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# Exploring Socio-Technical Features of Green Interior Design of Residential Buildings: Indicators, Interdependence and Embeddedness

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**Abstract:** This research aims to develop indicators for assessing green interior design of new residential buildings in China, grounded in the socio-technical systems approach. The research was carried out through a critical literature review and two focus group studies. The results show that the boundaries of green interior design were identified with respect to three dimensions, namely performance, methodology and stakeholders. The socio-technical systems approach argues for the recognition of the interdependence between the systems elements and the feature of embeddedness. The interdependence of the systems elements exists within each of these three dimensions and across them. It is also found that the socio-technical systems of green interior design are embedded in the social, regulatory and geographic context. Taking interior design of residential buildings as the empirical setting, this study contributes to the literature of green building assessment by presenting a socio-technical systems approach.

**Keywords:** environmental impact assessment; green interior design; green building; socio-technical systems; embeddedness; China

## 1. Introduction

Green development has become the national strategy for economy development and the topmost governmental agenda in China. The Chinese government initiated five principles for national development in the fifth Plenary Session of the 18th the Communist Party of China Central Committee in 2015. These are innovation, coordination, green, openness and sharing. According to the BP Statistical Review of World Energy, in 2012, China accounted for 21.9% of total worldwide primary energy consumption. The building sector consumes about 27.0% of the country's total energy. The building sector has accounted for approximately 43% of China's total energy consumption from the life-cycle perspective [1]. Thus, achieving green in the building sector will significantly contribute to a reduction in overall use of carbon and energy.

The Chinese Government has announced a series of action targets and roadmaps for achieving green buildings. For example, the Ministry of Finance (MOF) and the Ministry of Housing and Urban-Rural Development (MOHURD) jointly announced the 'Implementation Plan for Accelerating Green Building Development' that set the targets for creating 1 billion $m^2$ of new green building areas by 2015, constituting at least 30% of new building areas by 2020. In 2014, the Central Government and State Council initiated the "New National Urbanization Plan 2014–2020" in which 50% of new building are projected to reach the green building standards by 2020. The 'Evaluation Standard for Green

Building' (ESGB) was published and updated in 2006 and 2014 respectively [2]. All these regulatory contexts motivate the entire industry to strive for a green building paradigm shift.

Increasing studies also shade light on energy/carbon reduction in the building sector in China [3,4], either for commercial [5,6] or for residential buildings [7]. Studies also focused on specific stages of green building delivery, for instance design [8], construction [9] and retrofit [10]. Policies for addressing problems with respect to green building delivery were also extensively examined [4], in terms of challenges and opportunities [3,11,12].

However, the interior design of new residential buildings is rarely examined in China. Although pollution control and indoor environmental standards associated with interior design of residential buildings have been sparsely addressed, there is a lack of established tools for assessing their environmental impacts. This gap in knowledge is significant given that the interior design and construction constitute a considerable market share in the construction sector, and green interior design is of vital importance to the green building delivery.

This study aims to develop indicators for assessing green interior design of new residential buildings. This study argues for a socio-technical systems approach [3], which emphasizes that green interior design is characterized by systems and embeddedness features. The systems feature embraces the interdependence among the systems element [13,14] and the embeddedness feature implies that green interior design is embedded into the social, regulatory and geographic context. This study focuses on new residential buildings as they have distinct features from other building types (e.g., office and hotels) and existing residential buildings.

The paper is organized as follows. Section 2 presents a literature review of green interior design and socio-technical systems approach, followed by a conceptual framework for defining the boundaries of green interior design (Section 3). Section 4 reports on the research method of focus group studies. The key results of the indicators for assessing green interior design and discussion of the socio-technical systems features are presented in Section 5. Conclusions and recommendations for future studies are shown at the end.

## 2. Literature Review

### *2.1. Green Interior Design of Residential Buildings*

People spend 90% of their time indoors [15]. However, it is found that levels of indoor pollutants are usually two to five times higher than outdoor levels [16], which could be detrimental to the health and well-being of occupants [17]. Thus, improving the indoor environment is of great importance to their well-being [18]. However, in classical interior design, designers often prioritize on meeting the aesthetic and functional needs of the clients, rendering environmental issues less important [19].

Prior studies have fallen short of providing a cohesive description of the boundaries of green interior design of residential buildings thus far. In a simple manner, studies argued that green interior design intends to cover a wider scope than the classical approach. These include material, aesthetic qualities, environmental and health impacts, availability, ease of instalment and maintenance, and life-cycle cost [20]. Kang and Guerin [18] defined environmentally sustainable interior design practice as three aspects: global sustainable interior design, interior materials, and quality indoor environments.

In the green building standards for new construction or renovation, e.g., Leadership in Energy and Environmental Design (LEED), and the Building Research Establishment Environmental Assessment Method (BREEM), parts of the assessment credits are associated with interior design. In addition, six aspects of indoor environment are assessed in ISO 16813:2006. These are indoor air quality, thermal comfort, acoustical comfort, visual comfort, energy efficiency and HVAC system controls. These are applicable to environment design for new construction and the retrofit of existing buildings. However, it mainly deals with the indoor environment, referring less to space performance and material savings.

In addition, the LEED for Homes Design and Construction (LEED BD + C: homes and multi-family low-rise; LEED BD + C: Multifamily Midrise) specified the requirements on location and transportation, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation and regional priorities. It defined broader requirements for achieving green interior design, such as credits assigned to location and transportation, sustainable sites and outdoor water use. These aspects might not be applicable to the China's context as these aspects are dealt with by architectural designers and fixed prior to the interior design. Similarly, the local assessment tool ESGB comprises energy savings, land savings, water savings, material savings, environment protection, and building functional requirements during the complete building life cycle. Notwithstanding these evaluation tools, there is a lack of well-established tools, specifically with respect to assessing green interior design of new residential buildings.

Research has examined green interior design of offices and commercial buildings [21]. The LEED and BCA (Building and Construction Authority) Green Mark initiated assessment tools for offices and commercial interiors. The BCA published the "BCA Green Mark for Office Interior" [22]. It comprises energy efficiency, water efficiency, sustainable management and operation, indoor environmental quality, other green features [22]. LEED for commercial and institutional interiors addressed sustainable sites, energy and atmosphere, materials and resources, and indoor environmental quality [23]. The BREEAM UK non-domestic building refurbishment and fit-out schemes have four assessment parts. These are building fabric and structure, core services, local services and interior design. Refurbishment and fit-out projects can be assessed against one or all of the four parts, or any combination [24]. However, the indicators developed in these tools, while providing valuable inspiration for assessing green interior design of residential buildings, would not be applicable to the residential building in China.

### *2.2. Socio-Technical Systems Approach*

Socio-technical systems are referred to as "a somewhat abstract, functional sense as the linkages between elements necessary to fulfill societal functions" [25] (p. 898). The socio-technical systems approach not only focuses on achieving interior design at the design and construction stages, but also on functionality at the occupancy phase.

The systems approach highlights that system elements are tightly interrelated and interdependent with each other [25]. Open systems are another important feature of the socio-technical systems approach. Although sustainable building is increasingly recognized as involving complex socio-technical systems [3,14], studies rarely investigate their features. Drawing on the analytical framework [25,26], green interior design is considered to have complex socio-technical systems. Aside from the indicators for green interior design being developed, this study examined the socio-technical systems features of green interior design of residential buildings.

### *2.3. Empirical Context of Green Interior Design in China*

Given the open system feature of the socio-technical systems, the economic, social and regulatory contexts of green interior design of residential buildings in China are elaborated in detail. These contextual factors together shape the development of green interior design of residential buildings.

#### 2.3.1. Economic Context of Green Interior Design

Due to with rapid urbanization, the decorating industry has huge development potential. The capital of the decorating industry reached 3160 billion CNY in 2014, as compared to 1180 billion CNY in 2005 (see Figure 1). Residential decoration constitutes almost half of this capital. The growth rate in these years was kept stable around 10% [27]. This indicates there is a great market potential in interior design and construction.

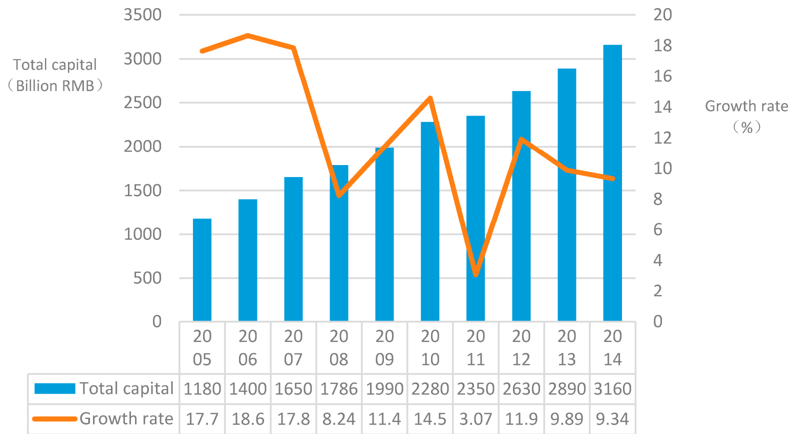


**Figure 1.** Total capital of the decoration industry and growth rate. Source: MOHURD [27].

Two significant drivers of this growth could be identified. The first is the political incentive of fine decoration (whereby the developer undertakes the decoration work) in the building sector. In the last decade, the majority of residential buildings were handed over without fine decoration; the interior design and construction is entirely left to the buyers. However, increasing studies found that this delivery system resulted in a huge amount of waste and environmental problems [28]. As a consequence, the policy now is re-oriented to incentivize fine decoration. According to MOF and MOHURD [29], all new residential buildings are suggested to be handed over with fine decoration already complete. The second driver is the booming market of the refurbishment of existing residential buildings. The first mass construction of residential buildings in China took place in the late 1990s. It was gradually observed that these buildings underwent varying degrees of refurbishment.

#### 2.3.2. Social Context of Green Interior Design

Contractor registration heads in China comprise three categories, namely general contractors, specialist contractors and labor subcontractors. Construction firms that undertake decoration work belong to one type of these specialists. Their work scope covers decoration work and directly related supporting works [30]. There were around 140,000 firms that undertook decoration work in 2014.

The old registration system was transformed from a three-class grade to two-class grade (i.e., first and second Class) in 2014 [30]. Grades are classified in accordance with financial capability, personals and track record. Firms in the class one have no limits in tender amount, whereas those in class two are limited to a contract amount below 20 million CNY. For design firms, there are three grades (see Table 1).

**Table 1.** Design and construction firm categories in residential decoration.

| Firm Types | Grades | Registration Criteria |
|---|---|---|
| Design firm | Class one<br>Class two<br>Class three | Financial capability and track record<br>Personals<br>Technology and management systems |
| Construction firm | Class one<br>Class two | Financial capability<br>Personals<br>Track record |

Source: MOHURD [30,31].

#### 2.3.3. Regulatory Context of Green Interior Design

Regulations of relevance to interior design fall into three levels, namely national, industrial and provincial levels. The former two are applicable to all regions, whereas the latter refers to local regulations coming into effect in a specific province. A review of the existing regulations, codes and rules in China was carried out. The national and industrial regulations cover one aspect and multiple aspects are presented in Supplementary Materials Annex 1 and 2 respectively. Provincial-level regulations are presented in the similar manner (see Annex 3 and 4). From these tables, three patterns could be observed.

First, existing rules and regulations are closely associated with interior design. Thus, the development of green interior design should be compatible with the existing regulations. Specifically, green interior design should comply with the civil building regulations. This is because buildings are classified into two types in China, namely industrial and civil building (see Figure 2); residential buildings belong to the latter category. In any case, rules and regulations are highly localized. Developing indicators for green interior design thus requires a contextualized plan.

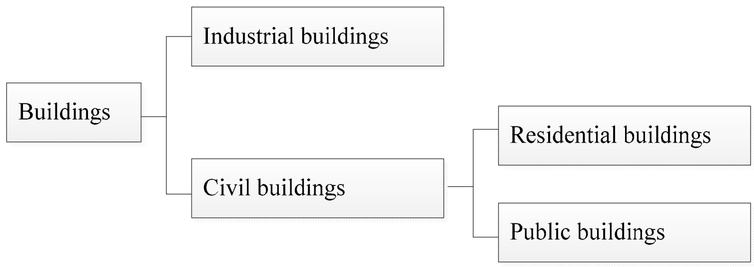


**Figure 2.** Building type classification in China. Source: adapted from Li & Yao [3].

Second, a lack of well-established assessment tool for green interior design is observable at national, industrial or provincial levels. Such a deficiency might severely hinder the green transformation of the interior design and construction for residential buildings.

Third, green interior design practices face complex and intricate regulation systems. Ye et al. [32] found that contents in most standards largely overlap; some mandatory provisions in local standards are unnecessary. Besides, green interior design could be controlled and monitored by multiple governmental entities. Thus, to promote such practices through regulations would require coordination among multiple governmental entities. Lack of such coordination would impose great obstacles to practice uptake and implementation.

## 3. Conceptual Framework of Green Interior Design for Residential Buildings

This study adopted the framework of Ju, Ning and Pan [33] to initially define green interior design of residential buildings. It deals with three dimensions, which are performance, methodology and stakeholders (see Table 2). The former two present the technical aspect, whereas the latter portrays the social aspect.

(1) The performance of green interior design comprises five aspects. These are effective space utilization, healthy indoor environment, energy saving, water conservation and material saving. These five aspects were initially identified from the extant literature and further verified through focus groups;

(2) The methodology deals with the temporal and spatial dimensions. The temporal dimension includes workflow and material flow. Work flow covers design, material selection, construction, maintenance and end-of-life. Although this study deals with green design, it is recognized that design solutions have great impacts on construction, maintenance stages. The material dimension deals with the material flow of the cradle-to-grave life cycle. The spatial dimension describes the location of physical subjects. It has to properly deal with the component of interior design, compatibility with architectural and mechanical, electrical and plumbing (MEP) design and outdoor environment;

(3) The stakeholder dimension refers to the actors who play a role in achieving green interior. These include developers, contractor, designers, suppliers, end-users, the government and industrial organizations.

**Table 2.** Boundaries of green interior design of residential buildings.

| Systems | Dimension | | Indicator |
|---|---|---|---|
| Technical systems | Performance | | Space performance, indoor environmental quality, energy efficiency, water conservation and material savings |
| | Methodology | Temporal dimension: workflow | Design, material selection, construction, operation, maintenance and end-of-life |
| | | Temporal dimension: material flow | Raw material extraction, Transportation from extraction site to factory, manufacturing, transportation from factory to building site, construction installation, operation, renovation, deconstruction and recycling/landfill site |
| | | Spatial dimension | Components of interior design, architectural design, MEP design and outdoor environment |
| Social systems | Stakeholders | | Developers, contractors, designers, suppliers, end-users, government and industrial organizations |

Source: Adapted from Pan and Ning [14] and Ju et al. [33]. MEP: mechanical, electrical and plumbing.

## 4. Research Methods

### *4.1. Focus Group Studies*

This study adopted focus groups to develop indicators for and explore the socio-technical systems feature of green interior design of residential buildings in China. Focus groups are useful for exploring a particular topic [34]. The purpose of the first-round focus group was to derive the indicators, and verify five categories in the conceptual framework as well as interdependence and embeddedness features. The second focus group aimed to validate the indicators and socio-technical systems features obtained in the first round.

Participants were selected using purposive sampling. Participants from a wide range of organization types were targeted. In the end, seven participants were invited in the first round. Detailed background information is shown in Table 3. In the second round, another two participants from environmental assessment firms and construction firms were invited, together with six participants from the first round. The reason for inviting the same participants in two rounds is because they would help to closely validate the framework derived from the first round. Each focus group lasted for three hours.

**Table 3.** Profiles of focus group participants.

| Participants | Organization | Designation | Round 1 | Round 2 |
|---|---|---|---|---|
| 1 | Government organization | Director | Yes | Yes |
| 2 | Government organization | Deputy director | Yes | Yes |
| 3 | Governmental organization | Officer | Yes | Yes |
| 4 | Environmental assessment firm | Director | Yes | Yes |
| 5 | Research institute for building science | Director | Yes | Yes |
| 6 | Construction group | Vice general manager | Yes | Yes |
| 7 | Academia | Associate professor | Yes | - |
| 8 | Environmental assessment firm | Engineer | - | Yes |
| 9 | Construction firm | Chief Executive Officer | - | Yes |
| Total | | | 7 | 8 |
| Duration | | | 3 h | 3 h |

Following the suggestion of Cyr [34], at the start of first focus group, participants were requested to: (1) comment on proposed definition (Table 2); (2) suggest specific indicators under each aspect and comment on the appropriateness of the five aspects; (3) discuss why the aspects and associated indicators are essential for interior design; and (4) comment on the socio-technical systems features.

### 4.2. Data Analysis

Data analysis was carried out following the rules of systematic combining approach [35]. Two types of unit of analysis were adopted, namely individual and interaction levels [34]. The individual level unit of analysis was used to triangulate the proposed indicators and socio-technical systems feature; the interactive unit of analysis was appropriate for exploring the indicator development and socio-technical systems features.

Themes (i.e., the five categories) and indicators identified from the literature review were verified from the focus groups, relying on labels that could represent similar descriptions across different participants. In the end, indicators of green interior design were identified. Emerged aspects were compared with the existing findings. Through going back and forth between framework, data sources and analysis, this step fulfilled the match between theory and data in systematic combining [35].

## 5. Results and Discussion

### 5.1. Importance of Green Interior Design and Socio-Technical Perspective

Participants agreed that developing indicators for assessing green interior design of residential buildings is of vital importance for green building delivery in China. They summarized three reasons. Firstly, the regulatory context of considering green building delivery as a national strategy in China has been widely accepted. Developing a standard for green interior design could well fit with the national policy vision. In addition, a green building paradigm shift requires concerted efforts from all parties throughout the building cycle. The interior design is an essential stage.

Secondly, in practice, there exists a considerable market demand for delivering green interior. Participants commented that end-users in China expressed enormous concern on the environmental pollution caused by the interior decoration. Thus, there is a strong demand for green interior design. However, the market still failed to fully meet the end-users' requirements.

Thirdly, participants acknowledged the importance of the systems approach in addressing green interior design. Existing standards and regulations prescribe some aspects of interior works, for example, the indoor air quality and energy efficiency. However, no tools are available for articulating green interior design in a systems approach.

### 5.2. Aspects of Green Interior Design

Participants agreed with the presentation of the five key aspects of green interior design and suggested specific indicators under each aspect (see Table 4).

**Table 4.** Indicators for green interior design for residential buildings.

| Aspects | Indicators | Description |
|---|---|---|
| Space performance | Efficient use of space (SP1) | • Properly-configured functions (SP11)<br>• Multiple functions-oriented (SP12) |
| | Adaptive use (SP2) | • Adaptive use and consideration of potential future needs (SP21)<br>• Space flexibility and adjustable when new requirements arise (SP22) |
| | Compatibility with architectural and MEP design (SP3) | • Compatibility with the architecture design (SP31)<br>• Compatibility with the MEP design and configuration (SP32) |

**Table 4.** *Cont.*

| Aspects | Indicators | Description |
| --- | --- | --- |
| Indoor environmental quality | Acoustic (IEQ1) | • Sealing of gaps around windows and doors, openings of high sound conduction (IEQ11)<br>• Use of materials for increasing sound absorption and insulation (IEQ12)<br>• Reduction of vibration noise arising from water flows in pipes (IEQ13) |
| | Lighting (IEQ2) | • Maximization of the use of natural daylight through openings without impairing the structure (IEQ21)<br>• Use of light-colored interiors that reflect light from windows or skylights (IEQ22)<br>• Use of high performance artificial lights and appropriate configuration (IEQ23)<br>• Avoid using materials with high surface reflectance (IEQ24) |
| | Thermal comfort (IEQ3) | • Increase air tightness through air barriers around windows and doors (IEQ31)<br>• Use of passive technologies, shading, reflection, absorption devices (IEQ32)<br>• Humidity control (IEQ33) |
| | Indoor air quality (IEQ4) | • Proper mechanical flushing of indoor pollutant sources (IEQ41)<br>• Air purification filters to prevent outdoor pollution (IEQ42)<br>• Improving air circulation (IEQ43)<br>• Prevent interior pollution migration (IEQ44)<br>• Selection of low-pollutant materials (IEQ45)<br>• Air quality monitoring systems (IEQ46)<br>• Removal of sources of water or moisture (IEQ47) |
| Energy efficiency | Envelope (EE1) | • Energy-saving windows and door treatments (EE11)<br>• Use of insulation in interior walls (EE12)<br>• Choice of appropriate shading devices (EE13) |
| | Lighting and daylight (EE2) | • Selection of high performance lighting and control devices (EE21)<br>• Selection of lighting supported by renewable energies (EE22)<br>• Implementation of a flexible lighting control systems with plug and play components such as wall controls, sensors, and dimming ballasts (EE23)<br>• Smart controls such as occupancy sensors and daylight dimming (EE24) |
| Water conservation | Water conservation (WC) | • Selection of water-efficient appliances, fixtures and fittings (WC1)<br>• Installation of devices to monitor water leakage (WC2)<br>• Reduction in the volumes of sewage (WC3)<br>• Water usage monitoring (WC4)<br>• Recycling of domestic wastewater (WC5) |
| Material-saving | Ease of maintenance (MS1) | • Selection of high performance decoration materials and products (MS11)<br>• Ease of maintenance finishes, materials and products (MS12) |
| | Environmental friendly materials (MS2) | • Use materials salvaged from waste (MS21)<br>• Selection of recyclable materials (MS22)<br>• Selection of localized materials (MS43) |
| | Buildability (MS3) | • Plan material use (MS31)<br>• Use of standard sizes of materials and products (MS32)<br>• The technical interface (MS33)<br>• Selection of industrial modules produced off-site (MS34) |
| | Life-cycle cost optimization (MS4) | • Consideration of different component service lives in order to achieve lowest life-cycle cost (MS41) |

#### 5.2.1. Space Performance (SP)

Participants indicated that the major concern of end-users is to maximize the interior space use. To enhance space performance, interior design should embrace occupants' behaviors and requirements. Three indicators were developed for guiding effective space utilization. These are proper space planning (SP1), adaptive use (SP2) and compatibility with the architecture and MEP design (SP3).

*Efficient use of space (SP1)*. The interior space should be properly configured (SP11), enabling a smooth activity flow. When planning the room spaces, multiple function purposes (SP12) should be taken into account, which would help to maximize space use for different functions. To achieve this, it is important to investigate the true requirements of users.

*Adaptive use (SP2)* indicates the consideration of future needs (SP21) and ensures space flexibility which presents adjustability when new requirements arise (SP22). Flexible designs aim to meet occupants' unforeseen requirements. Along with the rapid technological change as well as possible alteration of the function and workflows in the room, occupants may need more flexible and adaptable interiors to accommodate these unforeseen changes. One example is to maximize the user's control of the environment, for instance mobile furniture, or building utilities that are reconfigurable and expandable.

*Compatibility with the architecture and MEP design (SP3)*. As interior design is fully based on existing architectural design (SP31) and develops in tandem with the MEP design (SP32), it is important to ensure design elements are compatible with each other. The interior design needs to fully make use of the existing conditions imposed by the architectural design. The design team should be familiar with the base architecture in order to achieve unified scale and compatibility.

#### 5.2.2. Indoor Environmental Quality

The results show that achieving indoor environmental quality (IEQ) was manifested by acoustic (IEQ1), lighting (IEQ2), thermal comfort (IEQ3) and indoor air quality (IEQ4).

*Acoustic performance (IEQ1)*. Three strategies were proposed to enhance acoustic performance. These are sealing gaps around windows, doors and openings (IEQ11), selecting materials with high sound absorption and insulation (IEQ12) and reducing noise vibrations arising from water flows in pipes (IEQ13). Proper selection of the absorptive surfaces would help to eliminate noise disturbance.

*Lighting performance (IEQ2)*. To improve indoor lighting performance, passive strategies are helpful, such as maximizing the use of natural daylight through openings (IEQ21). This should also improve the daylight use efficiency through light-colored interiors that reflect light from windows or skylight (IEQ22). This is consistent with prior studies that conclude that internal reflectance of materials and finishes affect daylighting [36]. It might be necessary to avoid using materials of high surface reflectance (IEQ24). In addition, it is important to select high performance artificial lights and deploy appropriate configurations (IEQ23).

*Thermal comfort (IEQ3)*. To achieve thermal comfort, several strategies could be adopted, such as increasing air tightness through air barriers around windows and doors (IEQ31). It is also recommended to adopt various effective passive technologies, such as shadings, reflections and absorption devices (IEQ32). Lastly, humidity control technologies could be adopted (IEQ33) in certain period in Jiangsu Province.

*Indoor air quality (IEQ4)*. Participants commented that indoor air quality is the most serious concern in interior design and construction. The topmost strategy is to select low pollution materials (IEQ45), such as green labelling materials. Selecting low pollution materials will reduce the pollutants brought into the building. The second strategy is to improve air circulation (IEQ43), and adopt proper mechanical flushing of indoor pollutant sources (IEQ41). Quite often homes that are poorly ventilated will have high levels of biological contaminants arising from mould growth on damp surfaces. It is important to prevent interior pollution migration (IEQ44), for example preventing cooking smoke migrating from the chicken.

As haze is currently a serious concern in the north China, air purification filters to prevent outdoor pollution (IEQ42) and air quality monitoring systems (IEQ46) are considered to be a solution. The last strategy is to remove sources of water or moisture that encourage fungal growth (IEQ47). This needs to avoid external and internal leaks and adopt proper humidity control devices.

#### 5.2.3. Energy Efficiency (EE)

For interior design, energy efficiency could be achieved by improving envelope (EE1) and lighting and daylight (EE2). It is worth noting that the selection of air-conditioner and water heater is often decided by the end-users rather than the developer or the interior designers in China. Thus these two energy consumption sources were excluded.

*Improve envelope (EE1)*. It is common to adopt energy saving window and door treatments (EE11). Another strategy is to use high-insulation interior walls (EE12). Exterior insulation walls are excluded here because they are often included in the main structure construction work package rather than the interior work. It is also recommended to use internal shading devices (EE13).

*Lighting and daylight (EE2)*. High performance lighting and control devices (EE21) are suggested, to uptake lighting supported by renewable energies (EE22), and to implement a flexible lighting control system with plug and play components (e.g., wall controls, sensors, and dimming ballasts) (EE23). Various smart controls such as occupancy sensors and daylight dimming are preferable (EE24).

#### 5.2.4. Water Conservation (WC)

Through the focus group, five strategies were proposed to reduce water consumption. Two are of relevance to technological aspects, such as selecting water-efficient appliances, fixtures and fittings (WC1), and reducing the volumes of sewage (WC3). Two strategies are particular to monitoring water usage (WC4) and water leakage (WC2). The last strategy is to recycle domestic wasted water (WC5).

#### 5.2.5. Material-Saving

In order to save materials, four strategies would be helpful. These are use of materials with ease of maintenance (MS1), selection of environmentally-friendly materials (MS2), increase in buildability (MS3) and optimization of life-cycle cost (MS4).

*Ease of maintenance (MS1)*. To save materials, it is necessary to design for ease of maintenance. A first suggestion is to select materials that are of low maintenance (MS11). Using easily maintained finishes will be critical. Another useful method is to select high performance fittings and products (MS12). Extra consideration should be given to products used in heavy-use areas and specific functional areas.

*Environmentally-friendly materials (MS2)*. The environmentally-friendly materials indicate that there is life-cycle optimization, with respect to raw materials, manufacturing, transportation, installation, use and disposal or reuse. It is suggested to use materials salvaged from wastes (MS21) and use recyclable (MS22) and local materials (MS23). Using materials containing recycled content is also preferable. As the carbon labeling is currently on promotion in China, carbon labeling materials are suggested.

*Buildability (MS3)* is another important assessment criterion from the life-cycle perspective. In order to enhance buildability, it is helpful to use materials and products of standard sizes (MS32) and properly deal with the technical interface between products assembling (MS33). One important strategy is to promote industrial modules produced off-site (MS34). This would largely reduce the on-site waste. Lastly, it is better to draw a material use plan in advance (MS31). This would largely reduce waste and rework.

*Life-cycle costing (MS4)*. It is also recognized that short-term solutions, although less expensive, do not necessarily produce cost savings in the long run. Therefore, a life-cycle costing approach should be materialized in the green interior design. One important strategy is to systematically consider the life span of different components in order to optimize life-cycle cost (MS41). It is important to prepare a fine match of different finishes and products [37].

### 5.3. Socio-Technical Feature of Green Interior Design

Participants reached a consensus about the socio-technical systems feature of green interior design. These are two-layer system feature and embeddedness feature (see Figure 3).

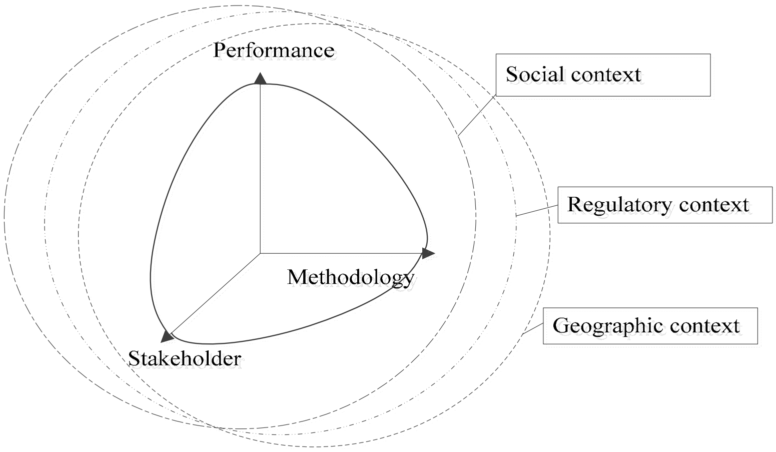


**Figure 3.** The socio-technical systems features of green interior design.

#### 5.3.1. Two-Layer Systems Features

Systems feature implies the necessity of examining interdependence among elements of the socio-technical systems. Three dimensions of green interior design, namely performance, methodology and stakeholders, are multifaceted and interwoven with each other. The former two present the technical aspect, whereas the latter has the feature of social systems. To achieve green interior design, it is important to properly deal with the interdependence of the socio-technical systems.

In the first layer, interdependence exists between performance, methodology and stakeholders. It is recognized that achieving green interior design is highly technical and requires technological advancement and various passive design solutions. However, mere reliance on the technologies is often found to be limited, which requires the complements from the social aspect. The social aspects refers to the collective endeavors of the key stakeholders. Participants commented that parties' interests are often not well aligned. This would further impede the technology adoption and implementation in green interior design and construction.

In the second layer, interdependence exists within each dimension. With regards to the temporal dimension, the green design solutions will influence the buildability and maintenance in the later stages. Feedbacks collected from the construction and maintenance will inform the design decision making. Within the performance dimension, it is found that independence exists among five aspects. For example, materials show multiple functions (e.g., buildability, maintenance, life-cycle cost and environmental impacts), which will influence the five aspects of interior design to a varying extent. In addition, some finishes may provide satisfactory durability, yet have limitations in the ease of maintenance. This leads to conflicts in the durability and level of maintenance.

#### 5.3.2. Embeddedness Feature of the Socio-Technical Systems

Embeddedness, considering green interior design as an open system, is another feature of the socio-technical systems of green interior design. Embeddedness feature could be interpreted in relation to the social, regulatory and geographic context.

(1) Social context of green interior design

Firstly, the interior design reflects the needs of the occupants who have inherent habit and preferences. Technical specifications thus need to be customized to the occupants' requirements. This is consistent with Li & Yao [3] who argued that it is important to understand building users' demands, expectations and behavior/lifestyle and this requires socio-technical knowledge. Thus, designers' skills for understanding the needs of end-users are desirable. Interior designers' behavioral intentions associated with the green interior design is determined by their attitude, subjective norms, and perceived behavioral control [38]. This indicates that it is hard to isolate the technical interior design solutions from the social settings.

In addition, persuading the client to accept green ideas is often difficult. This is consistent with the results from the survey of green building technology adoption in China which found that stakeholders' reluctance to use was the largest barrier [12]. High upfront investment and inertia might be possible reasons [39]. Thus, it is necessary to inform end-users on the long term value of green interior design.

Secondly, the green interior design practices are socially contextualized in the project setting. Although it is recognized that designer's knowledge of green interior design is of great importance to the implementation, they may not always put it into practice [40]. Project scheduling pressure might be one obstacle.

Thirdly, apart from designers and end-users, achieving green interior design requires the participation of other parties. For instance, interior design requires coordination with structural, mechanical, and electrical engineers. This entails an integrated approach. Key to achieving an integrated approach is open communication and early involvement [41,42]. These two strategies would help to avoid common errors, mistakes and rework.

Lastly, it is essential to investigate the cultural beliefs and customs. Many nationalities and religions attach significance to certain colors, patterns and materials. For instance, most Western cultures consider black the color of mourning. Eastern/Oriental cultures associate white with mourning.

(2) Regulatory context of green interior design

The articulation of the socio-technical systems of green interior design varies from one context to another due to regulatory differences. The regulatory context is manifested through two aspects. Firstly, green interior design must comply with current regulations. Secondly, it is recognized that the achieving green interior design involves co-option of various standards. For example, in the US, green interior design may be of relevance to selecting ENERGY STAR appliances and low-flow plumbing fixtures [23]. In Singapore, adoption of water efficient fittings covered under the Water Efficiency Labelling Scheme [22] is encouraged.

Participants expressed their concern of regulatory deficiencies for motivating practitioners to adopt green interior design in China. They compared the achievement of green interior works to green building in terms of political impacts. They commented that practitioners now have great motivation to invest in green building solutions because the ESGB exists for legitimating such behaviors and the government also provides momentary incentives. However, for the green interior works, no such policies could be used to recognize the green efforts. This could deter adoption and diffusion.

(3) Geographic context of green interior design

Weather conditions are one facet of the geographic context. China has five climate zones. These are Severe Cold, Cold, Hot Summer and Cold Winter, Hot Summer and Warm Winter, and Mild Zone [3]. This study examined interior design in the Jiangsu Province in the middle of China where the weather conditions is Hot Summer and Cold Winter. Purification filters would be suggested in the green interior because the outdoor air quality suffers due to severe haze pollution. But, in the South China, there may be high levels of humidity. This would require use of an air dryer.

Local climatic conditions are important criterion when selecting materials and finishes. Special maintenance requirements would be required for heavy snow or rain, very arid or humid climates, unusual soil conditions and sand and high level of sun exposure.

## 6. Conclusions

This study aimed to develop indicators for and explore the socio-technical systems of green interior design of residential buildings in China, grounded in the socio-technical systems approach. The study was carried out through a combination of a critical literature review and two focus group studies.

One important result is the conceptual framework for defining the boundaries of green interior design for residential buildings. Consistent with prior studies [33], it deals with three dimensions, namely performance, methodology and stakeholders. The performance dimension comprises space performance, indoor environmental quality, energy efficiency, water conservation and material saving. The methodology dimension deals with the temporal (i.e., work and material flow) and spatial dimensions. The stakeholder dimension refers to the actors who have a role in achieving green interior design. This framework provides a system understanding of the boundary of green interior design for new residential buildings.

Another finding is that this study verified proposed five aspects of performance (i.e., space performance, indoor environmental quality, energy efficiency, water conservation and material saving, see Table 3) and developed indicators for each aspect. The systems framework was verified to be valid.

The last finding is the identification of the socio-technical systems features of green interior design. Although prior studies argued for a socio-technical systems approach in green building delivery [3], this is rarely examined in a systems approach. Distinct from prior systems approaches that examine indicators in isolation, this systems approach focuses on three dimensions (e.g., performance, methodology and value) and emphasizes the interdependence between the systems elements. Interdependence exists both within and across each aspect. Crucial to the green interior design is their feature of being embedded into the social, geographic and regulatory context.

Taking interior design of new residential buildings in China as the empirical setting, this study contributes to the knowledge by presenting two features of socio-technical systems approach, namely the interdependence and embeddedness. The practical implication is that practitioners and policy makers should recognize the socio-technical systems feature of the green interior and take the one-fits-all green strategies with caution. This is because these strategies often take the end-users to be passive recipients, whereas the socio-technical system features argue for active and collective participation of the key stakeholders. In addition, practitioners and policy makers could customize the indicators developed in this study to their specific projects with considerations of the social, regulatory and geographic contexts.

This study only examined the green interior design in China, grounded in the socio-technical systems approach. To reinforce the socio-technical features of green interior design, comparative studies among different nations are recommended. Additional research design (e.g., case studies, interview, questionnaire survey) could be employed to further validate the key findings.

Another recommendation for future studies is to adopt larger scale surveys to further gauge the extent to which green interior design has been implemented in various geographic contexts. Despite the development of indicators for assessing green interior design, parameters for each indicator are worth further in-depth examination. For example, although internal shading devices at windows (EE13) are recommended to increase energy efficiency, the specific parameters of the shading devices are still not known. Further studies in this regard are thus recommended.

**Supplementary Materials:** The following are available online at www.mdpi.com/2071-1050/9/1/33/s1, Annex 1: Code and regulations of relevance to green interior design for residential building at the national and industrial level (1), Annex 2: Code and regulations of relevance to green interior design for residential building at the national and industrial level (2), Annex 3: Code and regulations of relevance to green interior design for residential building in Jiangsu province (1), Annex 4: Code and regulations of relevance to green interior design for residential building in Jiangsu province (2).

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