Article

Comprehensive Evaluation of Functional Diversity of Urban Commercial Complexes Based on Dissipative Structure Theory and Synergy Theory: A Case of SM City Plaza in Xiamen, China

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Abstract: Urban commercial complex is an architectural form formed in the high-density urban building environment based on the diversified concentration of human consumption behavior and the composite utilization of space. It can effectively cope with the problem of tight land resources and insufficient development capacity in urban centers and promote sustainable urban development. Additionally, the diversity of functions is the key to ensure its healthy operation. Based on the homogenization phenomenon of commercial complex development in some big cities in China in recent years, this study applies dissipative structure theory and synergistic effect theory to the study of functional diversity system of urban commercial complexes, and proposes a Shannon–Weiner biodiversity index model and calculation indexes based on the functional diversity measurement model. At the same time, correlation analysis and comparative analysis were conducted between the measurement results of spatial vitality and the calculation results of the diversity model to verify the scientificity and rationality of the proposed model. Finally, the SM City Plaza commercial complex in Xiamen was selected as a representative research object to measure the functional diversity of its weekdays and holidays and the coupling relationship between functional diversity and changes in spatial vitality. The calculation results show that although the comprehensive index of functional diversity of SM commercial complex is in a dynamic state of change, the overall level is high. The reasonable proportion of the six functional formats shows a high level of diversity, which effectively promotes the generation of commercial vitality and enhances the comprehensive benefits of the commercial complex; the change trends of functional diversity in time and space dimensions are in line with the actual situation, indicating that the proposed model has certain scientific and application values. On the basis of the completed empirical work, the scope of application and limitations of the calculation model and evaluation method, as well as the optimization of the index system are further pointed out.

Keywords: high-density built environment; urban commercial complex; biodiversity; dissipative structure; functional diversity; quantitative research; evaluation methodology

1. Introduction

On a global scale, the high-density concentration of population in large cities and megalopolises has been a common characteristic of Asian cities since the beginning of the 21st century [1]. Compared with cities in European and North American countries, some large cities in China and other Asian countries are distinctly characterized by a more compact layout and higher building density [2]. The high-density built environment has become one of the prominent spatial characteristics of urban construction and development in China. In some large cities, after stock renewal, especially in the central area, resources are highly concentrated under the comprehensive influence of land prices, cost benefit and other factors. Building aggregation, spatial environment and complex behavioral activities are interlaced to form a more complex urban system (Figure 1). This construction mode is
considered to be a significant approach to effectively promote the sustainable and healthy development of cities, mitigate traffic congestion and improve quality of life [3].

![Diagram](image-url)

**Figure 1.** The horizontal extension of city functions is shifted to vertical extension (source: self-drawn).

Against this development background, urban buildings expand themselves into the air or underground. They form complex space in a three-dimensional way, adapt to the high-density environment in an interactive symbiotic state [4], seek space compensation to improve the environmental quality, and finally promote the coordinated symbiosis between buildings and cities [5]. It is difficult for buildings with a single function to adapt to the development requirements, and buildings with multiple functions are required to solve the contradiction between land scarcity and social needs. This realistic demand for urban three-dimensional development and the intensive utilization of land resources has promoted the emergence and development of urban complexes.

As one of the relatively dynamic factors in cities, commerce has become a major part of urban commercial complexes. Although there are long-standing controversies over commercial complexes due to their high investment, high risk and uncontrolled expansion, which have a considerably negative impact on urban morphology and the environment, the compact, three-dimensional development model of cities represented by commercial complexes is currently one of the main ideological trends in urban development. The expansion of commercial complexes is more common in areas with a high-density built environment, such as Japan and Hong Kong. This expansion is a historical evolution of modern architecture based on the local social context and a continuation of the integration of buildings and cities. It also provides methods to solve the contradictions and problems in the urbanization process in China, to a certain extent.

The development of urban commercial complexes has often closely been related to urban due to their highly mixed functions and huge volume. This feature has been elucidated by many scholars in previous studies. Neil Wrigley et al. expounded on the vitality of commercial complexes and their role in the urban economic and industrial chain regarding its diversity and consolidation; they also comprehensively reviewed their ability to resist economic shocks [6]. In addition, they proposed that the role of commercial complexes can be fulfilled by enhancing the diversity of their functions, and highlighting their connection with surrounding commercial complexes. Rajakallio et al. maintained that the urban commercial complex is not an isolated consumption space, and has an extremely complicated relationship with the supply and demand of the city, which can be explored from the perspective of the whole city [7]. Yang et al. investigated the development of and changes in different functions in Chicago. They further elaborated on the coexistence and competition of different commercial functions in urban space from the perspective of the heterogeneity of urban agglomeration economy. Their findings indicated that the urban complexes with a higher systematization and mixed-use degree had higher development stability [8].
In most studies, the design of commercial complexes is explored from the commercial operation planning, internal format ratio, architectural space design, technical specification discussion, transportation system construction, “paradise + business” mode and other perspectives [9–11]. There are also some studies on the relationship between flow line, behavior and spatial performance from the perspective of consumers [12–14]. The focus of most existing studies with respect to commercial complexes is placed on space design behavior research and operational planning. However, there have been relatively few efforts to explore the distribution ratio of their internal functional components, coupling relationship and the functional diversity of comprehensive evaluation and quantitative calculation.

Diversity is one of the basic concepts of ecology, and biodiversity is the focus of these studies. As in urban development, diversity plays a significant role in the proper operation and sustainable development of cities. In the field of architecture and planning, urban spatial diversity is the focus of research. The correlation between diversity and urban vitality has been interpreted by abundant scholars in numerous studies [15–17]. At present, most studies on diversity at home and abroad are concentrated in the ecological field and urban field. Although there are relatively fewer studies in the field of architecture. Jing, Zhiqiang and other scholars systematically demonstrated the correlation between biodiversity and urban spatial system; they conducted an investigation into the Century Avenue in Shanghai Pudong New Area in an attempt to discuss the relationship between biodiversity and the built environment from the meso–micro perspective and concluded that the high-density built environment was the main factor affecting biodiversity [18,19]. Other scholars described the impacts of land use, climatic factors, urban landscape pattern, urban economic activities and social activities on urban biodiversity.

Moreover, the focus of quantitative studies with respect to diversity is placed on the index calculation and the exploration of evaluation and comparison methods. Index calculation is commonly performed based on a single mathematical model, while evaluation and comparison methods are mostly related to vitality measurement. Based on the evaluation criteria of diversity, the mixed-use degree of urban land can be calculated. Wen, Yaoqiu and other scholars conducted an exploration of the main urban area of Guangzhou City. In their study, the business district was the basic unit, and the POI data and Luoji No.1 nightlight data were integrated as the basic data needed to measure urban vitality. The Hill number diversity index was adopted to describe the correlation between urban vitality and diversity calculation models such as the Shannon–Wiener index and Simpson’s diversity index from a multi-dimensional perspective [20]. Luo et al. adopted information entropy to measure the mixing of activity types, in an attempt to reflect the diversity of urban public spatial vitality [21]. Chao, Shaowei and other scholars employed the theory of information entropy and the nonlinear fitting method based on land remote-sensing monitoring data and took the Shannon–Weiner index model as a calculation model to explore the land-use degree and functional land proportion in Guangdong Province [22]. Long et al. measured the influence of the mixed-use degree of block functions on block vitality by constructing a quantitative evaluation index system of block vitality and using the Shannon entropy index calculation method [23]. Cervero and Kockelman proposed the dissimilarity index in 1997, which can be employed to reflect the mixed-use degree of the grid by measuring the similarity of land function distribution between a single grid and eight surrounding grids after the rasterization of land. Compared with the calculation method related to Shannon entropy, the dissimilarity index can be employed to measure the mixed-use degree of land on a precise scale, which highlights the difference in the land function combination [24]. Moreover, the Herfindahl–Hirschman Index, Balance Index (BAL), Atkinson Index (ATK), Cluster Index (CLST) Gini Index and Mixed-Use Index have been adopted as diversity calculation models in related studies.

From the perspective of the structural system and components of an urban commercial complex, this can be regarded as a small ecosystem under a high-density built environment, which is self-sufficient to a certain extent and also exchanges materials and transmits information with the surrounding urban environment. In urban commercial complexes,
the functional format is an important system component that determines the operational efficiency and production efficiency of complexes. At present, there are still few studies on the calculation and evaluation methods regarding the diversity of complexes. The focus of most existing calculation models is on the calculation of the mixed-use degree of urban land and block function on a macro-scale. In addition, scientific and reasonable demonstration processes that apply these models to the architectural design on a micro-scale are lacking. Meanwhile, there is no consensus on an approach to evaluate and compare the obtained diversity index in the existing studies. A horizontal comparison is often made between multiple cases, the diversity is directly related to the vitality, and, subsequently, the vitality is measured through thermodynamic analysis, behavioral research or big data sample analysis.

In summary, the main contributions of this paper are presented as follows:

(1) The research perspective is broadened. The focus of most existing studies is placed on biodiversity, while there are few efforts to explore the diversity of urban space, especially from the perspective of architectural design. In this paper, the similarities and differences between urban complexes and urban space are explored based on biodiversity from the perspectives of development mode, research dimension, order direction and system composition. Further, the synergistic mechanism and characteristic function of urban complex internal functional diversity are deduced from urban spatial diversity by the synergy between biodiversity and urban diversity using the complex system theory. The findings of this study supplement the deficiency of related investigations on a micro-scale.

(2) The dissipative characteristics of urban commercial complexes are elucidated. In this paper, the dissipative structure characteristics of urban complexes are elucidated on the basis of previous studies and theoretical derivation. Additionally, three important subsystems (behavior, spatial environment, and functional constituent) of the functional diversity system of urban complexes are proposed, based on the dynamic mechanism, system composition and spatial environment of biodiversity. Moreover, the dissipative characteristics of urban commercial complexes and the definition of the open system and the far-from-equilibrium system are also interpreted. Subsequently, the construction process of evaluation models related to functional diversity is obtained based on information entropy.

(3) The evaluation model, evaluation criteria and test method of functional diversity of urban commercial complexes are proposed in this paper. As revealed from the overview of the above-mentioned literature, diversity is expressed by “heterogeneity” and “mixed-use degree” in the calculation of most existing models at the quantitative level. However, the interaction before different calculation units and the difference of functions caused by different functional categories are ignored during this expression. The calculation results are simple and often limited to horizontal comparison at the same level. In this study, a functional diversity evaluation model is proposed by combining a literature analysis and logical reasoning on the basis of the correlation between biodiversity and urban complex diversity, information entropy theory and the Shannon–Wiener diversity index model.

Meanwhile, research methods in the field of social investigation are introduced based on the influence mechanism of diversity on urban vitality. The verification methods of functional diversity evaluation models of commercial complexes are preliminarily established to verify the accuracy of the functional diversity evaluation model of commercial complexes quantified by small sampling data. Moreover, the correlation between the calculated functional diversity and the actual complex viability characterization is tested using SPSS statistical analysis to verify the effectiveness of the corresponding evaluation model. These findings provide a reference for the vitality measurement methods at the architectural design level.
2. Theoretical Basis for the Study of Functional Diversity System of Urban Commercial Complexes

2.1. Theoretical Framework

The urban commercial complex is selected as the research object to explore the connotation and characteristics of its diversity, namely, an investigation, in essence, into the diversity phenomenon in compact space. In the expansion space, high density is the principle of generating diversity, while a space with an extremely high density is the premise for the generation of diversity, high systematization is the new principle of generating new diversity. Therefore, studies into the diversity under restriction is also to explore complex systematic diversity.

The theoretical logical framework of the study is as follows:

First, based on the previous discussion, the changes in the connotation of diversity in the process of resource aggregation in urban centers are systematically summarized. The relationship between biosystems and urban spatial diversity has been argued by numerous studies [18,19]. Therefore, the study intends to consider the urban space as a mediator to link its biological system with the system of urban commercial complexes. Secondly, we cut from the theoretical source of diversity-biodiversity. Since the dissipative structure of biodiversity has been argued by scholars in related fields, the study also argues the characteristics of the dissipative structure of the functional diversity system of urban commercial complexes with the help of complex system theory as a basis for establishing a bridge between biodiversity and urban commercial complex diversity research.

Secondly, the academic grafting model of urban spatial diversity is studied, and the theoretical framework from biodiversity to functional diversity of urban commercial complexes is established based on the theory of synergism, and the synergistic mechanism and external characteristics of functional business forms are out, which is used as the basis for model construction and evaluation strategy in the process of comprehensive evaluation of functional diversity in the later paper. The natural synergetics of Hermann Haken provide a systematic research method with decomposition and construction, which led to the composition of system structure, from the characteristics of components to the writing relationship of each component. Based on one or more mathematical theories, the structures of the material world and the spiritual world are brought into a unified research framework [25]. The theory of synergetics has established a bridge between natural law, biological structure, sociology and scientific and technological research. It has become the theoretical support for the transformation from biodiversity research to the spatial diversity research of urban complexes.

There are various systems in the objective world, including social or natural systems, living or inanimate systems, macroscopic or microscopic systems, etc. However, there are profound similarities among systems that differ in appearance. The theory of synergetics was formed and developed on the basis of the common law used to explore the transformation mechanism of objects from an old structure to a new structure. This is mainly characterized by establishing a set of mathematical models and treatment schemes for phenomena, from disorder to order, using analogy. These are applied to a wide range of fields. Based on the principle that “a lot of cooperation subsystems are governed by the same principle and have nothing to do with the characteristics of the subsystem”, related laws could be explored by investigating the similarities in interdisciplinary fields. The overall logical framework is shown in the Figure 2.

2.2. From Urban Space Diversity to Urban Complex Diversity Diversity Systems

What distinguishes the urban complex from the general urban space is its three-dimensional, high-density compactness, which has a new characteristic of compactness and diversity. Diversity is, on the one hand, a characteristic given by the compact spatial environment and, on the other hand, a principle that architecture needs to accept in the compact spatial model. For the study of diversity of urban complex, if we study only diversity without compactness, we will stay in typology; if we study only compactness
without diversity, we will have only external development direction but lack internal operation method.

![Figure 2. Fitting diagram of the mechanism of biological diversity and the diversity of urban commercial complexes (source: self-drawn).](image)

There are many similarities and differences between the diversity of internal space and urban space in urban complexes.

1. **Similarities**

   The research object of urban spatial diversity mainly includes the block with dense crowd activities, in line with the conclusion drawn by Jane Jacobs in the process of urban investigation [26]. Blocks assume all urban functions and are divided by the road system. The function of urban complexes depends on the retail shop space, namely, the commercial function, which is divided and connected by pedestrian traffic. Generally speaking, both are important public spaces for the transportation and daily life of citizens.

2. **Differences**

   The three-dimensional, high-density, compact and diverse features contribute distinguish this from general urban space. For urban complexes, the highlight is the vertical and three-dimensional transportation system, while urban block space is horizontally expanded. Urban complexes are developed in a highly limited space, while urban blocks are usually developed in expanding space and in a self-organized manner. In urban complexes, density creation under limited external space is pursued, and blocks are formed in a horizontal expanding mode.

   In functional composition, retail shops along the block are independent, and are usually transferred or leased by the owners. Each commercial spatial unit is attached to a single building. All units are linearly arranged on both sides of the block, unrelated to each other, and each part can be independently divided. When investigating the diversity of this block, only the diversity of types, namely, the different kinds of shops in the block, would be explored, instead of the influence of different shops on the block. The functional orientation of urban blocks has generally been determined in the upper planning. For example, in terms of commercial pedestrian blocks, as long as the basic conditions of commerce are met, the significance of the block cannot be reflected by proportion, and it cannot be successfully deployed in a unified way. Therefore, it can be said that the diversity of streets cannot be compared to the orderliness of urban complexes due to their spatial type and the way they are generated. Meanwhile, the exploration of type and order is key, and comprises the peculiarity of this study into the diversity of urban complexes (Table 1).
Table 1. Comparative Analysis of Urban Complexes and Urban Spaces.

| Diversity of Urban Commercial Complexes | Urban Diversity |
|----------------------------------------|-----------------|
| Model                                  | High-Density Mode| Expanding Model |
| Dimension                              | Vertical        | Horizontal      |
| Direction                              | Research on type and order | Research on type |
| Objects                                | Buildings and public space under the influence of commercial functions | Blocks and public space |

2.3. Dissipative Structure of the Functional Diversity of Urban Commercial Complexes

As maintained by Ludwig von Bertalanffy, the system can be defined as a complex, including several interacting elements. There are three universal and essential features in the system. First, there is integrity in the system; second, the system is composed of some interactive and interdependent elements; third, the system is affected and interfered by the environment, and interacts with the environment [27].

In this paper, the common relationship between urban complexes and biological systems is explored by introducing the concept of thermodynamics—“entropy value” change as the foundation on the basis of the dissipative structure theory—an important achievement of complex system theory. The theory of synergetics is further introduced as the basis of derivation from biological units to commercial functions.

(1) Dissipative Structure Theory

The dissipative structure theory is a self-organization theory regarding non-equilibrium systems, proposed by Ilya Prigogine [28]. The theoretical content can be summarized as follows. A nonlinear and open system far from equilibrium state constantly exchanges matter and energy with the outside world. When the change in a certain parameter in the system reaches a certain threshold, the self-organization phenomenon can be generated through the actions of internal fluctuation and mutation, which makes the system spontaneously transform from its original chaotic state to an ordered state in time, space or function. This new ordered structure in the non-equilibrium state is the dissipative structure [29].

The dissipative structure is established based on the premise that the research system possesses openness and non-equilibrium. When the urban commercial complex possesses this feature, it can develop and evolve in the form of self-organization. The dissipative structure theory used to describe system evolution can be expressed as follows

\[ dS = deS + diS \]

where:
- \( dS \) represents the total entropy change of the system;
- \( deS \) represents the entropy exchange between the system and the environment;
- \( diS \) represents the entropy generated by the system.

As per the second law of thermodynamics, the entropy of an isolated system will increase with time. When the entropy reaches the maximum, the system will be in the most disordered equilibrium state. Under open conditions, the entropy generated in the system is always at a non-negative value, namely, \( diS \geq 0 \). If the entropy exchange between the system and the environment is less than 0 (\( deS < 0 \)) and \( |deS| > diS \), \( dS < 0 \) can be obtained; when the system is fully open and enough negative entropy is introduced from the outside to reduce the total entropy, the order degree of the system increases and an ordered structure is formed through the self-organization process.

The development of urban construction is phased from the initial incremental expansion to stock renewal. The changes in various elements in the city also show obvious phased characteristics, and commercial complexes are generally located in the city center, with complex surrounding elements.

Under the catalyst of multiple factors such as the transformation of urban development modes, the online consumption mode, improvements in surrounding service facilities and
upgrades to urban residents’ demand level, the internal functionalities of urban commercial complexes are constantly reorganized and optimized, and, at the same time, the means of space utilization also change with changes in consumption demand. \( d_s \) refers to the entropy value generated by the internal commercial operation, event holding, operation and maintenance management, and consumer leisure activities of the complex; \( d_i \) refers to the entropy value generated by the interaction process between the complex and the outside world during construction and operation, including the entropy value changes generated by the activities of crowd access, goods transportation, and information exchange, etc. \( d_s \) and \( d_i \) are in a state of dynamic change, which means that the total entropy value of the system is in a non-equilibrium state; therefore, it is considered that the urban commercial complex has obvious characteristics of a dissipative structure system.

(2) Synergetics Theory

The theory of synergetics of Hermann Haken, a scientist from the Federal Republic of Germany, provides a dynamic methodology for exploring nonlinear complex systems. As per the theory of synergetics, there is a competitive and cooperative relationship between different systems in the whole environment. The phenomenon of self-organization, order or structural mutation of the system originates from the effective cooperation among subsystems within the system. In an open system, the input of matter, energy and information in the environment could stimulate the internal subsystems to be in a state of fluctuation. Further, the input could promote the subsystems to constantly adjust themselves according to changes in the environment and constantly drive, compete with and restrict each other, so that the system is in the optimal cooperative state. The theory of synergetics reflects the development of dissipative structure theory. As revealed in this theory, the key to system self-organization lies in the internal system, namely, the synergetic phenomenon caused by the interaction and coupling of subsystems in the system under certain conditions.

(3) Structural Characteristics of Urban commercial Complex functional Diversity

As mentioned above, the biodiversity includes three levels, namely, gene diversity, species diversity and ecosystem diversity. Based on the three levels of biodiversity, three levels of urban commercial complex functional diversity are established, including gene element (a dynamic mechanism), image element (system composition) and peripheral element (space environment). They are summarized as three subsystems in the comprehensive system of diversity, including behavior activity, functional configuration and the spatial environment, which work together to form diversity (Figure 3).

- Dissipative Characteristics of Urban commercial Complexes

The composition of urban complex diversity goes through a continuous dynamic process, and the whole system forms a complete life-cycle of inception-growth-maturity. Internal and external interactions could destroy the original state to enter a higher level of development. It should also be noted that there may be conflicts between multiple subsystems in the diversity system (e.g., a mismatch between the internal space and function of the complex would induce decreases in benefits and space utilization rate). These conflicts would prevent the system from maintaining a balanced state and develop into a more orderly structure in the process of unbalanced and dynamic interaction.

- Far-from-equilibrium System

The diversity system of urban commercial complexes is composed of many subsystems, which have different development modes and levels. When the urban external environment interacts with the diversity system inside the urban complex, the equilibrium state breaks. Meanwhile, internal subsystems begin to form and fulfill their roles. However, when the function of each subsystem is less than that of the total functional diversity system, it enters the nonlinear region under a non-equilibrium state.
Figure 3. Dissipative structure of the functional diversity system of urban commercial complexes (source: self-drawn).

- Nonlinear System

In the process of system evolution, especially after the intervention of time dimension factors, the spatial environment, functional constituents and behavior are constantly changing, which causes random “fluctuations”. When the interaction between them reaches a certain degree, mutations begin to occur in the system. By reorganizing its resources and elements, the goal of self-evolution can be realized. Subsequently, new “fluctuations” are generated to move the system from the previous state to a more orderly state and enter a new dissipative structure.

Overall, urban complexes have the characteristics of non-equilibrium, openness, non-linearity and fluctuation, which contribute to the formation of a dissipative structure. Therefore, dissipative structure theory can be applied to the study of urban complexes. The functional constituent, spatial composition and consumption behavior jointly affect the entropy changes and formation of the system’s dissipative structure [30].

2.4. Synergistic Mechanism, External features of Functional Diversity of Urban Commercial Complexes

2.4.1. External Features of Functional Diversity

By applying synergetic theory to the relationship between biological groups, the relationships between species can be divided into three: symbiotic relationship, competitive relationship and predatory relationship. The symbiotic relationship includes mutually beneficial symbiosis and parasitic relationships [31].

As a compact cluster of urban functions, there are similar relationships among functional species in urban commercial complexes, including multiple complexes based on symbiotic relationships, hierarchical juxtapositions based on parasitic relationships, and diverse enhancements based on competitive relationships. Symbiotic relationships also include functional compounding and tenure compounding.

(1) Symbiotic relationship—multi-recombination

In biology, symbiosis refers to a relationship in which two biological organisms live together to benefit each other. This is a highly developed interrelationship between biological
In biology, symbiosis refers to a relationship in which two organisms can coexist and benefit each other. This relationship can be classified into various categories based on the nature of interactions between the organisms, such as mutualistic, commensalistic, and parasitic relationships.

Three types of symbiotic relationships are commonly recognized in the literature, which can also be applied to the context of urban spaces and commercial complexes:

① Mutualistic relationship—superposition

In urban commercial complexes, different city functions match diverse audiences [33]. After function recombination, in addition to the services for a specific group of people, each function provides added value to the target group of another function. For example, in the integration of high-end commerce and art exhibitions that has occurred in some complexes in recent years, customers of high-end commerce are unitary stable groups with a high purchase capacity. Regarding target groups, high-end commerce is similar to art exhibitions, as both are characterized by a low density of customers and large average use space. The space of high-end commerce serves as a background for art exhibitions. Therefore, the combination of art exhibition and luxury sales spaces will attract more customers and visitors, and increase the use rate of the commercial space in another way.

② Competitive relationship—multi-enhancement

Another possible circumstance is that there are two managers within the same space patch. After function recombination, in addition to the services for a specific group of people, each function provides added value to the target group of another function. For example, a coffee shop represents such a mode. At present, the joint operation of a bookstore and a coffee shop represents such a mode.

③ Attribute recombination

In urban commercial complexes, different city functions match diverse audiences [33]. By changing the attribute of the space—that is, a singular manager is changed to multiple managers—the attribute of the space will form new functional individuals. In a complex, each specific function space has a respective manager and operator. If all function spaces seek independent development based on the needs of respective managers, then there will be “diversified” types, which cannot be associated in the system (Figure 4a). Another possible circumstance is that there are two managers within the same space patch, but each manager takes charge of their respective part. In this case, there may be disputes over space style, space distribution and operating mode, etc. (Figure 4b). An eclectic strategy is that the managers take charge of their respective service spaces while sharing the public space. Under the premise of sharing space, only the addition of sharing attributes (or the joint development and management) will fuse the two different types of function into a specific space (Figure 4c). At present, the joint operation of a bookstore and a coffee shop represents such a mode.

Figure 4. Schematic diagram of space attribution: (a) independent space with its own development mode; (b) the same space with different attributes; (c) shared space with shared attributes (source: self-drawn).

(2) Competitive relationship—multi-enhancement

In ecology, the relationship between biological diversity and ecosystem function has always received a large amount of attention. Increased diversity does not necessarily indicate enhanced ecosystem functions as the ultimate result is still related to interactions among biological organisms. When each species occupies a different ecological niche...
and uses different resources, the ecosystem’s productivity will improve; however, if the ecological niches of species within a community are close or overlapped, some energy will be exhausted due to the competition for resources or space, and the increased diversity will lead to reduced ecosystem function [34].

In an urban commercial complex, people are the resources for which each function competes, and people’s demands correspond to the different ecological niches. Competitive relationships mainly occur between similar functions. For instance, the functional patches of catering functions will compete for resources to some extent. However, there is a symbiotic relationship between catering and other functions, as the clustering of catering functions will often attract more consumers.

2.4.2. Synergistic Mechanisms for Functional Diversity

If we apply the principle of biodiversity in nature and the theory of synergy to the study of functional diversity of commercial complexes, we can establish the concept of “synergy of functional systems of multiple commercial complexes”. The synergy is characterized by the interrelationship between diversity and diversity, which avoids the opposition, segregation and conflict between singularities. As mentioned above, the research on the diversity of commercial complexes focuses on its functional diversity, spatial diversity and temporal diversity, and the synergistic mechanism of its functional diversity is closely related to and interacts with function, space and time.

(1) Synergy between functions

In the commercial complex, different functions match different audiences, and the synergy between system functions and other functions not only serves a specific group of people, but also provides added value to the target group of another function. The organic integration of the two makes it fit the project’s positioning and theme.

Take the synergy between high-end commercial and exhibition functions in a commercial complex as an example. Due to the positioning and relatively low level of tenants in a commercial complex, it generally has the characteristics of a larger average customer flow, smaller area per capita, lower space grade positioning and lower purchasing power per capita, while the relatively high-end commercial complex, due to its positioning and relatively high level of tenants, has a larger area per capita, higher space quality, and the audience it serves has a relatively high level of purchasing power. These commercial complexes aim to obtain the corresponding value through the creation of high quality.

The combination of a high-end commercial function mode and exhibition function mode is essentially a manifestation of the synergy of function and function under the premise of satisfying their corresponding operation concepts. Specifically, there is a certain complementarity and synergy between the two in terms of their service audience groups: the service audience of a high-end commercial function mode points towards a specific group, while the service audience of the exhibition function mode (especially free exhibitions) has a wider range of service audience groups. Both of them have the requirements of a lower average customer flow density and large use area per capita in terms of space usage attributes. The high-end commercial mode matches the corresponding high-quality commercial space, which has a certain promotional effect on the creation of space atmosphere and exhibits in the exhibition function mode; the implantation of an exhibition function can attract a higher flow of people and improve the usage rate of its commercial space. It is an organic spatial compounding of two different functions with the same per-capita use-area requirement, effectively integrating the gathering of a short-period human flow and long-term stable commercial activities, and enhancing the spatial vitality of the commercial complex under high-frequency stimulation.

(2) Synergy of function and time

The time at which people gather in a commercial complex is always in the process of dynamic change, and the length of time for which people gather also reflects the synergy between the system function and the time of the commercial complex. For example, during
business hours in a commercial complex, the gathering of people and their consumption behavior changes continuously in the morning, lunch and evening, demonstrating the dynamic system function and time synergy characteristics. Over the same period of time, different floor locations, functional combinations and spatial combinations in urban complexes also vary in terms of commercial vitality.

(3) Synergy of function and space

① Grade Allocation
In a study on the influence of functional types on the usage status of commercial space in commercial complexes, scholars point out that department stores and specialty stores have a stronger influence on the flow of people, and can obtain a higher average usage status. Retail shopping and restaurants rank second, and entertainment and leisure and services have a smaller average usage status. The ratio of the influence of Class A functions (department stores and specialty stores) to Class B functions (restaurants, retail shopping, entertainment and services) regarding usage status is about 2:1 [35], which provides a reference for the synergy between the functions of the commercial complex system and its space in terms of grade allocation.

Grade allocation is one of the key points of functional synergy between a multifaceted commercial complex system and its space. Grade allocation is an inevitable means of accommodating multiple function types in a specific space. In the process of hierarchical allocation, one or more function types need to be allowed to dominate, providing a hierarchical advantage. If the traditional department store addresses all needs for purposeful consumption, the traditional shopping center, in the process of transformation and upgrading, refines different ages of consumer groups to tap the consumption potential. The new generation of commercial complexes are more focused on the reasonable hierarchical allocation of its system functions and space according to people’s differing activity needs, creating a diversity of commercial places in line with the project theme, to further stimulate space vitality.

② Temporary intervention
In urban commercial complexes, due to technical specifications and space requirements, evacuation spaces and conventional pedestrian traffic areas are large and cannot assume a consumer role, making it difficult to convert them into commercial benefits. Temporary interventions can usually be used to synergize commercial functions, improve utilization and indirectly enhance spatial vitality. Take the SM New Life Plaza in Xiamen (the main building is SM City Plaza) as an example (this case will be used later as the object of empirical analysis): the gray space is formed by the enclosure of three commercial blocks, while the urban atrium hosts public welfare activities, special sales or experiential consumption, etc. The temporary intervention function enriches the experience of the crowd. According to the statistics, when it held Xiamen’s “City of Light” architectural competition in 2016 (Figure 5), customer traffic increased by 6.7% year-on-year; during the Taiwan Food Festival and Auto Show in 2018, customer traffic and sales increased by 12.7% year-on-year. Pop-up stores, which are low-cost and temporary, are favored by major urban complexes as a model for the flexible use of space.

Figure 5. SM City Plaza Xiamen festival site illustration (source: self-photographed).
3. Methodology of Functional Diversity Evaluation Studies

Based on the previous discussion, the functional diversity system of urban commercial complexes satisfies the dissipative structural characteristics, and a preliminary correlation mechanism can be constructed from the diversity of biological systems to the diversity of urban commercial complexes. Based on the coupling mechanism of “diversity-urban vitality”, the study establishes a framework for evaluating the functional diversity of commercial complexes, which includes two parts: index calculation and model validation. Firstly, for diversity measurement, this study relies on the functional diversity index calculation model proposed by Shannon–Weiner in the process of ecosystem species survey based on information entropy theory, and proposes a functional diversity calculation model and constructs an evaluation index system, including three indexes: functional richness, functional dominance and functional diversity composite index. As for the measurement of internal spatial vitality of the complex, after systematically elaborating the mechanism of vitality generation in commercial complexes, three measurement indexes are proposed: Total Scale of Spatial Vitality; Average Density of Spatial Vitality; Public Space Distribution of Spatial Vitality, and the method of sociological survey research is introduced to measure the internal spatial vitality of commercial complexes based on small sample data in order to conduct correlation tests on the calculation results of diversity and vitality measurements, observe the correlation and change trend of the two, and verify the scientificity of the model and rationality of the model (Figure 6).

![Functional diversity evaluation process (source: self-drawn).](image)

3.1. Functional Diversity Index Calculation and Evaluation Criteria

3.1.1. Indicator Calculation

As revealed from the above discussion, the urban commercial complex is characterized by high complexity and uncertainty. The investigation into the functional diversity of the complex system from the perspective of biological systems is involved in the scientific and precise positioning of problems, covering different disciplines and fields. It is also necessary to establish a new evaluation system with the assistance of biological diversity evaluation methods and theoretical achievements related to urban research.

Therefore, an accurate and scientific evaluation cannot be achieved by adopting a single evaluation method. An analytic hierarchy process and multi-index measurement cannot be employed simultaneously, as this will inevitably induce a complex evaluation system. Even if the multi-index measurement method is adopted, it is not necessary to arrange excessive indexes, as the complex formula system will cause the rating system to lose its operability.

Under the technical limitations of this evaluation method, an urban complex diversity evaluation method is proposed based on the system index method, the information
entropy theory and the Shannon–Wiener standard index model. Sub-indexes are extracted through the functional classification and characteristic classification of urban complex diversity. Quantitative evaluation is realized by the qualitative principle of material attributes. To realize the various utilities of urban complex space, the diversity evaluation method of urban complexes is constructed, with the aim of serving the development and construction of urban complexes, and thus providing a basis for the planning and design of urban complexes.

(1) HP functional richness index

According to the above, a good degree of functional diversity ultimately responds to the relationships among species, including symbiotic, parasitic, and competitive relationships. According to the principle that a homogeneous and balanced distribution is optimal, when the size and number of functional patches are most homogeneously distributed in the system, the system diversity is optimal, and the interspecific relationships operate best. In most biological works, the species diversity index is referred to as the species richness index. Drawing on relevant studies in the field of biology, the concept and definition of functional diversity of commercial complexes is proposed as a single evaluation index based on the number of functional types in a commercial complex and the total number of unit spaces of each functional type, without considering the size of each functional space [36].

Based on the Shannon–Wiener standard exponential model, the formula for defining functional diversity by the number of functions and their probability regarding the total type:

\[
HP = - \sum_{i=1}^{n} \frac{A_i}{A} \log_2 \frac{A_i}{A}
\]

Formula (1) is based on the number of space types, where \( A_i \) is the number of the number \( i \) functions, and \( A \) is the number of all functions. When \( A_1 = A_2 = A_3 = \ldots N/n \), \( HIS = 1 \log_2 N \), and the \( \alpha \) index reaches the maximum value \( \alpha_{max} \). At this time, the function types are the richest.

The functions within a commercial complex are complicated. Since this paper mainly provides a discussion of the functional diversity of commercial space’s influence on space vitality, an explanation is offered taking the commercial part as an example. When the commerce is divided into six functions (department stores, catering, retail, entertainment, services and unique shopping places) if the number of each function is the same, \( \alpha \) diversity is the greatest, with a maximum value of \( HP = 0.78 \); when the corresponding area of each function is the greatest, \( \beta \) diversity also reaches the maximum value of \( HIS = 0.78 \). In practice, both values cannot be the greatest. The closer the evaluation result to \( HP = 0.78 \), the better the diversity.

Assuming that one of the six business functions occupies all the resources, qualitative analysis leads to the worst system diversity according to the evaluation principles. By substituting this into the formula, the calculation result is \( HP = \log_2 1 = 0 \).

The calculation results were divided into five intervals between \( HP = 0 \) and \( HP = 0.78 \) and used as evaluation criteria for individual indicators as follows:

- When \( HP = 0 \)–0.156, the diversity is poor; \( HP = 0.156 \)–0.312, the diversity is relatively poor; \( HP = 0.312 \)–0.468, the diversity is fair; \( HP = 0.468 \)–0.624, the diversity is good; \( HP = 0.624 \)–0.78, the diversity is excellent.

The evaluation criteria and value intervals were calculated based on six categories of business functions, and the specific values of the evaluation system could change with the complexity of the selected business complex by changing the base. This allows evaluators to control the entire evaluation system based on accuracy and operational costs.

(2) DSI functional dominance index

Functional dominance originates from the biological concept. It is the opposite to functional diversity as a measurement of concentricity, referring to the degree of dominance that a functional patch has in the entire system. The functional dominance index of commercial
complexes aims to express the functional composition of commercial complexes based on their functions. The study hypothesized that if two individuals are randomly selected from a set of S species containing N individuals and never put back, if the probability of these two individuals belonging to the same species is high, it indicates high concentration, i.e., low diversity [37]. The index of functional dominance of commercial complexes is an index further deduced from the functional type composition of commercial complexes to express the functional composition of commercial complexes. The formula is as follows:

\[
DSI = \lg n + \sum_{i=1}^{n} P_i \cdot \lg P_i
\]  

(3)

where \( n \) is the number of functions; \( P_i \) is the type of function; \( i \) is the proportion of area, \( P_i = \frac{S_i}{S} \).

The DSI index is the opposite of the diversity index. The smaller the value, the more reflective the system consisting of multiple patches with equivalent areas. For functions with the same number of types, the smaller the dominance, the better the functional diversity.

For example, in the classification of the six functions of a commercial complex’s commercial part, when each function occupies an equivalent area, DSI reaches the minimum value \( DSI = 0 \); when one function occupies the entire area, DSI reaches the maximum value \( DSI = \lg 6 = 0.78 \). The range is divided into five intervals, and the single-index evaluation criteria are follows:

- When \( DSI = 0.624 \sim 0.78 \), the dominance is the greatest and the diversity is poor; \( DSI = 0.468 \sim 0.624 \), the dominance is relatively great and the diversity is relatively poor; \( DSI = 0.312 \sim 0.468 \), the dominance is fair and the diversity is fair; \( DSI = 0.156 \sim 0.312 \), the dominance is small and the diversity is good; \( DSI = 0 \sim 0.156 \), the dominance is the smallest and the diversity is excellent.

Since there is a negative correlation between the DSI index and diversity, in the oval weighted calculation, \( 1-DSI \) was subject to normalization so that all indexes were in a positive correlation. The data were quantized; that is, the area of each function was calculated based on an onsite survey and the CAD drawings based on the online materials. However, since the CAD drawings were not original drawings and the size was not accurate, the area of each function was expressed as 1S or 2S in relevant statements in the subsequent empirical study.

(3) \( HSI \) Functional Diversity Composite Index

In this paper, the comprehensive evaluation of functional diversity of commercial complexes is based on the evaluation of functional richness index and functional dominance index, and the comprehensive evaluation index (HSI) of functional diversity of commercial complexes is provided by combining two single-type index evaluation data in a weighted definition. The expression formula is as follows:

\[
HSI = 0.5HP + 0.5(\lg n - DSI)
\]  

(4)

\( n \) is the number of functional types, \( HP \) is the functional diversity index defined by the number of functions and the probability of total types, and \( DSI \) is the functional dominance index defined by the overall dominance of functional patches in the commercial complex system.

Taking the six functional classifications of the commercial part of the commercial complex as an example, combined with the correlation analysis of the \( HP \) index and \( DSI \) index, we can see that when one function occupies the entire area, \( HP \) reaches the minimum value of \( HP = \lg 1 = 0 \) and \( DSI \) reaches the maximum value \( DSI = \lg 6 = 0.78 \). When each function occupies the same area, \( HP \) reaches the maximum value of \( HP = \lg 6 = 0.78 \) and \( DSI \) reaches the minimum value of \( DSI = 0 \). Based on the above elaboration, the range of HSI values is divided into five intervals, which are used as evaluation criteria for the composite index.
Five intervals between $HIS = 0$ and $HSI = 0.78$ are divided as the evaluation criteria for the composite index: When $HSI = 0.0~0.156$, the diversity is poor; $HSI = 0.156~0.312$, the diversity is relatively poor; $HSI = 0.312~0.468$, the diversity is fair; $HSI = 0.468~0.624$, the diversity is good; $HSI = 0.624~0.78$, the diversity is excellent.

The values of $HP$ and $(\lg n-DSI)$ weight shares are empirical reference values given by the author after a comprehensive analysis and comparison of relevant studies on comprehensive diversity evaluation in domestic biology [38-40]. The team found in the study that the values of the weight assignments of single research variables such as species richness and species size amount in the comprehensive evaluation of species diversity are basically equal in domestic biological targeting, which is briefly illustrated by the relevant research data within the last five years (Table 2). The roles and definitions of the sub-indicators such as species richness and species size in the comprehensive evaluation of species diversity are similar to the definitions and roles of the functional richness, functional dominance and functional diversity index of commercial complexes in this paper.

### Table 2. Schematic representation of relevant research data.

| Selected indicators for the comprehensive evaluation of wetland ecosystem diversity in Jinan, Shandong Province, China | Parameters | Weights |
|---|---|---|
| Diversity of wetland types | Number of wetland types1 | 0.211 |
| | Number of wetland types2 | |
| Wetland Scale | Number of wetland types1 Area share | 0.211 |
| | Number of wetland types1 Area share | Source: reference [38] |

| Selected Indicators for Evaluation of Forest Ecomorphological Diversity Complex in Jinan, Shandong Province, China |
| Sub-indicators | Parameters | Weights |
|---|---|---|
| Forest type diversity | Diversity of forest and shrubland types | 0.243 |
| Size of the forest | Forest cover, scrub cover | 0.243 |

| Selected index contents of the comprehensive evaluation of community diversity in Danxia Wutong Nature Reserve | Weights |
|---|---|
| Species diversity C1 | 0.300 |
| Species area distribution C5 | 0.300 |

In summary, this is the source of the corresponding values of $HP$ and $(\lg n-DSI)$ in the HP formula in this paper. It should be noted that although the values of their weight ratios are empirical reference values given by the author, their validity is proved through data analysis and comparison in the later empirical study of the influence mechanism of functional diversity on its spatial vitality-related research variables.

3.1.2. Evaluation Criteria

As per the basic assumption of economics, there are different “preferences” for all consumers, which indicates that each product forms a counterpoint relationship with the corresponding consumers, and there are more or fewer losses for other consumers. This loss is not a negative benefit, but does not meet the maximum expectation of consumer preference [41]. The part that is not fully satisfied is defined as utility dissipation [42]. According to microeconomics, decision-makers would take the utility from each scheme as a reference when making decisions with multiple schemes. In other words, the utility of different schemes directly determines the probability of being selected. As in the pursuit of utility maximization in urban development, rational consumers all pursue the maximization of utilities [43].
The following diagram explains the relationship between the diversity of explanatory functions and consumers. When there is only one type of store in a complex, as in an assembly line producing the same type of product, the concentration of a single quantity produces a scale effect. The result is that only one type of business can meet the needs of its target population, while other consumers are not satisfied (Figure 7a). In order to reduce this utility dissipation, it is necessary to have a greater variety of stores, the higher the selectivity, and the higher the degree of consumer satisfaction, and the greatest utility when everyone can choose to the target store, but at this point the smaller the economy of scale may be (Figure 7b). This means that the larger the scale effect of the complex, the higher the utility loss it generates.

![Figure 7. (a) Functional homogenization leads to utility loss. (b) Multifunctional introduction and reduced consumer utility depletion (source: self-drawn).](image)

The “scale” is defined by the types of “group preferences”, and the “scale” of urban complexes (potential demand rather than actual construction) is usually in line with their geographical location. There are many demands for functional types in the development of complexes in city centers. There are relatively few demands for functional types in the fringe area of cities. The larger the “scale” of urban complexes, the greater the demand utility loss. Only when the functions of complexes are designed for each consumer can the utility loss be minimized. However, there are conflicts between the comprehensively targeted development and limited land development. In city centers, there are more demands for urban complexes but less for urban space. Conversely, in the fringe area of cities, there are few demands for urban complexes but more for urban space. Therefore, the most effective way of reducing the demand utility loss is to improve the diversity of functions on the premise of ensuring compact space.

Referring to the functional synergy mechanism and ecosystem described in the previous section we use the minimum utility loss and the equilibrium distribution as the criteria for judging the results of functional diversity calculation, and use this as an important reference for the construction of the index system.

1. **Optimal Diversity Generated from Least Utility Loss**

   The geographical location of urban complexes and their relationship with the city determines their demand “scale”. The larger the demand “scale”, the more singular the supplied functional types, and the more serious the demand utility loss. Inversely, when the utility loss is the smallest, all consumers could obtain the effect of their demand, with the richest supplied by functional types and the optimal diversity.

   In the time dimension, there are different attractions of different functions to people in different periods. When the attraction of a function to people is always at a high level in the overall period, the utility loss of this function is the smallest in the time dimension, and its diversity attribute is the highest.

   In brief, the utility loss is an inevitable phenomenon (the total utility is positive). The utility loss in the dimensions of material function, space and time is the smallest, which is a sufficient condition for the high diversity of a system. In the following, the performance of functional diversity in terms of its own attributes (quantity, proportional structure,
etc.), time performance and spatial dimension would be taken as the main criteria for the determination of an evaluation grade.

(2) Homogeneous and balanced distribution is preferred

According to the synergistic mechanism of functions within the complex described above, the micro-state of resource distribution affects the dynamic balance of the macro-system from a biological perspective. Within the complex system, on the one hand, uneven distribution of material resources can lead to unreasonable interspecies competition relationships. The dominant party will overcluster resources and cause severe depletion of the utility of some similar functions. On the other hand, the expansion of the number and volume of single functions can affect the overall functional variety and make it difficult to fail to match the number of potential demands. Furthermore, the uneven distribution in spatial location can affect the traffic flow within the complex and prevent the organization of consumer walking routes through multiple points of interest. The principle is specifically described as that the more the functions within the complex tend to be homogeneously and evenly distributed in scale, type and space, the better the spatial diversity within the complex.

3.2. Vitality Measurement of Urban Commercial Complexes from the Space Static Dimension

In terms of the current situation of related research at home and abroad, a large number of scholars have analyzed and defined the connotation of urban spatial vitality from the perspectives of urban space design, environmental behavior, user psychology, etc., but relatively little research has been conducted on the spatial vitality of commercial complexes. This paper draws on the research of domestic scholars on the formation of urban spatial vitality and proposes the process of forming spatial vitality of commercial complexes: from the generation of commercial activities to the bearing of commercial activities to the gathering of commercial activities.

In terms of the current situation of related research at home and abroad, a large number of scholars have analyzed and defined the connotation of urban spatial vitality from the perspectives of urban space design, environmental behavior and user psychology, but relatively few studies have been conducted on the spatial vitality of commercial complexes. Drawing on the research of domestic scholars on the formation of urban spatial vitality, the study proposes the formation process of commercial complex spatial vitality: from the generation of commercial activities, to the bearing of commercial activities and then to the gathering of commercial activities (Figure 8).

![Figure 8. Schematic diagram of commercial complex vitality generation (source: self-drawn).](image-url)
for the generation of spatial activities in the commercial complex, and people and their generated activities are the subjects of its spatial vitality.

The carrying of the spatial object to the main body is the second step of spatial vitality generation—the carrying of activities within the urban commercial complex. In this link, the attractiveness and capacity of the commercial complex for people and their activities are the key elements to determine the degree of spatial vitality; the functional type, inner structure and physical environment quality of the commercial complex space all determine the attractiveness of the commercial complex space for people and the capacity of the commercial complex space to accommodate the activities of high-density people. As the object of spatial vitality, the intrinsic characteristics and environmental quality of the commercial complex space are the mechanism factors affecting the spatial vitality of the commercial complex.

The third step in the generation of spatial vitality is the gathering of activities in the commercial complex, including the clustering of human activities in the commercial complex in its spatial distribution and the continuity of human activities in the commercial complex in time. Firstly, in the commercial complex, the increase in the number of people or the increase in the density of people in the spatial distribution means that the possibility of human activities increases; the gathering of people and their activities in the space is the prerequisite basis for stimulating the spatial vitality; the density of human activities in the spatial distribution is often the most direct external expression of the degree of spatial vitality. Secondly, the time when people and their activities gather in a commercial complex is always in the process of dynamic change, and the length of time that people and their activities gather also reflects the spatial vitality. For example, in a commercial complex, during the business hours of a day, the gathering of people and their consumption behavior changes continuously in the morning, noon and evening, showing the dynamic characteristics of spatial vitality; and in the same period of time, the degree of spatial vitality varies among different floors, different functional combinations and spatial combinations in the urban complex.

The quantitative research data on vitality measurement include mobile phone signaling data, sign-in data, POI distribution, heat map, etc. These are used as data sources for quantitative evaluation. The research contents mainly include the influencing factors and influencing mechanisms of vitality, as well as the influence that the built environment, transportation system, travel behavior and other factors have on vitality. The research objects mainly include urban areas, commercial circles and block spaces [44–47].

Although there have been increasingly extensive studies on urban vitality in recent years, there are still few methods to measure the vitality from the architectural design level. It is also difficult to directly adopt many technical methods and data due to the limitations of the indoor environment, which hinders relevant measurements. In the following, the validity of the calculation model can be tested based on a measurement of the spatial vitality of urban commercial complexes. In addition, the influence that the synergistic mechanism of complexes’ functional diversity has on spatial vitality would be further verified.

As was revealed from the vitality composition and generation mechanism of urban commercial complexes (Figure 8), the exploration of the spatial vitality of commercial complexes was conducted by not only analyzing the distribution and aggregation law of the crowd and their activities in the spatial dimension, but also analyzing the persistence of and fluctuations in the vitality of urban commercial complexes in the time dimension. However, as the focus of this functional diversity calculation model was placed on calculations using timeline slicing, the vitality measurement in the time dimension was not considered. The highlight is the static dimension of spatial vitality of urban commercial complexes.

The research variables of the spatial vitality of commercial complexes were employed to describe the degree of vitality of commercial complex space, mainly looking at the static characteristics of the crowd’s activities in a commercial complex space. This avoids the influence of the varying activities of the crowd over time. In the following, the exploration is elucidated from three aspects, namely, total scale, average density and public space
distribution. Of note, the total scale of spatial vitality of commercial complexes is often affected by the scale of spatial units of commercial complexes. However, the commercial space areas in the selected research objects were relatively similar (floors that are not at the same level, as most floor spatial units are not included in the final correlation analysis). Therefore, this research variable can effectively characterize the spatial vitality characteristics of commercial complexes.

3.2.1. Measurement Variables and the Data Collection

Regarding the data sources of variables in empirical studies, namely, the quantitative data related to the spatial vitality of commercial complexes, the small sampling data obtained from field investigation were used for correlation analysis and research.

(1) Total Scale of Spatial Vitality

The total scale of spatial vitality is used to describe the total number of crowd activities that are distributed and gathered in the commercial complex space, such as the total number of daily crowd activities on working days and rest days at each floor of the commercial complex, and the average crowd activities per hour on each floor of the commercial complex.

It was necessary to collect the total vitality scale of each floor of an urban commercial complex during one-day business hours, over a period of three working days and two rest days (namely, the total customer flow on each floor during one-day business hours). The related data were collected by an observation method at the gate. The sampling period was set as 10:00–22:00 (the one-day business hours of the selected commercial complex), and a total of 12 periods were divided by the “equidistant random sampling” method. The survey map of spatial commercial vitality was plotted. (The space of each floor was partitioned according to the definition of “convex space” in spatial syntax, and the possible scope covered by a single investigator. The position of each observation point was determined in the partition according to the actual situation. Generally, the public space sections with a large customer flow on each floor were selected to cover the most representative spaces.)

On cloudy or sunny days, investigators were assigned to perform sampling at all preset cross-section observation points marked on each floor plan for 3 min on 3 working days and 2 rest days during each investigation period, and record the customer flow passing through the cross-section and the sampling period. After statistical processing, the total scale of spatial vitality on each floor of a commercial complex can be calculated using the basic data on customer flow on each floor during each sampling period.

(2) The average density of spatial vitality

The average density of spatial vitality is used to describe the distribution of crowd activities in commercial complexes. This is the ratio of total crowd activities to the spatial plane area. In terms of the crowd activities in a commercial complex, there are differences in the distribution of activity density due to the number of floors, functional distribution, spatial environment and personal preferences. The average density of spatial vitality can be used as a supplementary explanation for the total scale of vitality.

It is necessary to collect the total scale of spatial vitality of each commercial complex and the plane area of each floor. The total scale of commercial complex vitality can be obtained according to the related description. The area of each floor in a commercial complex refers to the area occupied by different functional spaces and public spaces based on network data and CAD drawings drawn during field investigation, excluding spaces that were inaccessible by ordinary people (spaces only for personnel working in the commercial complex or the void space, namely, the space above the central component). Of note, the parking area was not included in the statistical scope. For instance, the F2, B1 of SM City Plaza was selected as the research object. The area data selected for the average density of spatial vitality are presented (Figure 9).
(3) Public Space Distribution of Spatial Vitality

The public space distribution of spatial vitality is used to describe the distribution of the crowd’s static activities in different public spaces of a commercial complex, such as aggregation and dispersion and sparse and dense location characteristics, which are mainly obtained using the activity annotation method under spatial analysis. There is a significant difference in the number of people in a place during peak periods and off-peak periods, which is mainly related to the travel environment. However, the distribution mode of people in space is almost constant, which leads to differences in the intensity of space use. Therefore, it is necessary to pay attention to records of spatial location.

The data for the static dimension of spatial vitality were separately collected on working days and rest days. One-day business hours of commercial complexes were regarded as the scope limit. Therefore, these can be effectively employed in relevant empirical studies into the influence that the functional diversity of commercial complexes has on their spatial vitality.

It was necessary to collect the floorplans of each commercial complex and its spatial vitality distribution data. The spatial vitality distribution data for public spaces on each floor of the commercial complexes were collected. The public space distribution of spatial vitality is characterized by the distribution of the types and quantities of static behavior in public space. The activity annotation method was adopted to conduct the field investigation. Specifically, using the prepared observation tables and floorplans of commercial complexes, the behavior on each floor of the commercial complex was recorded by photographing, counting and description (Figure 10).

In this paper, the field survey was all day (10:00–22:00) using the activity annotation method. One day was randomly selected on working days and rest days to reduce the influence of contingency (usually, similar behavior modes were considered from Monday to Thursday, Friday had different modes, and there were similar behavior modes on Saturday and Sunday). The sampling was performed every two hours, and the sampling scheme was implemented using the “equidistant random sampling” method, in an attempt to reflect the difference between peak and off-peak periods, and the internal use modes of commercial complexes. During specific statistics, “day” was taken as the time unit in the data summary, and the corresponding data of each statistics unit during one-day business hours were summarized.

3.2.2. Calculation Model

The aforementioned calculation models are summarized in the following Table 3:
In this paper, the field survey was all day (10:00–22:00) using the activity annotation method. One day was randomly selected on working days and rest days to reduce the influence of contingency (usually, similar behavior modes were considered from Monday to Thursday, Friday had different modes, and there were similar behavior modes on Saturday and Sunday). The sampling was performed every two hours, and the sampling scheme was implemented using the “equidistant random sampling” method, in an attempt to reflect the difference between peak and off-peak periods, and the internal use modes of commercial complexes. During specific statistics, “day” was taken as the time unit in the data summary, and the corresponding data of each statistics unit during one-day business hours were summarized.

3.2.2. Calculation Model

The aforementioned calculation models are summarized in the following Table 3:

| Research Dimension | Research Variable | Data Processing | Parameter Definition |
|--------------------|-------------------|-----------------|----------------------|
| **Total vitality scale** | | | $A_{\text{hour}} = \frac{60}{T} \sum_{i=1}^{n} A_i$ |
| | | | $A_{\text{day}} = \sum_{i=1}^{n} A_i$ |
| | | | $E = \frac{1}{3} \sum_{i=1}^{3} A_{\text{day}}$ |
| **Space Static Dimension** | **Average density of vitality** | | $D = \frac{A_{\text{day}}}{n}$ |
| | **Public space distribution of spatial vitality** | The field observation is conducted based on the activity annotation method. The corresponding spatial data are sorted out. Further, the correlation analysis diagram is plotted after collating the survey photos. | Analysis Diagram of Public Space Distribution of Spatial Vitality + Statistical Table of the Number of Personnel with Static Behavior and Static Behavior Types in Each Region |

Figure 10. Schematic diagram of the activity notation method for recording relevant data (source: self-drawn).

Table 3. Spatial vitality measurement data-processing statistics of commercial complexes.

4. Demonstration Based on Examples

4.1. Selection of the Study Sample

In this paper, SM City Plaza in Xiamen City, where the project team is located, is chosen as the research object. It belongs to the SM business district of Xiamen, and is located at the intersection of Jiahe Road and Xiangyue Road in Siming District, Xiamen. The plaza is adjacent to the two main traffic lines connecting Xiamen and is directly connected to
the entrances and exits of some stations of Wushipu subway of Xiamen subway line 1, which makes the location convenient. The surrounding area has medium and high-grade residential communities and some commercial offices and hotels. The overall commercial service group of the plaza is relatively wide, mainly young customers. The square has a construction area of 126,000 m² and more than 1100 parking spaces. The functional formats cover services, entertainment, catering, department stores, supermarkets, retail stores, etc. It carries out SM Group’s commercial operation concept of “rent only, not for sale”, and the overall commercial atmosphere and quality of space environment are guaranteed. The plaza is the first choice for landmark consumers in Xiamen and the surrounding areas. It is a city-level commercial complex. In the process of urban renewal development, SM Plaza has continuously enriched its functional types and enhanced its comprehensive service capacity by erecting a flyover to link the third phase of the project. This is the reason why its development as one of the earliest commercial complexes built in Xiamen still maintains a high level of commercial vitality today. As the core commercial project of the listed company SM Group, it belongs to the world chain brand project. To sum up, this plaza has high research value (Figure 11).

As listed in the below Table 4, the number of formats in Xiamen SM City Plaza is counted based on the number of catering, retail and department stores, and entertainment, service and exclusive shops. According to the format statistics on each floor, there are 52 catering shops, 188 retail shops, 4 department stores, 4 entertainment shops, 18 service shops and 4 exclusive shops (Figure 12).

### Table 4. SM City Plaza Floor Statistics.

| Functional Format     | Floor | Total | Proportion |
|-----------------------|-------|-------|------------|
|                       | B1    | L1    | L2    | L3    | L4    | L5    |       |           |
| Catering              | 18    | 6     | 2     | 9     | 2     | 15    | 52    | 19.2%   |
| Retail                | 21    | 16    | 47    | 37    | 20    | 47    | 188   | 69.6%   |
| Department Store      | 1     | 1     | 1     | 1     | 0     | 0     | 4     | 1.5%    |
| Entertainment         | 1     | 1     | 0     | 2     | 0     | 0     | 4     | 1.5%    |
| Service               | 5     | 3     | 1     | 5     | 1     | 3     | 18    | 6.7%    |
| Exclusive Shop        | 2     | 0     | 0     | 0     | 2     | 0     | 4     | 1.5%    |

Figure 11. Aerial view of SM City Plaza Xiamen (source: self-drawn).
Table 4. SM City Plaza Floor Statistics.

| Functional Format | Floor | Total | Proportion |
|-------------------|-------|-------|------------|
| Catering          | L1    | 6     | 19.2%      |
| Retail            | L2    | 47    | 69.6%      |
| Department Store  | L3    | 20    | 1.5%       |
| Entertainment     | L4    | 2     | 1.5%       |
| Service           | L5    | 3     | 6.7%       |
| Exclusive Shop    |       | 4     | 1.5%       |

Figure 12. SM City Plaza floor plan by floor (source: self-drawn).

4.2. Calculation of Functional Diversity Comprehensive Index

4.2.1. Functional Richness

After the data in the above table were substituted into the formula used to calculate functional richness, \( HP = 0.407 \), and the number of categories is 6. Therefore, the maximum richness in this mode is \( HP = \log_6 6 = 0.78 \). According to this conclusion, the corresponding single index evaluation criteria are established as follows. Five intervals are divided between \( HP = 0 \) and \( HP = 0.78 \), and they are regarded as the evaluation criteria for the single index, namely:

- When \( HP = 0–0.156 \), the functional richness is poor;
- \( HP = 0.156–0.312 \), the functional richness is relatively poor;
- \( HP = 0.312–0.468 \), the functional richness is moderate;
- \( HP = 0.468–0.624 \), the functional richness is relatively excellent;
- \( HP = 0.624–0.78 \), the functional richness is excellent.

The functional richness index of SM City Plaza in Xiamen City is \( HP = 0.407 \), and SM City Plaza in Xiamen City is preliminarily evaluated as having a moderate functional richness level.
The HP value of B1-L5 and their functional richness levels in the single index evaluation can be obtained by further calculation (Table 5).

Table 5. Statistical table of functional richness evaluation of each floor during working days.

| Floor | B1  | L1  | L2  | L3  | L4  | L5  |
|-------|-----|-----|-----|-----|-----|-----|
| HP Value | 0.556 | 0.491 | 0.168 | 0.424 | 0.310 | 0.310 |
| Functional Richness Level | Relatively excellent | Relatively excellent | Relatively poor | Moderate | Relatively poor | Relatively poor |

The above data and evaluation results were applied to the empirical study in this paper. With reference to the functional diversity index of SM City Plaza in Xiamen City on working days, the functional richness index on rest days changes compared with that on working days due to the implantation of a temporary functional format in public space. This is a concrete embodiment of the coordination between function and time in the synergistic mechanism of functional diversity.

Specifically, the B1-F5 of SM City Plaza in Xiamen City were implanted and replaced with temporary retail function and temporary service function with different area sizes (with differences due to different the sizes and shapes of each floor of public space) on rest days (Figure 13). Partial display and explanation were created with the field photos of some temporary format implantation on F1 and F2 on rest days (as shown in Figure 13). The functional richness of SM City Plaza in Xiamen City on rest days is evaluated according to the data of specific conditions and the corresponding drawings, with the results shown in the Table 6.

Figure 13. SM City Plaza rest day temporary function implantation diagram (source: self-drawn).
4.2.2. Functional Dominance

The plane CAD drawings of each floor of SM City Plaza in Xiamen City were plotted based on the field investigation and existing data, and the areas with different functions were counted. The ratio used in the abovementioned method was adopted to calculate and express the area.

In SM City Plaza in Xiamen City, the area devoted to catering shops, retail shops, department stores, entertainment shops, service shops and exclusive shops is $0.150S$, $0.331S$, $0.325S$, $0.003S$, $0.025S$ and $0.166S$, respectively. After being substituted into Formula 3, $DSI = 0.288$ can be obtained. As the number of categories is six, the maximum diversity in this mode is $DSI = \lg 6 = 0.78$. According to the above results, the corresponding evaluation criteria for the single index were established as follows.

- When $DSI = 0–0.156$, the dominance is small and the functional diversity is excellent;
- $DSI = 0.156–0.312$, the dominance is relatively small, and the functional diversity is relatively excellent;
- $DSI = 0.312–0.468$, the dominance is moderate and the functional diversity is also moderate;
- $DSI = 0.468–0.624$, the dominance is relatively large, and the functional diversity is relatively poor;
- $DSI = 0.624–0.78$, the dominance is largest, and the functional diversity is poor.

The $DSI$ index of SM City Plaza in Xiamen City is 0.288, ranging from 0.156 to 0.312. Therefore, the functional dominance of this plaza is relatively small, and the functional diversity of it is relatively excellent.

In the evaluation of functional dominance of each floor of SM City Plaza in Xiamen City, the data in the following Table 7 can be obtained as per the functional area data of each floor of SM City Plaza in Xiamen City.

Table 7. Statistical table of functional area (Si value) of each floor.

| Functional Format | Floor | B1       | L1       | L2       | L3       | L4       | L5       |
|-------------------|-------|----------|----------|----------|----------|----------|----------|
| Retail            |       | 0.121S_0 | 0.562S_1 | 0.531S_2 | 0.346S_3 | 0.139S_4 | 0.450S_5 |
| Department Store  |       | 0.657S_0 | 0.425S_1 | 0.266S_2 | 0.477S_3 | 0         | 0         |
| Catering          |       | 0.159S_0 | 0.137S_1 | 0.012S_2 | 0.132S_3 | 0.052S_4 | 0.499S_5 |
| Entertainment      |       | 0.008S_0 | 0.005S_1 | 0         | 0.007S_3 | 0         | 0         |
| Service           |       | 0.017S_0 | 0         | 0         | 0.039S_3 | 0         | 0.052S_5 |
| Exclusive Shop    |       | 0.037S_0 | 0.319S_1 | 0         | 0         | 0.809S_4 | 0         |

After the data in the above table are substituted into the formula for the calculation of functional dominance, the $DSI$ value of B1-L5 and their dominance and diversity levels in the single index evaluation can be obtained (Table 8). Specifically, the $DSI$ value of B1 is 0.320, which indicates that the functional dominance is relatively small and the functional diversity is relatively excellent. The $DSI$ value of L1 is 0.279, which indicates that the functional dominance is relatively small and the functional diversity is relatively excellent. The $DSI$ value of L2 is 0.456, which indicates that the functional dominance is moderate and the functional diversity is also moderate. The $DSI$ value of L3 is 0.295, which indicates that the functional dominance is relatively small and the functional diversity is relatively excellent. The $DSI$ value of L4 is 0.498, which indicates that the functional dominance is relatively large and the functional diversity is relatively poor. The $DSI$ value of L5 is 0.404, which indicates that the functional dominance is moderate and the functional diversity is also moderate. The data and evaluation results were adopted as the reference for the functional dominance index of SM City Plaza in Xiamen City on working days in this empirical study.
Table 8. Strength rating statistics for each floor during the working day.

| Floor | B1 | L1 | L2 | L3 | L4 | L5 |
|-------|----|----|----|----|----|----|
| DSI Value | 0.320 | 0.279 | 0.456 | 0.295 | 0.498 | 0.404 |
| Functional Dominance Evaluation | Relatively small | Relatively small | Moderate | Relatively small | Relatively large | Moderate |
| Diversity Evaluation | Relatively excellent | Relatively excellent | Moderate | Relatively excellent | Relatively poor | Moderate |

Compared with the functional dominance index of working days, there are some changes in the functional diversity index of rest days due to the implantation and replacement of temporary functional formats in public spaces (Table 9). These changes are essentially the concrete embodiment of the coordination between function and time in the synergistic mechanism of functional diversity. The functional dominance of rest days in SM City Plaza in Xiamen City was evaluated. The corresponding contents in the drawings were adjusted according to specific situations, and the data statistics were also found, with the results shown as follows.

Table 9. Statistical table of functional dominance evaluation during rest days.

| Overall Situation | B1 | L1 | L2 | L3 | L4 | L5 |
|-------------------|----|----|----|----|----|----|
| DSI | 0.305 | 0.262 | 0.151 | 0.391 | 0.265 | 0.385 | 0.329 |
| Dominance Evaluation | Relatively small | Relatively small | Small | Moderate | Relatively small | Moderate | Moderate |
| Diversity Evaluation | Relatively excellent | Relatively excellent | Excellent | Moderate | Relatively excellent | Moderate | Moderate |

4.2.3. Functional Diversity Comprehensive Index

Based on the above-mentioned data calculation of functional diversity index (HP) and functional dominance index (DSI) for SM City Plaza in Xiamen City, the corresponding data were substituted into the formula: $HSI = 0.5HP + 0.5(\lg n - DSI)$. The functional diversity comprehensive index of SM City Plaza in Xiamen City is $HSI = 0.639$. As the number of categories is six, the maximum diversity in this mode is $HSI = \lg6 = 0.78$. Five intervals were divided between $HSI = 0$ and $HSI = 0.78$, and the corresponding comprehensive index evaluation criteria were established as follows.

When $HSI = 0–0.156$, the functional diversity is poor; $HSI = 0.156–0.312$, the functional diversity is relatively poor; $HSI = 0.312–0.468$, the functional diversity is moderate; $HSI = 0.468–0.624$, the functional diversity is relatively excellent; $HSI = 0.624–0.78$, the functional diversity is excellent.

The comprehensive evaluation index of functional diversity of SM City Plaza in Xiamen City is $HSI = 0.392$, which indicates that the functional diversity is moderate. According to the functional diversity comprehensive evaluation method of each floor of SM City Plaza in Xiamen City and the above-mentioned results, the evaluation results of working days are listed in the following Table 10. The data and evaluation results were adopted as the reference for the functional diversity comprehensive index of SM City Plaza in Xiamen City on working days in this empirical study.

Compared with the functional diversity comprehensive index of working days, there were some changes in rest days due to the implantation and replacement of temporary functional formats in public spaces. These changes are essentially the concrete embodiment of the coordination between function and time in the synergistic mechanism of functional diversity. Based on the data of the functional diversity index (HP) and functional dominance index (DSI) of rest days of SM City Plaza in Xiamen City, the functional diversity...
comprehensive index of rest days of SM City Plaza in Xiamen City was substituted into the formula, with the results listed in the Table 11.

**Table 10.** Comprehensive evaluation statistics of functional diversity on each floor during the working day.

| Floor | B1   | L1   | L2   | L3   | L4   | L5   |
|-------|------|------|------|------|------|------|
| HSI   | 0.508| 0.496| 0.246| 0.454| 0.296| 0.343|
| Comprehensive Level of Functional Diversity | Relatively excellent | Relatively excellent | Relatively poor | Moderate | Relatively poor | Moderate |

**Table 11.** Comprehensive evaluation statistics of the functional diversity of each floor during the rest days.

| Overall Situation | Overall  | B1   | L1   | L2   | L3   | L4   | L5   |
|-------------------|----------|------|------|------|------|------|------|
| HSI   | 0.476    | 0.553| 0.581| 0.302| 0.493| 0.402| 0.431|
| Comprehensive Level of Functional Diversity | Relatively excellent | Relatively excellent | Relatively excellent | Relatively poor | Relatively excellent | Moderate | Moderate |

4.3. Spatial Static Vitality Measurement

4.3.1. Total Scale of Spatial Vitality

The data on the total scale of spatial vitality collected from field investigations are summarized in the following table. These data are graphically expressed as the Table 12.

**Table 12.** Statistical table of the total scale of spatial vitality for two types of statistical days (working days and rest days).

| Statistics Unit | Working Days | Rest Days |
|-----------------|--------------|-----------|
|                 | Total Amount of Spatial Vitality in One Day (in Person) | Total Amount of Spatial Vitality per Hour (in Person/h) | Total Amount of Spatial Vitality in One Day (in Person) | Total Amount of Spatial Vitality per Hour (in Person/h) |
| Overall         | 14,070 | 1173 | 20,183 | 1682 |
| B1              | 1347   | 112  | 3667   | 322  |
| L1              | 1050   | 86   | 3985   | 332  |
| L2              | 1164   | 99   | 3522   | 294  |
| L3              | 936    | 78   | 3227   | 269  |
| L4              | 1144   | 95   | 2839   | 237  |
| L5              | 869    | 72   | 2743   | 229  |

From Figure 14, it can be seen that the total spatial vibrancy of SM City Plaza (hereinafter referred to as SM) shows a decreasing trend with the increase of floors in a day. Comparing the total spatial vitality of the two types of business hours in a day, it can be found that the corresponding figures for the rest days are significantly higher than those for the weekdays. Combined with the fact that the spatial capacity remains unchanged, this indicates that the attractiveness of SM to the crowd is much higher on rest days than on weekdays. Combined with the analysis of the field research and interview data conducted by the research team, the main reasons are as follows: (1) the wider source of visitors on rest days; (2) the implantation and replacement of temporary functional formats on weekends.
(in line with the synergistic mechanism of functional diversity discussed above) enriching its functional diversity.

![Figure 14. Statistics of total spatial vitality reversions for two types of days (source: self-drawn).](image)

For the specific analysis of the data, a comparison of the overall data shows that the ratio of the total spatial vitality of SM during the rest day is 1.434, and the corresponding values are higher than this overall ratio for L1, L2, B1, and three spatial units. Combined with the above quantified values of functional diversity of SM, it can be seen that the level of functional diversity of L1 and B1 are in a relatively good state, while the level of functional diversity of L2 is in a relatively poor state. Comparing the values of the functional diversity indices of the two, it can be concluded that the high total scale of spatial vitality of L1 and B1 during one day’s business hours is largely reflected in their rich functional diversity, while the total scale of spatial vitality of L2 during one day’s business hours is at a relatively high level, which, according to the field survey, is mainly due to its superior traffic accessibility: it connects SM1 and SM2, and is responsible for the development of SM2. According to the field survey, the main reason for this is the accessibility of the building: the crossing bridge (with high pedestrian flow), which connects SM1 and SM2, is located on the L2 floor.

### 4.3.2. Average Density of Spatial Vitality

The data on spatial average density, collected from the field investigation, are summarized in the Table 13. These data are graphically expressed as follows. Through horizontal comparison based on Figure 15, it can be seen that the average density of spatial vitality during one-day business hours of rest days is higher than that of working days in SM City Plaza in Xiamen City (hereinafter referred to as SM). Based on the premise that space capacity remains unchanged under actual situations, the SM’s attraction on rest days is higher than that on working days. The reasons for this are as follows. First, it is a common phenomenon for the customer flow in urban commercial complexes to be greater on rest days than on working days. Second, as per the field investigation results, the implantation and replacement of temporary functional formats in SM on weekends (conforming to the synergistic mechanism of functional diversity) enriches its functional diversity.

### 4.3.3. Public Space Distribution of Spatial Vitality

The study used the distribution of stay activities (stay behavior) in SM public space to characterize the public space distribution of its spatial vitality. The observation points and observation areas of each level of public space are shown in Figures 16–18. The data on the number of dwell activities (dwell behavior) and dwell activity types recorded during the field observation and research were graphically represented (shown in Figures 19–24 below).
### Table 13. Statistical table of the average density of spatial vitality for the two types of days.

| Statistics Unit | Area (in m²) | Working Days | Rest Days |
|-----------------|--------------|--------------|-----------|
|                 | Total Amount of Spatial Vitality (in Person/day) | Average Density of Spatial Vitality (in Person/m²/day) | Total Amount of Spatial Vitality (in Person) | Average Density of Spatial Vitality (in Person/m²/day) |
| Overall         | 55,636.1     | 14,070       | 0.253     | 20,183     | 0.363     |
| B1              | 6872.4       | 2713         | 0.395     | 3867       | 0.563     |
| L1              | 9994.6       | 2775         | 0.278     | 3985       | 0.399     |
| L2              | 9884.6       | 2402         | 0.243     | 3522       | 0.356     |
| L3              | 9004.2       | 2433         | 0.270     | 3227       | 0.358     |
| L4              | 10,114.5     | 1933         | 0.191     | 2839       | 0.281     |
| L5              | 9765.7       | 1814         | 0.186     | 2743       | 0.281     |

*Figure 15. Statistical chart of average density of spatial vitality (source: self-drawn).*

*Figure 16. Analysis of the scope of each observation area on the B1 floor and L1 floor (source: self-drawn).*
Figure 16. Analysis of the scope of each observation area on the B1 floor and L1 floor (source: self-drawn).

Figure 17. Analysis of the scope of each observation area on the L2 floor and L3 floor (source: self-drawn).

Figure 18. Analysis of the scope of each observation area on the L4 floor and L5 floor (source: self-drawn).

Figure 19. Statistical analysis chart of the number of stay activities in each observation area on B1 floor (source: self-drawn).
Figure 19. Statistical analysis chart of the number of stay activities in each observation area on B1 floor (source: self-drawn).

Figure 20. Statistical analysis chart of the number of stay activities in each observation area on L1 floor (source: self-drawn).

Figure 21. Statistical analysis chart of the number of stay activities in each observation area on L2 floor (source: self-drawn).

Figure 22. Statistical analysis chart of the number of stay activities in each observation area on L3 floor (source: self-drawn).
Figure 23. Statistical analysis chart of the number of stay activities in each observation area on L4 floor (source: self-drawn).

Figure 24. Statistical analysis chart of the number of stay activities in each observation area on L5 floor (source: self-drawn).

From the comprehensive comparison in Figures 19–24, it can be seen that the spatial vitality public space distribution in SM City Plaza (hereinafter referred to as SM) in Xiamen during one day’s business hours, the number of stay activities for both types of days, and the corresponding stay activities for each observation area on rest days are higher than the data for the same period on weekdays. In terms of the number of dwell activity types, the corresponding values for rest days are greater than those for weekdays. This indicates that the overall types of stopping activities on SM rest days are richer than those on weekdays. Combined with the fact that its spatial capacity remains unchanged. The above two points show that the attractiveness of SM to the crowd is much higher on rest days than on weekdays. On the other hand, the number of daily stay activities in the public space on each floor of SM is higher than that on weekdays. On the other hand, the number of daytime stays in public spaces on SM floors is higher than that on weekdays. Specifically, the L1 unit space has enriched its own unit space stay activities by implanting temporary functional businesses such as car shows, handicraft exhibitions, children’s entertainment facilities, etc., in observation area 1 and observation area 3 on rest days and replacing some of the spaces that serve as temporary retail stores and temporary seats on weekdays. (From 3 to 5, there are two more types of stay activities, such as children’s play and cultural behavior, compared with weekdays), and the corresponding stay behavior has increased significantly compared with the same period of weekdays: according to the statistical results, the observation area 1 and observation area 3 of L1 are 114 and 102, respectively, while the corresponding data values of 177 and 146 stay on rest days. In addition, the temporary functional business implantation on the L1 floor during the rest day affects the stay activity of the people in each observation area from L2 to L5, including
the air corridor, and the stay behavior of the corresponding observation area also increases significantly compared with that of the weekday. This also supports the above view that the total spatial vitality scale of L2 unit space is influenced by the traffic properties of the crossings themselves.

4.4. Correlation Analysis

4.4.1. Functional Diversity and Total Scale of Spatial Vitality

Based on the comparison between L2 and B1, the quality of L2’s spatial environment is better than that of B1 (B1 represents the underground space). The functional area and public space area of B1 are smaller than those of L2. L2 is equipped with an overbridge connecting the SM Lifestyle Center (the overbridge also bears crossing traffic for both sides of the road, with a huge customer flow), and its accessibility is far better than B1.

Based on the above analysis, theoretically, the total scale of spatial vitality of L2 in two types of day should be better than that of B1. However, specific statistical analysis reveals that the corresponding values of the total scale of spatial vitality of B1 on working days and rest days are 2713 persons/day \((HSI = 0.508)\) and 3867 persons/day \((HSI = 0.553)\), respectively, which are higher than the corresponding values of L2 (2402 persons/day \((HSI = 0.246)\) and 3522 persons/day \((HSI = 0.302)\)). According to the analysis and comparison of data from field investigation, these results are because the functional diversity comprehensive index of B1 on two types of day is much higher than that of L2.

Combined with the corresponding data in the Table 14, the commercial complex is taken as the analysis unit, and the corresponding scatter analysis diagram is plotted with the data of the total scale of spatial vitality and functional diversity comprehensive index (HSI) of each spatial unit in two types of day (Figure 25). The correlation analysis is performed with SPSS software. As the data of the total scale of spatial vitality are of scaled value, while the functional diversity index (HSI) is of an ordered value, Spearman’s rank correlation analysis was adopted.

Table 14. Statistical table of the composite index of functional diversity and its total spatial vitality for the two types of day.

| Day Type | Statistics Unit | Total Scale of Spatial Vitality (in Person/day) | Functional Diversity Comprehensive Index (HSI) | Day Type | Statistics Unit | Total Scale of Spatial Vitality (in Person/day) | Functional Diversity Comprehensive Index (HSI) |
|----------|-----------------|-----------------------------------------------|-----------------------------------------------|----------|-----------------|-----------------------------------------------|-----------------------------------------------|
| SM City Plaza | Rest days | B1 | 3867 | 0.553 | B1 | 2713 | 0.508 |
|          |       | L1 | 3985 | 0.581 | L1 | 2775 | 0.496 |
|          |       | L2 | 3522 | 0.302 | L2 | 2402 | 0.246 |
|          |       | L3 | 3227 | 0.493 | L3 | 2433 | 0.454 |
|          |       | L4 | 2839 | 0.402 | L4 | 1933 | 0.296 |
|          |       | L5 | 2743 | 0.431 | L5 | 1814 | 0.343 |

As revealed from the above analysis results (Table 15), the functional diversity is positively correlated with the total scale of spatial vitality. The Spearman’s correlation coefficient of SM is 0.721, which indicates that the correlation is significant. The P value is 0.019, far less than 0.05, which indicates that there is statistical significance and a significant correlation.

Table 15. Spearman’s rank correlation coefficient of functional diversity and its total spatial viability.

| Commercial Complex | Spearman’s Rank Correlation Coefficient | p Value (Sig.(2-Tailed)) |
|--------------------|----------------------------------------|--------------------------|
| SM City Plaza in Xiamen City | 0.721 | 0.019 |

The correlation is significant at the level of \(p = 0.05\).
It should be noted that the correlation scatter diagram for correlation analysis is plotted based on eliminating the corresponding outliers of each commercial complex. The outliers are judged and eliminated based on the following criteria. The relevant data of L2 in SM City Plaza in Xiamen City are judged as outliers according to the field investigation results. The attributes of the spatial traffic function of L2 are far greater than those of the commercial function. The spatial customer flow is mainly composed of walking customers, and the total customer flow data are not representative.

4.4.2. Functional Diversity and Average Density of Spatial Vitality

According to the previous discussion, combined with the field investigation data collection, data analysis and data mining, it can be seen that under the synergistic effect of functional diversity of commercial complexes, the promotion of functional diversity contributes to the promotion of average density in the spatial vitality of commercial complexes. Combined with the corresponding data in the Table 16, the spatial units of each floor of a commercial complex are selected as analysis units. In addition, the corresponding scatter analysis diagram is plotted based on data on the one-day spatial vitality average density of two types of day in each spatial unit and the corresponding functional diversity comprehensive index (Figure 26).

Table 16. Statistical table of the average density of functional diversity–spatial vitality for two types of day.

| Day Type | Statistics Unit | Average Density of Spatial Vitality (in Person/m²/day) | Functional Diversity Comprehensive Index (HSI) | Day Type | Statistics Unit | Average Density of Spatial Vitality (in Person/m²/day) | Functional Diversity Comprehensive Index (HSI) |
|----------|-----------------|------------------------------------------------------|-----------------------------------------------|----------|-----------------|------------------------------------------------------|-----------------------------------------------|
| SM City Plaza | Rest days | B1 | 0.563 | 0.553 | B1 | 0.395 | 0.508 |
| | | L1 | 0.399 | 0.581 | L1 | 0.278 | 0.496 |
| | | L2 | 0.356 | 0.302 | L2 | 0.243 | 0.246 |
| | | L3 | 0.358 | 0.493 | L3 | 0.270 | 0.454 |
| | | L4 | 0.281 | 0.402 | L4 | 0.191 | 0.296 |
| | | L5 | 0.281 | 0.431 | L5 | 0.186 | 0.343 |

Figure 25. Scatter analysis of functional diversity and its total scale amount of spatial vitality (source: self-drawn).
Based on the above table, a horizontal comparison is drawn between the corresponding average density of spatial vitality and functional diversity comprehensive index of two types of day in each statistics unit. It can be generally found that if the functional diversity comprehensive index is large, the corresponding average density of spatial vitality is also relatively large. Furthermore, an SPSS correlation analysis was performed on the data in the table. As the data of the average density of spatial vitality are scaled value while the functional diversity index ($HSI$) is ordered value, Spearman’s rank correlation analysis is adopted. The results are listed in the Table 17.

**Table 17.** Spearman’s rank correlation coefficient of functional diversity and its average density of spatial vitality.

| Commercial Complex                  | Spearman’s Rank Correlation Coefficient | $p$ Value (Sig.(2-Tailed)) |
|-------------------------------------|----------------------------------------|-----------------------------|
| SM City Plaza in Xiamen City        | 0.839                                   | 0.002                       |

The correlation is significant at the level of $p = 0.05$.

The analysis results demonstrate that there is a positive correlation between functional diversity and the average density of spatial vitality. The Spearman correlation coefficient is 0.839 and the $p$ value is 0.002, showing a significant correlation. Similarly, the correlation scatter diagram and correlation analysis are also performed under the premise of eliminating outliers via the same method.

### 4.4.3. Functional Diversity and Public Space Distribution of Spatial Vitality

According to the previous discussion, combined with the field investigation data collection, data analysis and data mining, it can be found that, under the synergistic effect of functional diversity of commercial complexes, the improvement in their functional diversity enriches the types of staying activities in relevant public space and contributes to the improvement in the number of persons involved in staying activities. Combined with the corresponding data in the Table 18, the spatial units of each floor of a commercial complex were selected as analysis units. In addition, the corresponding scatter analysis diagram (Figure 27) was plotted based on the number of the staying activities (staying behavior) on two types of day in each spatial unit (in this paper, the total public spatial
vitality is characterized by the number of staying activities in the public space) and the corresponding functional diversity comprehensive index.

Table 18. Number of functional diversity–public space stay behavior statistics for two types of days.

| Day Type | Statistics Unit | Number of Staying Behavior in Public Space | Functional Diversity Comprehensive Index (HSI) | Day Type | Statistics Unit | Number of Staying Behavior in Public Space | Functional Diversity Comprehensive Index (HSI) |
|----------|-----------------|------------------------------------------|-----------------------------------------------|----------|-----------------|------------------------------------------|-----------------------------------------------|
| B1       | SM City Plaza   | 932                                      | 0.553                                         | B1       | SM City Plaza   | 514                                      | 0.508                                         |
| L1       | SM City Plaza   | 1077                                     | 0.581                                         | L1       | SM City Plaza   | 632                                      | 0.496                                         |
| L2       | SM City Plaza   | 257                                      | 0.302                                         | L2       | SM City Plaza   | 133                                      | 0.246                                         |
| L3       | SM City Plaza   | 831                                      | 0.493                                         | L3       | SM City Plaza   | 565                                      | 0.454                                         |
| L4       | SM City Plaza   | 593                                      | 0.402                                         | L4       | SM City Plaza   | 331                                      | 0.296                                         |
| L5       | SM City Plaza   | 723                                      | 0.431                                         | L5       | SM City Plaza   | 405                                      | 0.343                                         |

Figure 27. Functional diversity; scatter plot of the number of stay behaviors in public spaces (source: self-drawn).

Based on the Table 19, it is necessary to judge the single function based on the function dominance of each floor and eliminate outliers. An SPSS rank correlation analysis was performed. As shown in the following figure, the correlation coefficient is 0.839, and the p value is 0.001, showing a significant correlation. This indicates that functional diversity is positively correlated with the number of staying activities in a public space.

Table 19. Spearman’s rank correlation coefficient of functional diversity and the number of stay behavior in public space.

| Commercial Complex               | Spearman’s Rank Correlation Coefficient | p Value (Sig.(2-Tailed)) |
|-----------------------------------|----------------------------------------|--------------------------|
| SM City Plaza in Xiamen City      | 0.839                                  | 0.001                    |

The correlation is significant at the level of p = 0.05.

4.4.4. Results of the Empirical Analysis

Based on the above-mentioned quantitative analysis results, the single-day data with respect to the total scale of spatial vitality, the average density of spatial vitality and the public space distribution of spatial vitality are compared to the calculated functional...
diversity comprehensive index (HSI). The correlation was analyzed by calculation. It can be preliminarily concluded that there is a certain practical value and rationality in the proposed functional diversity comprehensive evaluation index system in terms of SM City Plaza in Xiamen City.

However, it should be noted that the demonstration of the effectiveness and rationality of functional diversity is limited by the numerical range regarding the statistical data sample number and variable interpretation. Therefore, the research team needs to draw a horizontal comparison of various types of commercial complexes in the future, to determine the applicable scope of the calculation model.

5. Discussion

In this paper, based on synergetics under the complex system theory, the structural research of functional diversity of commercial complexes is conducted by combining the principle of biodiversity in nature. In addition, the concept of a “functional system coordination of multi-commercial complexes” is established. The functional system of multi-commercial complexes is considered to be composed of various types, clear levels and interrelated functions within a commercial complex in a specific geographical and cultural context. The synergetics of this system are essentially characterized by a more dependent interrelation between diversity and diversified structures, which avoids opposition, isolation and conflict between individual functions. Based on this, the dissipative structure characteristics of urban commercial complexes and the structural characteristics of the functional diversity system are systematically elucidated. Additionally, the synergistic mechanism of functional diversity is proposed and expounded from three perspectives, namely, the synergy between function and function, the synergy between function and space, and the synergy between space and time. Moreover, the functional diversity index (HP), functional dominance index (DSI) and functional diversity comprehensive index (HSI) are also proposed. Furthermore, the effectiveness and application scope of the model are verified from the dimension of a spatial vitality measurement in the complex.

However, it should also be noted that this study on the diversity focuses on the level of the functional system, and comprises a basic effort in the comprehensive quantitative evaluation of the diversity system. Based on the connotation of diversity, a multi-level, multi-content and multi-object exploration is required to perform a quantitative analysis and evaluation of urban commercial complex diversity. Spatial diversity, traffic system diversity, landscape diversity and other indexes should be put forward to establish a more comprehensive evaluation system.

(1) Based on the above discussion, the study on the diversity of urban complexes from the perspective of biodiversity is based on the high consistency between biological systems and urban complexes at the level of the system structure, which conforms to the development law of complex systems and provides certain scientific and reference values. Nonetheless, in a subsequent empirical study, more typical commercial complexes should be included in samples for a comprehensive comparative analysis and optimization of the comprehensive evaluation system, to verify the scientificity of the model.

(2) There are certain restrictions on the target objects and the application scope of the calculation model. In this model, the evaluated object must be located in a mature urban construction area, not a developing area, and its surrounding area must be dominated by commercial and business offices, rather than residential buildings. For some commercial complexes in suburban areas, or with community-oriented services, their scale and internal functional composition are relatively homogeneous, and there may be a situation where one function dominates the other. Just as we eliminate outliers in the correlation analysis, for such cases, the calculation model may not be applicable. In addition, the complex should have a high degree of combined functions and a relatively centralized building layout rather than a scattered layout, which may result in external factors interfering with the formation of a diversity system.
6. Conclusions

With the development of urbanization in China, the urban spatial morphology is inevitably characterized by its high density and compactness. Furthermore, the aggregation of resources in the urban center will induce the diversification of commercial complex construction. Against the background of the improvement in resident demands and transformation of urban construction modes, online consumption behavior is becoming more popular. The convenience of e-commerce services has exerted significant impacts on traditional commercial complexes, resulting in a rapid saturation of their development [48]. In the future, urban commercial complexes will no longer be limited to commercial functions. Functions such as community service, landscape compensation and cultural output will be gradually implanted in the architectural form of complexes, which will continue to grow and expand in urban space as a form of resource agglomeration, thus generating a new spatial morphology to adapt to the sustainable development of cities. Hence, quantitative research and a comprehensive evaluation of their functional diversity are of great significance.

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