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From Maslow to Architectural Spaces: The Assessment of Reusing Old Industrial Buildings

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Abstract: In many cases, the purpose of reusing old industrial buildings is to serve the public. Converting a building that had a particular function and is unfamiliar to the public to a civic building is a great challenge. Significantly, the public's curiosity towards a special-purpose industrial building alone is not enough to give the building a long life following its conversion and regeneration. To be sustainable in public life, the design of reused old industrial buildings should also meet the needs of the public. It is important to realise, however, that everyone's needs are different. This paper will therefore analyse whether Abraham Maslow's (1943) famous psychological theory, the Hierarchy of Needs, which not only summarized the content of human needs, but also divided them into levels, can be applied to the reuse of former industrial buildings. The paper translates this into the field of architecture to develop an assessment framework for the reuse of old industrial buildings. This assessment framework is able to combine mathematical models for quantitative assessment of future projects, and uses Shanghai 1933 Old Millfun, China as a case study for its demonstration. This provides an evaluation of a completed project and identifies challenges for further development, as well as providing guidance for future adaptive reuse projects.

Keywords: adaptive reuse; old industrial buildings; user requirements; Maslow's Hierarchy of Needs; assessment framework; fuzzy comprehensive evaluation method

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1. Introduction

Changes in technical capability, economic opportunity, social and demand awareness, and the understanding of sustainable development have been important factors in determining architectural development in urban areas [1]. As a result, urban renewal has often eliminated older buildings and structures without considering their future potential in urban areas. Indeed, old industrial buildings, that are often an inevitable and obsolete product of urban regeneration, are a prime example of this. Old industrial buildings can be defined as: an industrial building that is unable to satisfy the needs of urban development in a certain period as a result of the building's original industrial activities having ceased [2]. Although the functional life of the manufacturing has already finished for these buildings, structural and cultural life can still coexist within the built environment. The subsequent demolition of such buildings may not be the most appropriate outcome due to various sustainability issues, such as the embodied energy in the buildings, but also importantly the destruction of the architectural diversity, meaning attachment and urban identity. Adaptive reuse can be an effective way to deal with old industrial buildings in cities [2–4]. At present, there are numerous famous and successful reuse projects around the world, such as the Tate Modern art gallery in London, England, which was transformed from an old power plant; the Musée d'Orsay in Paris, France, which was converted from an old railway station; and the mixed-used public building, 1933 Old Millfun in Shanghai, China, which was reused from a slaughterhouse.

A space becomes a place when it is used and valued by people [5–7], often involving a process of appropriation that leads to a sense of belonging and symbolic meaning [8].

However, there is often a conflict in information exchange and understanding between architects and building users. Although both parties do their best in their respective areas of responsibility, the medium of communication between them is not as direct as speaking or writing, but indirectly through the architectural spaces, layout, materials, and atmosphere of the building. Architectural design tends to result from the application of an architect's subjective and technical knowledge and understanding; however, architectural design also needs to consider the needs and desires of the potential building occupants and users. Therefore, it can be important for architects to be able to apply the public's ideas to architectural design. Thus, when old industrial buildings that were originally closed are reused and reopened to the public, how to attract the public and gain their affection is a key challenge.

Historically, the response to the public's needs in relation to the reuse of old industrial buildings was to treat them as exhibits [2]. Nowadays, however, old industrial buildings, combined with the tightness of land resources, have become an intrinsic part of people's lives, such as squares, shopping malls, hotels, and so on, and the approach is now to give them a real use or purpose [1,9]. The public tends to increasingly treat reused old industrial projects as they do other public buildings [10]. As a result, the public expects similar levels of comfort, environment, and experience, whilst also paying particular attention to the special values that come from the transformation of old industrial buildings, namely its cultural, historical, technical, aesthetic, economic, educational, and social values [2,11]. Any assessment of the reuse of old industrial buildings will therefore need to be comprehensive and complex from the point of view of meeting the needs of the public [12].

The question of how to evaluate the adaptive reuse of an industrial building that meets the needs of the public is the main focus of this research. The research focuses on the public users and how their needs can be satisfied by using Maslow's Hierarchy of Needs as the basis for an evaluation standard. The research then attempts to establish an assessment framework for reusing old industrial buildings from the perspective of the public's experiences. Maslow's hierarchy of psychological needs has been applied by many scholars in the fields of architecture and urban planning [13–15]. Psychology and architecture seem to be two different disciplines, but they are closely linked by the 'Human being'. The human being is the basis for the study of psychology, while in architecture, it is the object of service. In this paper, firstly, Maslow's theory, as the foundation of the research, is examined including how this can be adapted to understand the public's psychological needs in relation to the adaptive reuse of industrial buildings. Secondly, after understanding public needs, the paper will address how the built environment can be evaluated from an architectural perspective to assess whether the building can meet these needs. At the same time, an assessment framework that can evaluate whether reused old industrial buildings can meet the needs of the users will be developed based on Maslow's theory. The proposed assessment framework will then be tested using the case of the 1933 Old Millfun in Shanghai, China, in order to assess its potential as a foundation for future evaluations. Finally, the article will demonstrate the feasibility and importance of using the fuzzy comprehensive evaluation method to evaluate the application of this assessment framework. The idea and structure of the article are shown in Figure 1.

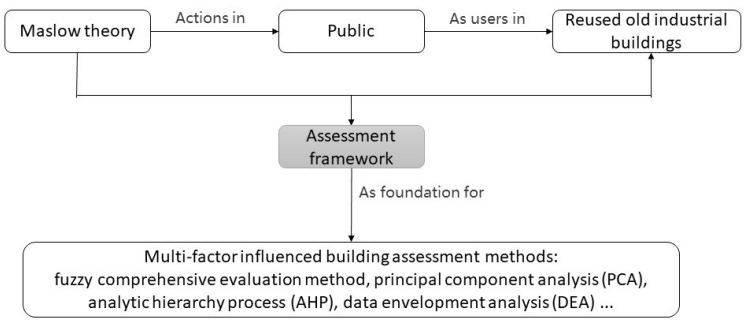

Figure 1. Brief mention of article patterns (by author, 2022).

2. Reviewing Maslow's Hierarchy of Needs

The Hierarchy of Needs is a theory developed by Abraham Maslow in his 1943 paper "A Theory of Human Motivation" published in the *Psychological Review* journal [16]. Maslow proposed that five core needs form the basis for human behavioral motivation and describe the evolution of human needs. This has subsequently become a popular structure for sociological research, management training, higher education, and many other psychology programs [17–19]. These five levels of needs are organized into a pyramid that clearly describes the order and hierarchy of human needs. The so-called basis of composition is meant to illustrate that the lower-level needs in the pyramid have to be met before attention can be paid to the adjacent higher needs [16]. However, this pyramid structure is not absolute, and Maslow also pointed out that different levels of needs may occur in parallel due to different motivations; for example, for some people, creative fulfillment may be even more important than basic needs [16].

The five levels of Maslow's Hierarchy of Needs can be further grouped into three dimensions: basic needs, advanced needs, and challenging needs (Figure 2). The lower two tiers of the pyramid, basic physiological and safety needs, are considered to be the fundamental basis of life and therefore needs according to Maslow's theory. After meeting these basic needs for survival, people should then be given higher ideological needs, or so-called advanced needs, which express a human being's pursuit of spiritual civilization. In modern times, the improvement of the human mind has not only enhanced spiritual civilization, but also in turn demanded better services and guarantees for life. For example, advanced human thought has created medical care and food supplies. Finally, challenging needs will come from people's need to grow beyond themselves, that is, the value of self-actualization, which for the individual may include: "I learned", "I discovered", "I created", and so on. The highest level of need is therefore seen in this study as a challenge, self-challenge, and self-transcendence.

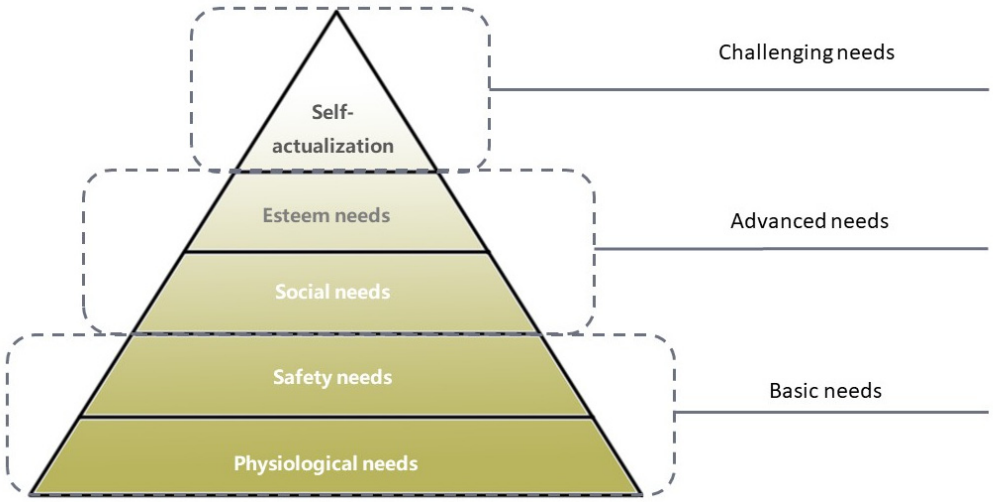

Figure 2. Maslow's pyramid of human needs with further categorization (adapted by author, 2022).

3. Construction of an Assessment Framework

Maslow's Hierarchy of Needs will be considered as a foundation in this research. It will be developed in order to analyze the extent to which adaptive reuse projects can be evaluated on the basis of the human needs proposed by Maslow. This will then be collated so that an assessment framework can be established for contemporary reuse of old industrial buildings.

3.1. Basic Needs

Failure to meet either physiological needs or safety needs is a threat to life. These needs are similar to instincts and play a major role in motivating behavior [16]. According

to Maslow, some of these needs involve people's efforts to meet the body's need for homeostasis, that is, maintaining a body temperature of 37 °C [16]. In addition to that, it is also a threat to life (physiology) on a higher level when safety needs cannot be met. At the same time, Maslow pointed out that the safety statement is not limited to life safety, but also health, emotional safety, and property safety [16].

From Maslow's hierarchy of needs in relation to the field of architecture, most contemporary public buildings do not endanger the lives of their users as a result of strict building codes and regulations; however, enhanced comfort conditions also need to be considered.

3.1.1. Physiological Needs

Maslow proposed that physiological needs are biological needs for human survival, such as air, food, drink, shelter, clothing, warmth, sex, sleep, and so on [16]. Of course, not all these needs can be met in public buildings; however, some basic physiological needs must be met, such as the air environment in the building (e.g., comfort in terms of temperature and humidity), the facilities in the building (e.g., provision of drinking, meals, or toilets), etc.

- Air environment

The measurement of the air environment in a building focuses mainly on the quality of the air environment, which refers to temperature, humidity, and ventilation. Overall, the aspect of the air environment can be seen as a comprehensive test of mechanical, electrical, and plumbing (MEP) performance of a building. Advanced building technology can significantly reduce the impact of the external environment on the internal air environment of buildings. Nevertheless, many buildings do not have access to such building technology due to a number of factors, especially in the case of reused industrial buildings, which are limited by the preservation of the original building elements and therefore present a challenge for designers. Both the temperature and humidity of the air can affect people's physiological comfort. Generally speaking, the comfort range for humidity is at the levels of 40–50% [20]. For the temperature of the air environment, although studies have concluded that the comfortable indoor temperature for humans is around 20–24 °C [20], this indicator can be used as a reference only due to the different times of use and how much the users wear. In addition, enough fresh air can make people have clear minds [21]. To maintain fresh air in a building, good ventilation will play a significant role [22,23]. A building equipped with heating, ventilation, and air conditioning (HVAC) systems can control indoor temperature, humidity, and ventilation and guarantee suitable comfort levels.

- Facilities

Users may feel thirsty, hungry, or need to go to the toilet when they arrive at a public building. Without appropriate facilities, these physiological needs can have a negative impact on the experience of the building because of people's physiological discomfort. To make the experience of using the building better for users, public buildings should provide opportunities for people to purchase and consume drinks and food through facilities like convenience stores in (or around) the building, cafes, and restaurants. A particular advantage of convenience stores is that they can also sell a wide range of goods, including tissues, hand sanitizers, chargers, and other necessary items for visitors.

Toilets are another essential facility of public buildings. The accessibility of the toilets (clearly signposted, user-friendly, etc.), and in sufficient numbers is an elemental measure of a successful public building [24]. In addition, toilets in contemporary life also have a hand sanitization and hygiene role. Significantly, the toilet environment and quality can also influence building users' perceptions regarding a building's level of management, maintenance, and safety [25].

3.1.2. Safety Needs

Maslow considered that safety needs can be summarized in two main aspects: threat and safeguard [16]. Safety incidents are a safeguard system that can be divided into three

stages: before, during, and after the occurrence. Before it happens, it is necessary to prevent, to the greatest extent possible, the potential threats. Once the danger has occurred, the corresponding person or function should be available to stop it in order to prevent the problem from worsening. In cases where neither of the first two can be prevented, the victim should be able to receive compensation after a safety problem has occurred. Eliminating threats and providing safeguards are therefore the assessment of the active (operation management of the building) and passive (constructions of the building) safety dimensions of the building. Obviously, in public buildings, adequate fire safety prevention (before) and means of escape (during) need to be carefully considered in the design stage and the on-going management and operation of the building.

- Management

The management of safety usually refers to the management of the property and the operational aspects of the building after the building is completed. This is dominated by the human factor, which can be adjusted by the management of staff. The presence of security staff keeps order in the building and has a "deterrent" effect, whilst also assisting people in emergency situations. Moreover, closed-circuit television systems can help to provide on-going monitoring [26]. Furthermore, depending on the characteristics of different regions and social emergency events, the building management should have responses in place. For example, during the COVID-19 epidemic, social distancing became a necessity and corresponding management measures to reduce the spread of the virus had to be implemented and enforced in public buildings. These included measures such as temperature measurement, maintaining safe distances, and supervision of formal mask-wearing.

- Construction design

The transformation of the function of the building (from an industrial building to public use) means that the users of the building change both in terms of the number and the diversity of users. Thus, it is important to discuss whether the old building design can still meet the requirements of contemporary safety regulations. The fire safety and evacuation design in buildings can be effective in reducing damage [27–29]. This will need buildings to be well-equipped with fire warning signs and smoke extraction devices together with suitable spatial division to restrict fire spread. The layout of a building space should also allow people to escape to a safe area as quickly as possible and to safely reach the open outdoor spaces within short distances.

Typically, old industrial buildings, whose main purpose is manufacturing, often give the impression of high spaces and balconies, basic and narrow stairs and corridors, dangerous manufacturing facilities, and so on. Combined with rough treatment and negligent maintenance, this makes the components of old industrial buildings unfriendly to public visitors, especially the young, elderly, and those with disabilities. Much of the existing industrial building might therefore need significant upgrading; however, it is worth noting that there may be important industrial elements contained in some parts of the building that constitute important industrial heritage.

3.1.3. Summary of the Items Used to Measure the Provision for Basic Needs

In the study of basic needs, the physiological and safety needs at the bottom of Maslow's pyramid can be translated into the adaptive reuse of old industrial buildings (Figure 3). Here, the physiological needs will measure the air environmental quality of the building and the basic facilities to meet people's basic physiological needs; the safety aspects of the building will mainly concern the safety of the building components during the design of the transformation and the safety management of the building operation. These are the aspects of the building that make the users feel safe and comfortable and allow them to better experience the building. At the same time, it is a good basis for the building to subsequently meet the higher needs of the users.

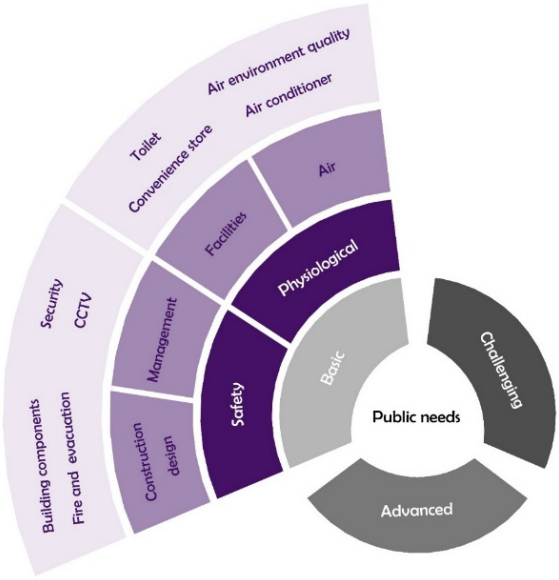

Figure 3. Measuring framework for basic needs (by author, 2022).

3.2. Advanced Needs

Maslow pointed out that once basic needs are fulfilled, the psychological dimension of the pursuit will emerge. Indeed, in contemporary society, most people are no longer satisfied with just physical comforts and the pursuit of the psychology has gradually taken on more importance [16]. Indeed, the need to communicate with others and obtain feedback from others as part of social interaction and respect is particularly important. The higher-level needs of Maslow's theory are thus reflected in socializing needs and esteem needs [16]. It is clear that the needs at these two levels mainly require the participation of people. What public buildings can do is to offer the users the possibility of socializing and esteem in a way that satisfies these needs.

3.2.1. Socializing Needs

The third level of human needs is interpersonal which involves feelings of belonging [16]. As an individual in a social group, socializing is an essential part of most human lives. In addition to the socialization within a common group, it also includes the passing of information to strangers, which can be extremely brief, such as a conversation with a salesperson when shopping. As a realm where social behavior occurs, public buildings can therefore provide places that promote social interaction and can indirectly provide opportunities for users to socialize through the organization of activities.

- Place

With safety needs met, people are encouraged to open their hearts and minds, to accept strangers, and to build communities. Social behavior is based on establishing communication with others [30]. To promote the communication of different social groups, architecture should provide communication places and opportunities to serve the contemporary needs for social interaction; for example, providing open spaces around the entrances of public buildings. Indeed, well-designed landscapes or public realms around a building can be places for people to rest in sunny weather, or spend time with family and friends, or even meet new friends. Inside a building, there are also ancillary places such as lounges and cafes where people can stay and gather, thus also stimulating social interaction. In addition to these functional spots, unobtrusive corners and other ad-hoc spaces in a building may also be a good encouragement to socialize. Importantly, Gehl suggests "varied transitional forms", where a lack of activity in a building's functional transitions will make functional boundaries too clear and will reduce the chance of social interaction [31]. In some transitional corridors, seating can be provided to support social

interaction; it can even be common to see people chatting together in designated smoking areas. All of these architectural spaces can provide a relaxing slow-paced atmosphere to encourage planned or spontaneous interaction among visitors.

- Opportunity

It has often been reported that face-to-face connectedness or interaction can bring positive psychological outcomes [32–34]. Despite virtual socialization being very advanced now, face-to-face socialization, such as the exchange of feelings and emotions, in the form of voice, facial expressions, and body language, can still bring positive benefits to people [30,35]. In the case of public buildings, it can be difficult to avoid interpersonal communication due to the social behavior of the users and engagement with staff. Indeed, users' perceptions of a place can depend greatly upon their engagement experience with a building's staff [36]. The operational aspect of the building should therefore provide good social opportunities and various public events and activities for users. In relation to reused old industrial buildings, this can take full advantage of the industrial culture and large industrial spaces to attract users to partake in activities. For the organizers, these activities can be organized to promote the project's publicity, thereby facilitating the users' social needs.

3.2.2. Esteem Needs

Maslow stated that esteem in terms of the individual is mainly reflected in the respect from others and self-respect [16]. However, for the public, respect will happen between individuals. As users enter a public building, the network of interactions that is formed is not only between the users but also between the users and the building itself. The respect of architecture for the users is essentially a dialogue between the designer and the building's users. Therefore, an emphasis upon humanistic design can allow the user to feel cared for and thus respected by the designer; at the same time, the user has a good experience of using the building and feels admiration for the designer's work. In addition, the designer should aim to make the building legible and comfortable to the users.

- Inclusiveness

All people, or in this case building users, should be treated equally. The publicness of a public space can also be reflected by the fact that it is inclusive of all groups of people. In practical terms, it is the demographic factors of the users that directly reflect the equality of the building [37,38]. Indeed, the users in the building should include a range of ages, genders, different backgrounds, and different incomes [39]. Additionally, from the perspective of class and racism, public buildings should be the embodiment of inclusiveness in their treatment of these issues [40]. It is also important that all potential building users are considered in the design process to ensure, for example, that the disabled, the elderly, those with young children in pushchairs, pregnant women, etc., are not discouraged by tangible or intangible barriers to their use of the building [36]. It is also important that any others with special needs are considered in the design and management of the building and not just as a result of legislation [39,41]. For the reuse of old industrial buildings, the former building use may not require the relevant barrier-free designs, but the transformed public building definitely will. This might, for example, include lifts, ramps, and accessible toilets.

- Legibility

People in unfamiliar surroundings can feel uneasy, as can users entering a building for the first time [42]. In public buildings, users want to become familiar with their environment as soon as possible [42,43]. This familiarity with the environment is primarily a sense of orientation to the layout of the building, otherwise, they will rapidly lose confidence in experiencing the building [44]. Therefore, legibility becomes an important point in measuring a successful public building [39,45,46]. However, it is worth noting that it is not necessary to know every detail of a building, otherwise, some people might lose interest in

exploring, with some scholars highlighting the need and value of "surprise" and "mystery" in environments [47].

The legibility of a building's layout is often linked to the images in the mind. Navigation within a building's interior tends to be dependent on maps, information panels, and signage to inform the users [48]. Generally speaking, maps should be available at the entrance to a building, and signage should be easily visible, so that users can find them quickly and obtain the information they need. Furthermore, the content represented by the maps and signs should be comprehensive and include the locations of key places, such as lifts, stairs, toilets, exits, etc. The content also needs to be easy to read and understand by the wide spectrum of users and therefore be multilingual and include international symbols.

3.2.3. Summary of the Items Used to Measure the Provision for Advanced Needs

Social behavior is an indispensable part of human activity. In order to better enhance the social quality of a building for users, old industrial transformation projects should provide suitable social places and facilitate social opportunities. Furthermore, the differences between individuals in society tend to create the psychological aspect of respecting and being respected. The inclusive design of a building will lessen this difference and at the same time, the legibility of the building will promote the formation of the self-esteem of the users and improve the experience of the building by amplifying the advantages of the building's respect for the users (Figure 4).

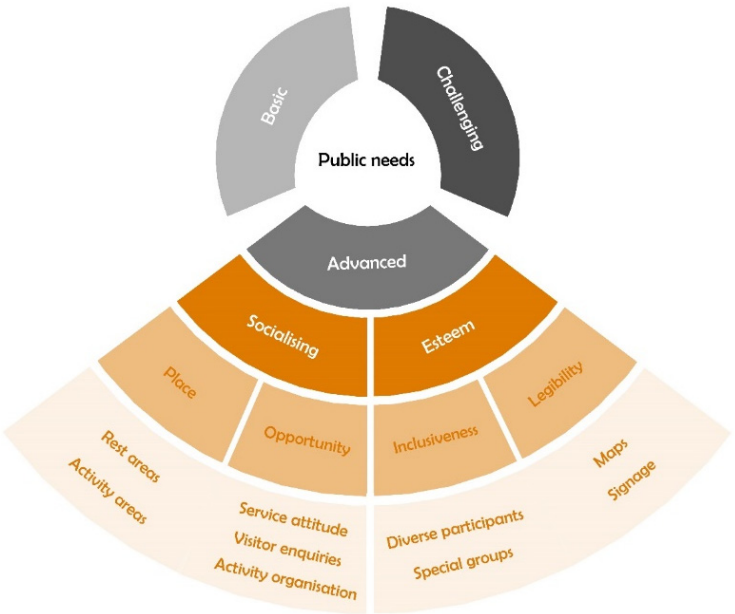

Figure 4. Measuring framework for advanced needs (by author, 2022).

3.3. Challenging Needs

Basic and advanced needs are considered to be those that public buildings should meet for the users. All public buildings should, however, also provide for challenging needs in order to provide the best possible environment for their users. As the highest level in Maslow's theory, self-actualization is considered to be a growth need [16,49], which can be considered as people realizing their own potential by making a contribution to something [50,51]. The self-actualization and self-transcendence of public users are the awareness of the value of the building's existence after using it, and even the discovery of its problems. Users who achieve this level can have a sense of pride in self-accomplishment, in being able to discover the potential value and meaning of the building. Obviously, achieving such needs for self-actualization are challenging; indeed, Maslow himself estimated that only two percent of people would reach the state of self-actualization [52].

The users' understanding and interpretation of industrial culture and heritage is a significant challenge in the reuse of old industrial buildings. Indeed, industrial culture can be abstract, wide-ranging, and in some cases even invisible [4,53,54]. The fusion of historical elements and heritage with new functions after the transformation can inspire users and help them achieve self-actualization needs; however, each individual is unique and their motivation for self-actualization can be different [55]. The acceptability of the information delivered by the language of architecture to the public is a characteristic that can distinguish the reuse of old industrial buildings from other buildings. This study therefore considers that the transformation and communication of the industrial culture and heritage in the building can contribute to users' challenging needs.

3.3.1. Needs of Historical Culture

Through the above analysis of self-actualization needs in Maslow's theory, successful projects should enable users to experience the meaning of industrial culture or draw inspiration from reused old industrial buildings. Elements in an old industrial building which are markings of life and manufacturing, left at a particular time, are the material industrial elements [2]. As a tangible carrier of historical culture, material industrial elements should be preserved in the transformation process and ultimately displayed in the new building in the form of the architectural language. At the same time, important historical culture and heritage should be interpreted and explained in order to be transmitted successfully to the public.

- Preservation

Most industrial buildings can be seen as a true reflection and important witness of the evolution of industrial history, helping to demonstrate important historical events and significant points in time [10]. Time has reduced the presence of industrial remains and raised the importance of the heritage value of industrial buildings. Indeed, some old industrial buildings are not only products of history but also creators of history, culture, and community. As a scarce resource, many are examples of pioneering industrial architecture or have helped to create the unique industrial cultures. As a result, the more complete the material industrial element, the more historical and cultural information it will be enriched with. Preserving the integrity of those industrial elements will therefore be a great contribution to peoples' understanding of the past and to future research.

- Transmission

When material industrial elements are preserved, it is also a sign that the historical culture behind them has been recognized by experts. As industrial archaeology, this important culture not only needs to be recorded in the archives [56,57], but also this culture needs to be accessible to the public [58]. The language of architecture is a symbolic system of shaped spaces that transmits a message to the users, so that the public can experience and interpret these architectural meanings [59]. Although it is not possible to give a clear introduction to the user through the architectural language, this does not affect the conveyance of the industrial culture. For example, the crane system or the steel columns and gantries allow visitors to mentally connect the building with a former industrial period. Furthermore, industrial buildings have a specific aesthetic significance due to their distinction from normal civil buildings, often with a strong sense of scale, form, robustness, etc. The aesthetics of industrial culture are often subjective and vary from person to person; however, the discovery of the aesthetic value of industrial aesthetics and how this might be perceived by users is key to the transformation of obsolete industrial buildings.

3.3.2. Needs of Hybrid Culture

The essence of the transformation of old industrial buildings is the "selective preservation and strategic addition" of architectural elements [2]. After preserving the old industrial elements, the designer should set up a matched relationship between old elements and new functions and new elements. In a building with both old and new, the integration

between the two can result in a hybrid culture and this integration allows the two types of elements to amplify their respective strengths. This can present a new aesthetic and freshness to users whilst also endowing the project with a unique character and identity and the creation of a new culture that can meet the new needs of a new era.

- Visual integration

Vision is one of the most important dimensions in the evaluation of architecture and the environment [30,39]. "Beauty" is usually due more to harmonious relationships among elements of a composition than to the elements themselves; therefore, visual beauty is primarily about relationships, including integration [30,60,61]. In general, visual integration expresses a sense of wholeness and the overall architectural style should be unified, with the exception of certain important heritage elements and details that may need to be emphasized. There will definitely be gaps in the architectural elements from different eras. However, this should not affect the users' overall impression of the building, otherwise, the "big idea" will become confused and may prevent the satisfaction of challenging needs.

The decoration of an architectural surface (interior or exterior) can provide visual clues for people via the materials, scale, proportion, and rhythm [39]. The wise use of elements can sharpen or soften differences between the various parts of the surface, as well as to improve the connection between it and its surroundings. With an appropriate approach, the fusion between old and new architectural elements will provide a sense of visual depth and solidity, enriching architectural spaces, and attracting people to explore the culture of the building. The emphasis is only on the overall impression of the space that the users get visually in a very short period of time. After the overall impression of the building has been established, the details within the architectural elements will continue to be explored by the users, otherwise, the building might become boring. Details require the participant to get closer and focus their attention on a smaller area of space. Such detailed elements may be the texture of materials, patterns on windows, hidden elements, and so on.

- Innovative culture

In addition to visual integration, the innovative culture comes mainly from the new activities and psychological awareness of the users in the transformed buildings. What used to happen in the industrial building was an industrial culture of manufacturing and working, whereas after the transformation, people have completely new activities (visiting, playing, relaxing, etc.) in the building and therefore a new culture is formed.

The activities take place in different contexts giving rise to different cultural characteristics. The historical legacy of the transformation project could become an added attraction to the project. This rare and innovative culture can also enhance the regional identity, which distinguishes one area, domain, or social collective from others [30,39]; at the same time, the attractiveness of the project is then increased, thus contributing to the vitality of the project and the presentation of new cultural activities [62]. The challenge for the architects will thus be about how to make use of these historical industrial assets in order to present the project as special and innovative.

Overall, the appeal of the transformed buildings is to make the most of the historical industrial culture and heritage, relying on the historical asset to attract more people to the buildings. The hybrid culture is unique to a reused project and it can help to promote the rise of some new industries within an old industrial context. As a result, more people will get to know the old industrial culture of the project and, at the same time, more people will participate in the innovation of the hybrid culture. Furthermore, the old culture is spread through the attraction of new functions, with public participation making it possible to promote a sustainable culture of creation.

3.3.3. Summary of the Items Used to Measure the Provision for Challenging Needs

Challenging needs are a need for a cultural dimension, translated from self-actualization at the top of Maslow's pyramidal hierarchy of needs. This research has divided the culture of reused industrial buildings into two categories: old historical culture, and

innovative hybrid culture. Material industrial elements are the evidence of historical culture and heritage in the architecture, and their preservation and the expression of historical information should be an important part of the reuse of historical buildings. Indeed, their transformation should not avoid the integration of new architectural elements, and the adaptive treatment of the old and new elements will not only enhance the attractiveness of the project with history, but can also help to create a new regional culture (Figure 5). The concept of culture is extremely broad, and its meaning is constantly evolving and expanding, and only a small part of it can be specified at present. Thus, challenging needs are more of a vision of the future of humanities research. While the challenging needs may not satisfy many of the users, the users' activities in the buildings have in fact become part of the culture. Users are just not aware or have not yet achieved what they consider to be self-actualization. Architects therefore have a responsibility to use architecture to help the public achieve their self-actualization. As such, in the process of transformation, the architectural culture, both old and new, needs to be perceived and accepted by the users as much as possible.

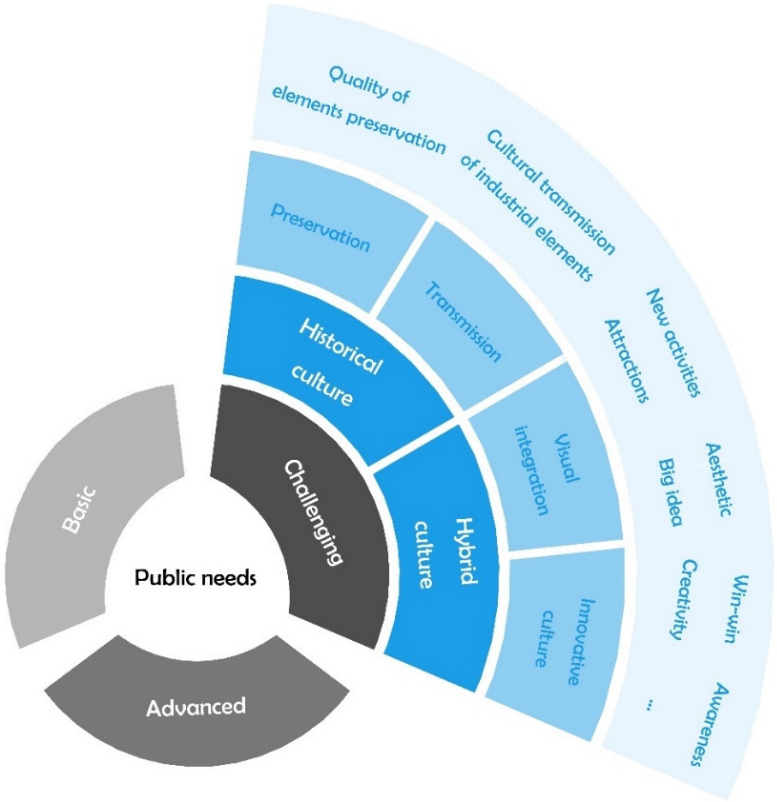

Figure 5. Measuring framework of challenging needs (by author, 2022).

3.4. Assessment Framework Output

The analysis of Maslow's hierarchy of human needs and its application to the adaptive reuse of old industrial buildings have helped to develop an assessment framework (Figure 6). This has also helped to highlight the main measurement items (questions) that need to be considered in the evaluation of projects (see Table 1). It is, however, necessary to highlight that these issues are not absolute and that they should be applied flexibly in different projects; they can be expanded or reduced accordingly. Indeed, future studies should detail the assessment framework according to specific practical projects, while conducting a questionnaire survey and statistical analysis to discover the relationship between each factor and the overall assessment system.

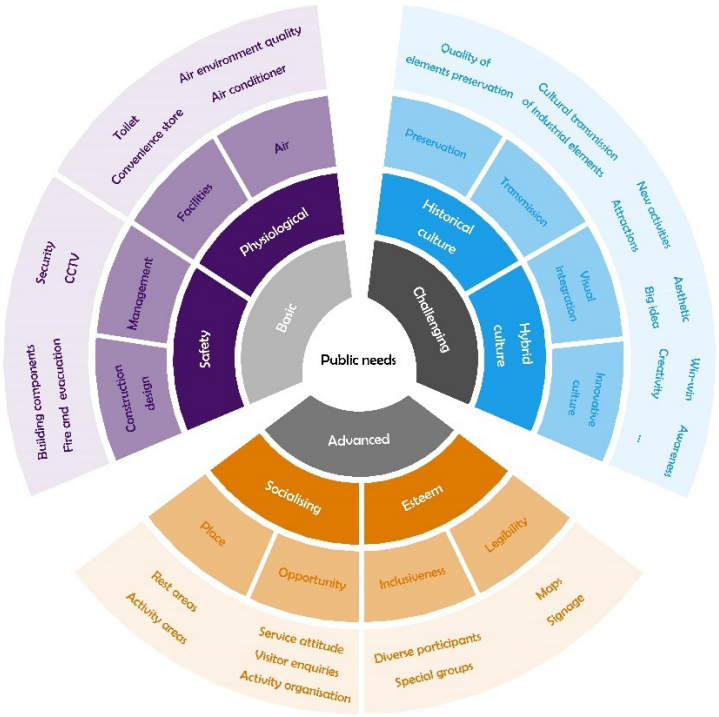

Figure 6. Full assessment framework of basic, advanced, and challenging needs (by author, 2022).

Table 1. Questions to consider in the application of the measuring framework (by author, 2022).

	Basic needs
Physiological needs	Are the ventilation, temperature, and humidity in the building within a comfortable range? Is there an HVAC system in the building? Is the building equipped with the appropriate number of toilets and are they easy to find? Are the building's toilets clean, and does the water supply work? Is there a convenience store in or around the building and does it sell items for daily emergencies, such as drinks, snacks, fast food, tissue paper, chargers, and so on?
Safety needs	Is there a security officer in the building? Is there a CCTV system in the building? Are the firefighting facilities (e.g., fire hydrants, sprinkler systems) in the building up to current codes and best practices? Does the fire escape design (e.g., escape stairs, escape distance) in the building meet the building code? Are the building's easily damaged elements regularly maintained? Are the floors, stairs, hand-railings, and other elements of the building safe for users? Are there suitable warnings about safety hazards such as crashes, falls, graze, and so on?
	Advanced needs
Socializing needs	Are there areas within the project that offer relaxation (e.g., coffee, tea bars, lounge areas)? Are there any behavioral activities evident, for example, exercise, chatting, picnics, and so on? Is there an information desk, patrolling staff, or volunteers? Is the attitude of the service staff welcoming? Are there regular or irregular community events for the public?
Esteem needs	Is there a good gender balance of users? Is it used by people of different ages and ethnic groups? Are there barrier-free designs, such as lifts and ramps, to make wheelchair access possible? Are there barrier-free toilets and a nursing room(s)? Does the project provide free assistive devices for special groups (e.g., wheelchairs, hearing aids, prams)? Is there a layout map in the building? Are the maps comprehensive, clear, and easy to understand? Is there any clear signage in the building (e.g., smoking, warning signs, exit signs, visit descriptions)?

Table 1. *Cont.*

	Challenging needs
Cultural needs	Are there any preserved material industrial elements, and are these easy to find? Do the material industrial elements have historical value? Is there information about the important industrial elements, or an official website with relevant descriptions? Can users associate with the industrial scene of the past from these material industrial elements? Does the building use its industrial background and heritage to attract visitors? Will the project achieve local recognition in a short time?

4. Application of the Assessment Framework

In this section, a case study of the 1933 Old Millfun in Shanghai, China, will be used to demonstrate the potential application of the assessment framework developed in this research. The case study will use the fuzzy comprehensive evaluation method, a mathematical theory, for the evaluation of the 1933 Old Millfun. Although the paper mainly reflects an assessment framework based on Maslow's theory of hierarchy, the combination of this mathematical theory is used to demonstrate the potential for the further development of the assessment framework.

In the field of architecture or urban planning, often the evaluation of a place in terms of good or bad is influenced by several factors, which helps to break down the evaluation problem naturally [63]. Although the application of fuzzy comprehensive evaluation methods is still in the experimental stage, the results of this research will hopefully be the driving force behind its further development.

4.1. An Overview of the Principles of the Fuzzy Comprehensive Evaluation Method

A fuzzy comprehensive evaluation model is a mathematical calculation that allows for a comprehensive evaluation result under the influence of multiple factors [63]. The multiple factors can be summarized into two finite discourse domains: $U = \{U_1, U_2, \cdots, U_m\}$; $V = \{V_1, V_2, \cdots, V_n\}$, where U represents the factor set which has m factors, and V is the evaluation set which has n evaluation levels (perfect, very good, good, satisfactory, unsatisfactory).

The evaluation results for different factors will tend to converge to different levels in n. The comprehensive evaluation can be seen as a fuzzy subset $B = \{b_1, b_2, \cdots, b_n\}$ of V, and the B depends on the weight distribution of various factors, which can be regarded as the fuzzy vector $A = \{a_1, a_2, \cdots, a_m\}$ (the sum is equal to 1) of U. The fuzzy relation R is regarded as a "fuzzy converter", which is input, A is output and B is shown in Figure 7. Finally, B will be a fuzzy calculation result, which reflects the affiliation of the evaluation levels V (perfect, very good, good, satisfactory, unsatisfactory).

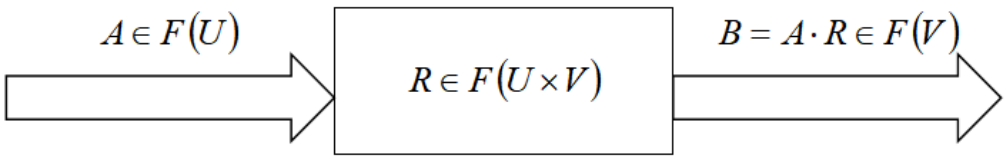

Figure 7. Fuzzy converter.

4.2. Survey and Statistics

Located in the Shanghai city center, the 1933 Old Millfun is a creative industry cluster (mixed use) transformed from a former slaughterhouse (Figure 8). It now comprises 30,000 square meters of space, which brings together a wide range of uses and activities such as culture, fashion, creativity, exhibitions, exchanges, launch events, and trade events. The building was converted in 2006 and was not overly decorated and the designer used "subtraction" by retaining the original concrete facades throughout to showcase the historic and industrial nature of the building. Significantly, in a country where death is taboo,

saving an old slaughterhouse was a particularly awkward and sensitive task. Nevertheless, the preserved structure has managed to balance dark memories with historical authenticity. Indeed, the strategic "forgetting" and "selective memory" in the transformation of the 1933 Old Millfun has been described as translating killing and death into art [64].

Figure 8. Restored facade of the 1933 Old Millfun (by author 2021).

Based on the assessment framework in Section 3.4 (Figure 6 and Table 1) and combined with the actual situation of the 1933 Old Millfun, data was collected for the 16 sub-items in the 3 dimensions $U = \{U_1, U_2, \cdots, U_m\}$. These sub-items are the key to the comprehensive evaluation. As a result, Table 2 illustrates the measuring framework for the qualities of the 1933 Old Millfun. The sub-items that are detailed are used as the project evaluation, and each item was scored and weighted by experts in the relevant field. This provides the foundation for the quantification of the evaluation.

Table 2. Evaluation factor system of reused old industrial buildings (by author, 2022).

Index bed of basic needs U_1	
Physiological needs	Air environment quality u_{11} Toilet u_{12} Convenience store u_{13}
Safety needs	Security u_{14} Fire and escape u_{15} Building components u_{16}
Index bed of advanced needs U_2	
Socializing needs	Rest and activity areas u_{21} Visitor enquiries u_{22} Activity organization u_{23}
Esteem needs	Diverse users u_{24} Facilities for special groups u_{25} Map and signage u_{26}
Index bed of challenging needs U_3	
Cultural needs	Preservation of historical industrial elements u_{31} Transmission of historical culture u_{32} Integration of 'old and new' u_{33} Attractiveness u_{34}

The collected data will be calculated and analyzed by the fuzzy comprehensive evaluation method, which is a method to evaluate things collectively in multi-level and multi-factor situations. Because of the complexity, fuzziness, subjectivity, and difficulty in quantifying and defining the quality of reused projects, the fuzzy comprehensive evaluation method can be calculated, in order to determine the final assessment of the project. The assessment has been divided into evaluation levels (perfect, very good, good, satisfactory, unsatisfactory).

The 100 points have been distributed to the 5 levels of each sub-item by engaging expert opinions on the project. The researcher, in collaboration with five experts, visited the 1933 Old Millfun to investigate each of the 16 items of the project, including measurements, photographic evidence, and questionnaires. The five experts then discussed and scored each item, resulting in 5 levels of affiliation, as shown in Table 3.

Table 3. The scored measuring framework (by author, 2022).

Basic Needs R_1	Perfect	Very Good	Good	Satisfactory	Unsatisfactory
Air environment quality u_{11}	87.2	0	1.6	0	11.2
Toilet u_{12}	91.7	0	0	8.3	0
Convenience store u_{13}	50	0	0	50	0
Security u_{14}	60	0	40	0	0
Fire and escape u_{15}	0	50	0	25	25
Building components u_{16}	25	25	0	50	0
Advanced Needs R_2					
Rest and activity areas u_{21}	100	0	0	0	0
Visitor enquiries u_{22}	0	25	0	50	25
Activity organization u_{23}	0	70	30	0	0
Diverse users u_{24}	33.4	0	33.3	33.3	0
Facilities for special groups u_{25}	0	25		50	25
Map and signage u_{26}	0	20	20	60	
Challenging Needs R_3					
Preservation of historical industrial elements u_{31}	100	0	0	0	0
Transmission of historical culture u_{32}	0	0	0	12.5	87.5
Integration of 'old and new' u_{33}	0	50	50	0	0
Attractiveness u_{34}	25	75	0	0	0

For the establishment of the fuzzy matrix R_1, R_2, R_3 for factor evaluation, the specific process is as follows:

$$R_1 = \begin{bmatrix} 87.2 & 0 & 1.6 & 0 & 11.2 \\ 91.7 & 0 & 0 & 8.3 & 0 \\ 50 & 0 & 0 & 50 & 0 \\ 60 & 0 & 40 & 0 & 0 \\ 0 & 50 & 0 & 25 & 25 \\ 25 & 25 & 0 & 50 & 0 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 100 & 0 & 0 & 0 & 0 \\ 0 & 25 & 0 & 50 & 25 \\ 0 & 70 & 30 & 0 & 0 \\ 33.4 & 0 & 33.3 & 33.3 & 0 \\ 0 & 25 & 0 & 50 & 25 \\ 0 & 20 & 20 & 60 & 0 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 100 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 12.5 & 87.5 \\ 0 & 50 & 50 & 0 & 0 \\ 25 & 75 & 0 & 0 & 0 \end{bmatrix}$$

Combining the weight given by experts and the statistics above, the final assessment frame can be established as shown in Table 4:

Table 4. The scored matrix framework with weightings (by author, 2022).

Basic Needs R_1	**Weight**	**Perfect**	**Very Good**	**Good**	**Satisfactory**	**Unsatisfactory**
Air environment quality u_{11}	16.77%	87.2	0	1.6	0	11.2
Toilet u_{12}	17.56%	91.7	0	0	8.3	0
Convenience store u_{13}	12.38%	50	0	0	50	0
Security u_{14}	15.97%	60	0	40	0	0
Fire and escape u_{15}	19.36%	0	50	0	25	25
Building components u_{16}	17.96%	25	25	0	50	0
Advanced Needs R_2						
Rest and activity areas u_{21}	16.20%	100	0	0	0	0
Visitor enquiries u_{22}	16.20%	0	25	0	50	25
Activity organization u_{23}	15.33%	0	70	30	0	0
Diverse users u_{24}	16.20%	33.4	0	33.3	33.3	0
Facilities for special groups u_{25}	18.36%	0	25		50	25
Map and signage u_{26}	17.71%	0	20	20	60	
Challenging Needs R_3						
Preservation of historical industrial elements u_{31}	23.95%	100	0	0	0	0
Transmission of historical culture u_{32}	24.85%	0	0	0	12.5	87.5
Integration of 'old and new' u_{33}	25.45%	0	50	50	0	0
Attractiveness u_{34}	25.75%	25	75	0	0	0

According to the formula of the fuzzy comprehensive evaluation method and combined with the data derived from Table 3, the matrix and weights (A) have been multiplied and will result in a fuzzy comprehensive evaluation result for each section B_1, B_2, B_3.

$$B_1 = A_1 * R_1$$

$$= \begin{bmatrix} 16.77\% \\ 17.56\% \\ 12.38\% \\ 15.97\% \\ 19.36\% \\ 17.96\% \end{bmatrix} * \begin{bmatrix} 87.2 & 0 & 1.6 & 0 & 11.2 \\ 91.7 & 0 & 0 & 8.3 & 0 \\ 50 & 0 & 0 & 50 & 0 \\ 60 & 0 & 40 & 0 & 0 \\ 0 & 50 & 0 & 25 & 25 \\ 25 & 25 & 0 & 50 & 0 \end{bmatrix}$$

$$= (50.988\ 14.17\ 6.656\ 21.467\ 6.718)$$

In the same way, the fuzzy comprehensive evaluation results of B_2, B_3 are:

$$B_2 = A_2 * R_2 = (21.611 \quad 22.913 \quad 13.536 \quad 33.301 \quad 8.64)$$

$$B_3 = A_3 * R_3 = (30.388 \quad 32.038 \quad 12.725 \quad 3.106 \quad 21.744)$$

In the formula, '$*$' is the operator for multiplication.

These results reflect the affiliation to the five evaluation judgment levels (perfect, very good, good, satisfactory, unsatisfactory). The level in which the largest score is located is the result of the judging of the section.

4.3. Analysis and Discussion

The scores of perfect in the assessment of basic needs are very high (87.2, 91.7, 50, 60, 0, 25). This indicates that most areas in the 1933 Old Millfun meet the needs of the public

well. As far as modern buildings are concerned, well-equipped HVAC systems, functional layouts, and ratios tend to be in strict accordance with regulations, and therefore a good foundation for meeting basic needs. The results of the comprehensive fuzzy evaluation calculations also show that perfect has the significantly highest affiliation (Perfect: 50.988). This is also because, as mentioned earlier, modern buildings undergo strict approval processes before they are opened for public use. Thus, the case received a high rating on basic needs.

In terms of the advanced needs, the performance of the case varies widely across the different items. It is clear from the survey that the various exhibitions and events held in the case are trying to meet people's social needs. In the 1933 Old Millfun, although it has a perfect rest area and rich activities, other aspects are somewhat neglected, such as visitor enquires, special groups, and so on. Unlike basic needs, there is no clear trend in these scores, so it does not easily reflect the overall evaluation of the project in terms of advanced needs. The application of fuzzy mathematics helped to obtain a comprehensive evaluation of the project in this dimension. According to the principle of largest affiliation, the overall evaluation of advanced needs is satisfactory (33.301). The result identifies that the project should improve in this dimension in the future, especially in the provision of humanistic care for public users.

With regard to the challenging needs, the 1933 Old Millfun has its own unique historical atmosphere and is successful in terms of feedback data (very good: 32.038). However, as industrial heritage, its important historical context needs to be further explored and cultural knowledge needs to be further disseminated to the public. Although the project has provided a successful visual environment for the public, industrial culture is not limited to this, with the historical, scientific, and social values contained in industrial history being important as well. Therefore, how to help the public understand, interpret, and be inspired by the knowledge contained therein is a question that needs to be considered by the project in the future.

In summary, the three dimensions in the case evaluation can be understood as follows: the basic needs are evaluated at the level of the building infrastructure, advanced needs are about humanistic care, and challenging needs are about the distinctiveness and attractiveness created through their own characteristics. The evaluation shows that for the 1933 Old Millfun, the basic needs of the contemporary building are of high quality; the challenging needs could be seen as the driving force behind making the project unique and attractive; however, the advanced needs are probably the most neglected. More importantly, the issues of the project that have been exposed in this evaluation are well-placed to guide the direction of the project's future development.

5. Conclusions

This research has involved the translation of Maslow's Hierarchy of Needs (psychological systems) to the evaluation of architecture; in particular, it has established an assessment framework to analyze the success of the reuse of old industrial buildings as public buildings. The assessment framework identifies aims to meet the needs of the public users by measuring and analyzing reused industrial buildings from the perspective of three dimensions identified from Maslow's theory (basic needs, advanced needs, and challenging needs). Meanwhile, a number of sub-items in the assessment framework are used as critical factors in the evaluation of these buildings. The application of this evaluation framework can then not only be used to evaluate completed adaptive reuse projects, but can also inform and provide guidance for architects in the design and assessment of future projects.

Overall, the research simplifies the problem and often subjective nature of judging the relative successes and failures of projects into multiple factors of influence and analyses them one by one in a quantitative approach. After establishing the assessment framework, the study demonstrates the feasibility of its application by examining the case of the 1933 Old Millfun in Shanghai. In doing so, we combined the evaluation framework with mathematical-statistical methods. Although the application of the fuzzy comprehensive

evaluation method is not the main focus of this research, it has provided a reference point for future similar multi-factor-influenced building assessment methods, such as principal component analysis (PCA), analytic hierarchy process (AHP), and data envelopment analysis (DEA). In addition, this assessment framework does not need to be limited to the adaptive reuse of old industrial buildings as public buildings, and in the future, it can be evolved to evaluate many other types of buildings.

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