative Science Quarterly*, Special issue: Technology, Organizations and Innovation. 35(1), 9-30.

7. Gospodini, A. (2004). Urban morphology and place identity in European cities: Built heritage and innovative design. *Journal of Urban Design*, 9(2), 225-248.
8. Gregory, J. (2004). *Rehabilitation: New ways for older housing*. New South Wales Department of Housing.
9. Smith. S.M. (2003). The constraining effects of initial ideas. *Creativity: Innovation through Collaboration*. New York: Oxford University Press, 15-31.
10. Conejos, S., Langston, C., and Smith, J. (2013). AdaptSTAR model: A climate-friendly strategy to promote built environment sustainability. *Habitat International*, 37, 95-103.
11. Nagai, Y.; and Taura, T. (2006). Formal description of concept-synthesizing process for creativity design. *Design Computing and Cognition '06*. Houten: Springer Netherlands, 443-460.
12. Conejos, S., Langston, C., and Smith, J. (2014). Designing for better building adaptability: A comparison of adaptSTAR and ARP models. *Habitat International*, 41, 85-91.
13. Tao, W. (2007). *Study on the Interior Design Innovation*. Doctoral dissertation, Harbin Institute of Technology, Harbin, China, 35-85.
14. Sabrina Santos. (2016). 20 Creative Adaptive Reuse Projects. Retrieved June 22, 2018, from https://www.archdaily.com/783283/20-creative-adaptive-reuse-projects?ad_medium=mini-landing&ad_name=articles.
15. Bromley, R.D.; Tallon, A.R.; and Thomas, C.J. (2005). City Centre Regeneration through Residential Development: Contributing to Sustainability. *Urban Studies*, 4*2*(13), 2407-2429.
16. Rohracher, H. (2001). Managing the technological transition to sustainable construction of buildings: A socio-technical perspective. *Technology Analysis and Strategic Management*, 13(1), 137-150.
17. Kohler, N. (1999). The relevance of green building challenge: An observer's perspective. *Building Research and Information*, 27 (4-5), 309-320.
18. Kendall, S. (1999). Open building: An approach to sustainable architecture. *Journal of Urban Technology*, 6(3), 1-16.
19. Jouer, C. (2016). European classic case inventory: When the old building turned trendy art space. Retrieved September 20, 2017, from http://art.ifeng.com/2016/0623/2945654.shtml.
20. Xiao Z. (2002). Transformation, expansion and symbiosis - On the Renewal and development of historic buildings and the symbiosis of old and new buildings. *Planner*, 18(2), 29.
21. Nowogońska, B. (2016). The permanence of a building in the game of shadows. *Czasopismo Techniczne. Architektura Zeszyt*, 9-A(15), 245-248.
22. Haishan, H.R.X. (2009). The aesthetical value of the old buildings reuse in ecological context. *Huazhong Architecture*, 8, 49.
23. Runco, M.A.; and Pritzker, S.R. (2011). *Encyclopedia of creativity* (2nd ed.). London: Academic Press.
24. Ming, Z.H. (2011). *Sustainable interior design theory*. Beijing: China Construction Pub.

25. Lee, Y.S.; and Weber, M.J. (1984). Development of an instrument to measure the aesthetic quality of housing environment. *Social Indicators Research*, 15(3), 255-279.
26. Crysler, C.G.; Cairns, S.; and Heynen, H. (2012). *The SAGE Handbook of architectural theory*. London:Sage Publication Ltd.
27. Kebir, L.; Crevoisier, O.; Costa, P.; and Peyrache-Gadeau, V. (2017). *Sustainable innovation and regional development: Rethinking innovative Milieus*. Cheltem, United Kingdom: Edward Elgar Publishing Ltd.
28. Johnstone, N.; Hascic, I.; and Popp, D. (2010). Renewable energy policies and technological innovation: Evidence based on patent counts. *Environmental and Resource Economics*, 45(1), 133-155.
29. Zhenping, X. (2014). Analysis of commercial space conditions and design features of the old industrial buildings. *Journal of Dali University*, 2014(3), 62-65.
30. Andreeva, T.; and Ikhilchik, I. (2011). Applicability of the SECI model of knowledge creation in Russian cultural context: Theoretical analysis. *Knowledge and Process Management*, 18(1), 56-66.
31. Finke, R.A.; Ward, T.B.; and Smith, S.M. (1992). *Creative cognition: Theory, research, and applications*. Cambridge, Massachusetts: MIT Press.
32. Runco, M.A.; and Jaeger, G.J. (2012). The standard definition of creativity. *Creativity Research Journal*, 24(1), 92-96.
33. Fernandez, J.E. (2006). *Material architecture: Emergent materials for innovative buildings and ecological construction (1st ed.)*. Burlington. Massachusetts: Architectural Press.
34. Shao, D.; and Nagai, Y. (2017). The innovative application of eco-technology in architectural design. *Journal of Engineering and Applied Sciences*, 12(10), 2592-2596.