

Research On Planning and Design of University Technology Industrial Park Based on Modulus Space Theory - A Case Study of Southwest University of Science and Technology

Bin Cheng^{1*}, Qiushuang Feng¹, Yangliu Fu¹, Haifeng Lan¹

¹School of Civil Engineering and Architecture, Southwest University of Science and Technology, Mianyang, China

Email Address

chengbin@swust.edu.cn (B. Cheng), fengqiushuang@mails.swust.edu.cn (Q. Feng),
fuyangliu@mails.swust.edu.cn (Y. Fu), lanhaifeng@mails.swust.edu.cn (H. Lan)

*Correspondence: chengbin@swust.edu.cn

Received: 29 June 2018; **Accepted:** 20 July 2018; **Published:** 10 September 2018

Abstract:

University Technology Industrial Park as an independent economic entity, facing future unpredictable investment situation, its own spatial adaptability for different research enterprises on architectural space requirements is the key to sustainable development of the park. The planning and design of Southwest University of Science, considering the actual terrain of the base, adopting the modulus space, combining with the design modes of the network group and the courtyard group, the 8m×8m grid is superimposed in the base and the building module layout. In the planning structure, the design from the perspective of spatial flexibility, through the wrong and deformation techniques, and ultimately the formation of a unified style and rich form of architectural space. After the modularization of the building, the regular column network not only has a good economy, but also according to their own needs, flexible division of indoor space for settling scientific research units and enterprises. The spatial pattern created by the planning and design has good flexibility, successfully solved the problem of spatial flexibility, and solved the layout of the various functional zoning of the park. Additionally, adapting the layout of the different investment subjects lays the functional foundation for the smooth investment.

Keywords:

Modulus Space Theory, University Technology Industrial Park, Planning Structure, Urban Design, Southwest University of Science and Technology

1. Introduction

1.1. University Technology Industrial Park's Origins

University Technology Industrial Park (The following abbreviation is UTIP) originated in the United States, since the rise of "Silicon Valley" has passed 60 years so far. With the rise of Silicon Valley and other well-known science park, academia also started researching the theory of UTIP. Some researches on the construction of UTIP are mainly a comprehensive analysis, Hall and Castells in the "High-tech park of the world: the making of twenty-first century industrial complexes" that the park is "to promote the development of high-tech industry complex"[1]. The IASP's description of what science parks should have is as follows: creating new business opportunities for the enterprise; incubating entrepreneurs while also providing incubators for start-ups; providing a place of employment for the people gathered and innovative talents, strengthen the interaction between universities and enterprises, through these elements to achieve economic development [2]. The "Planning, Development and Operation of Science Parks" prepared by the British USTP Association explores the construction and development of the park from the perspective of the functional disposition of the park [3].

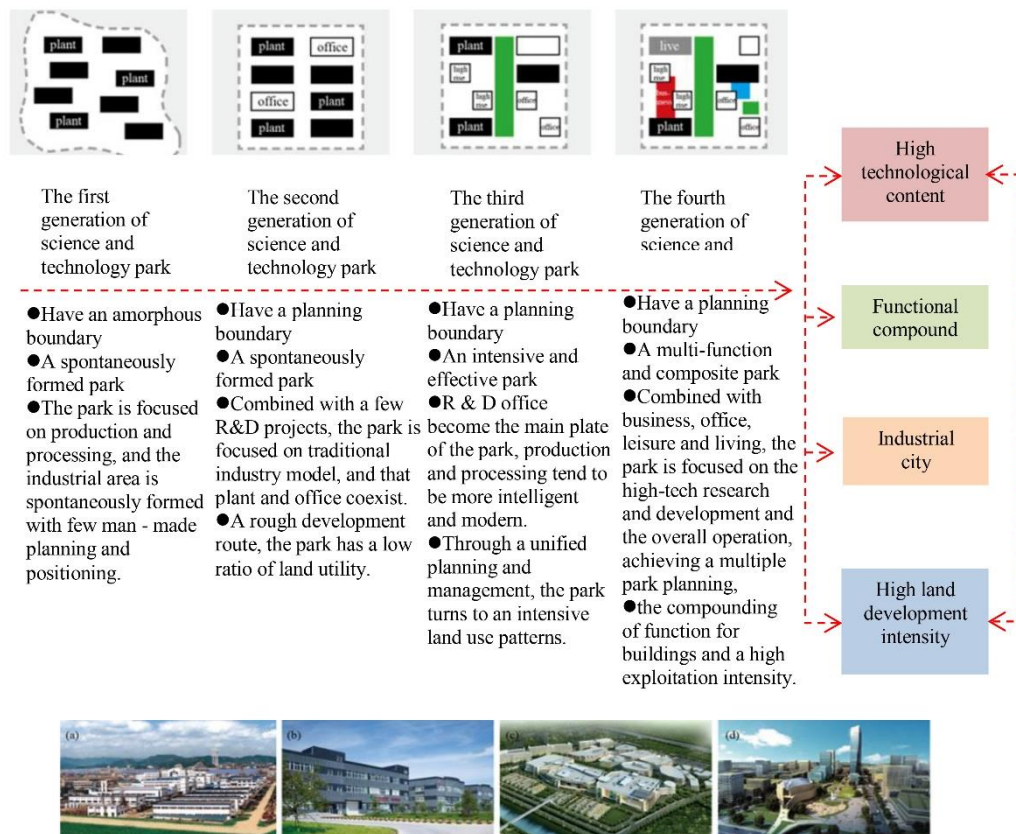


Figure 1. The historical stage and characteristics of the development of UTIP:(a) Pingyin Industrial Park, (b) Wuning Industrial Park, (c) Zhenjiang Industrial Park, (d) Xiuzhou Ecological Industrial Park.

1.2. Developmental Stages and Characteristics of UTIP in China

In the history of the development of UTIP [4] shown in Figure 1. The first generation of the park focus on production and processing, shown in Figure 1(a), which has amorphous boundaries. The second generation of the park apply a small amount of research and development to adjust the traditional industry, and the construction that plant and office coexist present a low and empty sight, shown in Figure 1(b). R&D office became the main plate in the third-generation park model,

and land mode tend to intensive, shown in Figure 1(c); the fourth generation of the park focus on the high-tech research and the overall operation, then forming a multi-functional compound park space, shown in Figure 1(d).

1.3. The Historical Stage and Characteristics of the Development of UTIP

Using talent, technology, information, laboratory equipment, cultural atmosphere and other comprehensive resource advantages of the university, through diversified investment channels including venture capital, under the government policy guidance and support, UTIP is a kind of the university-based high-tech park that is engaged in technological innovation and enterprise incubation activities near the university. The park is the base of technological innovation in colleges and universities, the base of high-tech enterprise incubation, the base of innovation and entrepreneurship gathering and cultivation, and the base of high-tech industry radiation catalytic [5]. The planning of today's university science park is subjected to internal factors and external objective conditions, described in Figure 2, so the development of University must rely on its own advantageous subjects and cooperative enterprises.

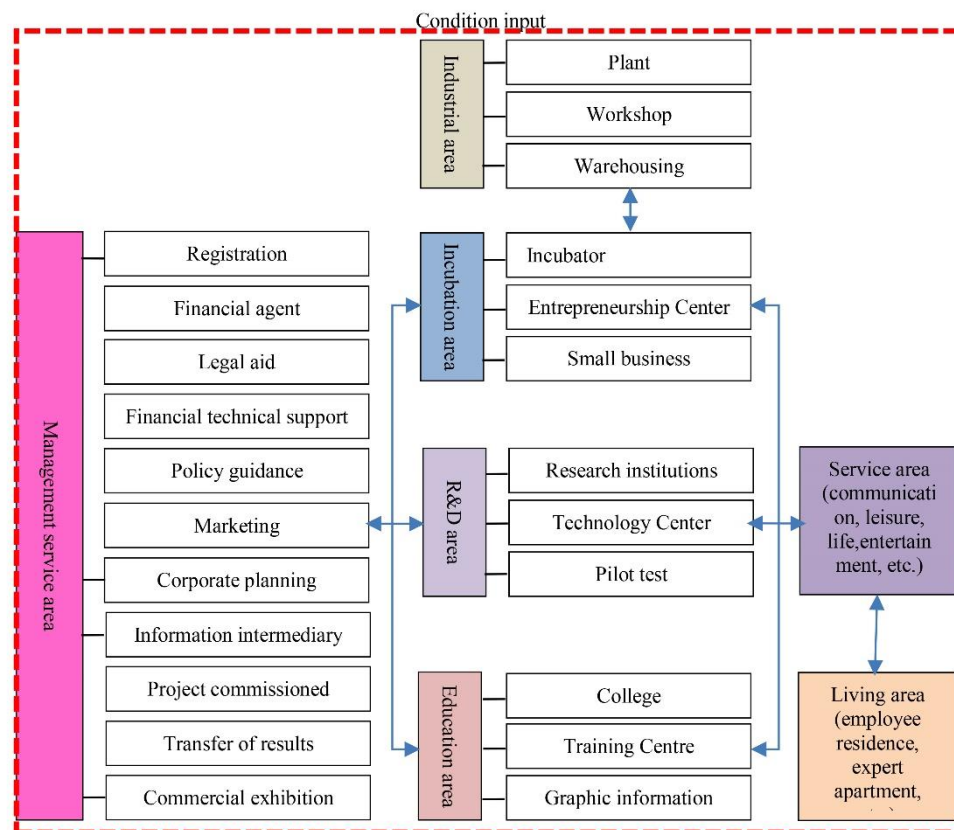


Figure 2. The internal functional structure of UTIP.

1.4. The Planning Challenges of the Construction of SWUST 's UTIP

The factors of making planning and design, some are determined. For example, the square blocks are limited, the dominant industries and disciplines are clear, the urban structure and function positioning is clear, but there are many uncertain conditions, such as all kinds of indefinite investment enterprises come in with uncertain scale, shape uncertainty, industrial type [6]. How to adapt this kind of development to the current urban design to complete a planning and design of industrial park that can

dynamically adjust the space to be transformed and forming a uniform style, mainly considers the following three aspects [7]. Firstly, how to organize functional modules to adapt to the unpredictable investment situation, followed by how to create high-quality environmental space in the park while addressing the variable combination of building functions, and how to combine the S&T resources between Southwest University of Science and Technology Park and Mianyang City, described in Figure 3. In the face of these problems, the modular design under the concept of modeling space can better adapt to the requirements of the block and Party A.

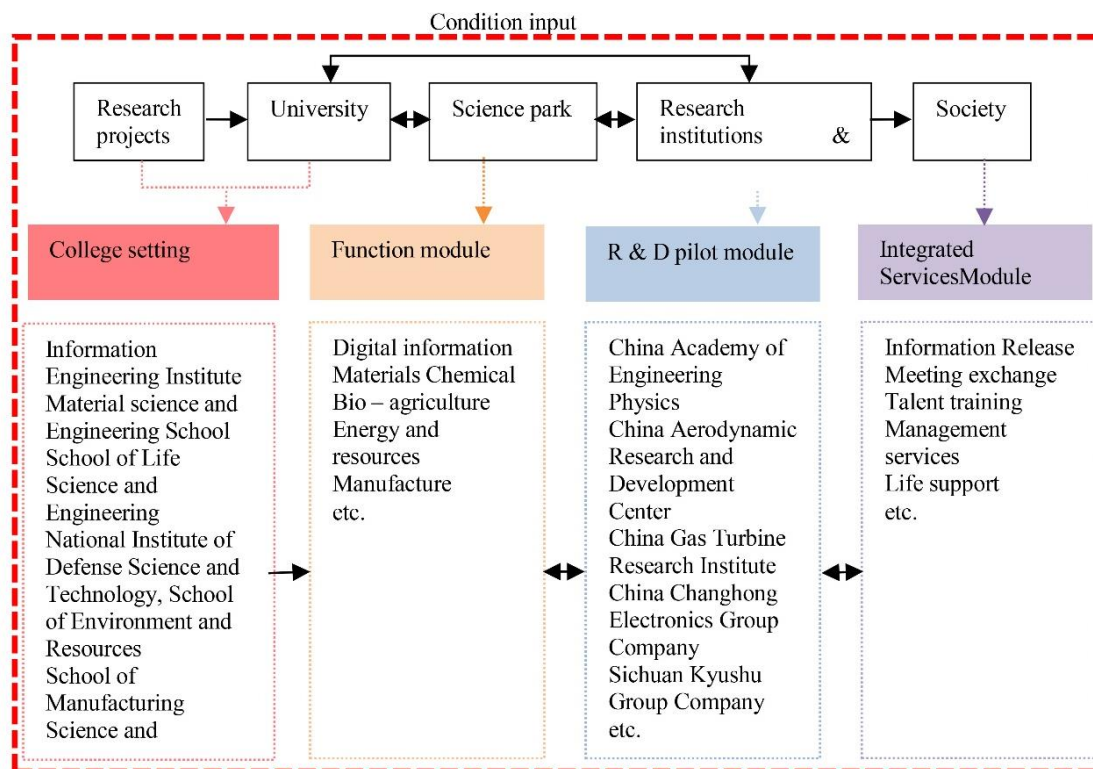


Figure 3. The advantageous subjects and cooperative enterprises of Southwest University of Science and Technology Park.

1.5. The Historical Stage and Characteristics of the Development of UTIP

The idea of modeling design under the modeling space can be traced back to the early structuralist period, In order to pursue the overall flexibility and adaptability of the building structure, A number of architects like Norman Foster and Pico have always been inclined to explore a new structure style [8]. By their influence, people's exploration of the structure did not just stay in the construction of the mechanical structure, but also began to explore their own internal organizational structure of the entire city and building, Especially the later "metabolism". They have been opposed to an unchangeable state of modernism, and hold that it lacks "the view that they evolved over time ". They use the growth process of the natural body as a research model to study the "eternal structure" of urban development, and advocate "Growing building" and "process design"[9]. They introduce the concept of organic organization into the construction field, emphasizing that the interior of the building should have a systematic and organic structure [10].

Modular, under the modeling space, unlike the building modulus system we thought, is also different from the industrial products that using modular standardized

production [11], but also to meet the needs of realistic and practical, and also for the convenience in the design, construction and future expansion design. Combined with ergonomic research, the designer divided the typical space on the basis of use functional and summarize a reasonable spatial organization that plane grid, structural column net, light-weight partition and equipment layout man use [12]. This organization can meet the needs of flexible and diverse, but also leave room for future extension design. This approach is a good way to ensure the flexibility of the building space, and this modeling design guarantee the integrity and growth of phased work, reflecting the growth of a sustainable. The idea of “modular thinking” and “growing building” has been developed in Urban planning, such as the University of Jordan Moore and Algeria Oran University, which de-signed by the Japanese late architects Kenzo Tange, seen in Figure 4.

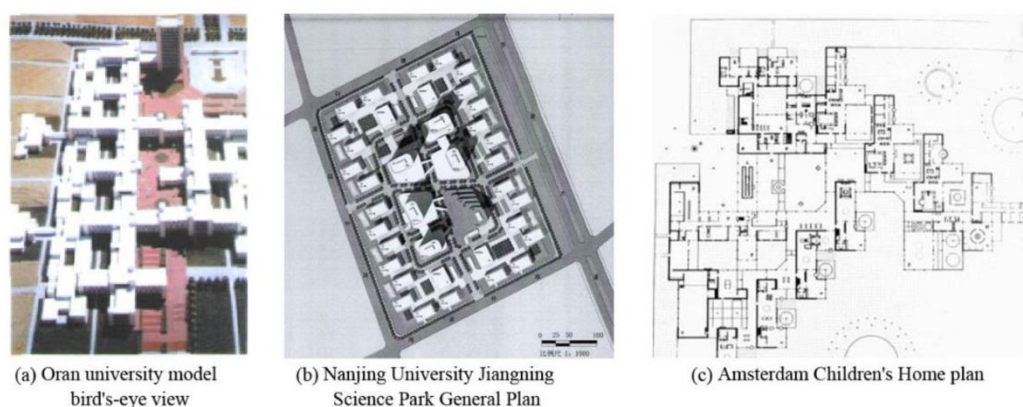


Figure 4. Practice of urban planning and architectural design under the concept of modeling space: (a) Oran university model of a bird's-eye view, (b) Nanjing University Jiangning Science Park General Plan, (c) Amsterdam Children's Home Plan.

2. Materials and Methods

2.1. Flexible Modulus Multiples System

Derived from the Latin "Modulus", the term "module" refers to the smallest unit of measure [13]. As the benchmark for building space and component size changes, module is first used in construction. Its function is to simplify the size of the components in an industrial building, making it reasonable and simple to achieve the purpose of size matching [14]. In the area of urban planning, the module makes it possible for land to be reasonable simplicity and flexibility to consolidate and divide, laying the theoretical basis for land use, neighborhood division and development timing flexibly and orderly [15]. Modeling system is based on the spatial module that multiply 1000m by 900m gives 90 hectares, which is composed of the basic modulus that 500m times 300m is 15 hectares, then forming an elastic modulus multiple system of 90 hm², 60 hm², 45 hm², 30 hm² and 15 hm².

According to the system, there are four levels of base scale that can apply to high-tech park. (a) An area of 90 hectares is suitable for general multinational enterprise to construct its core production base. (b) An area of 60 hectares is suitable for large enterprise base construction, also suitable for a comprehensive university campus or a residential area. (c) An area of 30-45 hectares is suitable for medium-sized enterprises

base or an independent college. (d) An area of 15 hectares is suitable for small and medium enterprises. Figure 5 shows the modeling space concept.

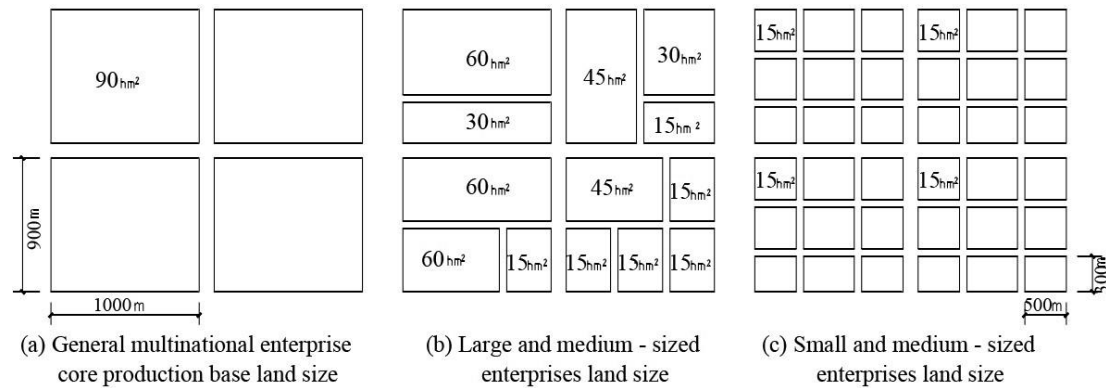


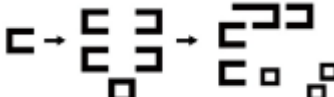
Figure 5. Modeling space concept map: (a) General multinational enterprise core production base land size, (b) Large and medium - sized enterprises land size, (c) Small and medium - sized enterprises land size.

2.2. The Spatial Structure of University Science Park under the Idea of Modulus Space

In the large residential area planning, campus planning and park planning, there are six kinds of space group approach are described in Table 1. Due to the uncertainty of function, the problem of space change and combination can be resolved well by the modeling space. Therefore, the courtyard group and grid group become two main methods of spatial composition [16].

Table 1. Types and characteristics of space group.

Group type	Pattern	Introduction
Centripetal cluster structure		Dominated by a major central space, and the rest of the building is surrounded by a ring. Applicable to larger central groups.
Courtyard cluster structure		Based on the arrangement of the teaching building, though special extraction and modeling deformation, forming a cohesive enclosing area. Applicable to group structure.
Giant cluster structure		Though the connection the interspersed and the occlusion, the inner special element of the teaching area forms an accumulation, freedom, flow, continuous, open and other characteristics space. Suitable for the group structure of a strong visual impact.
Tree cluster structure		The groups formed by the unit linear array of the most basic teaching, through the axis of the trunk to form a group space of the tree pattern. Suitable for long-shaped campus,

		emphasizing the design of the walking series.
Grid cluster structure		Take the network as a skeleton, and in the form of rules to form a multi-level campus space environment. Apply to create a rigorous and orderly teaching area space.
Scatter cluster structure		The scattered public buildings and the regular teaching groups form a strong contrast and layer contrast in space shape. Applicable to the cluster of that there are more public buildings.

2.3. Formation of Courtyard form Under the Concept of Modeling Space

In the courtyard cluster structure, each institution around a courtyard as a unit, attributed to the definition of a typical space, comprises "individual cells" [17]. Then a group of such cells together to make up an entire system that keeps closely contact, both to meet the needs of the building image, but also provide convenience for future use and expansion, without changing the original appearance of the building [18]. The architectural pattern is also different from the basic fixed mode of the traditional office or R & D space, but instead use large space, no interval design, unified layer, uniform column network and unified load, showing a transparent and extended large plane [19]. The biggest advantage is that it can re-divide the space for use in the future according to their needs, "divided into two" or "combined" that will become easy, without having to go to work. Figure 6 shows the formation of courtyard form under the idea of modeling space.

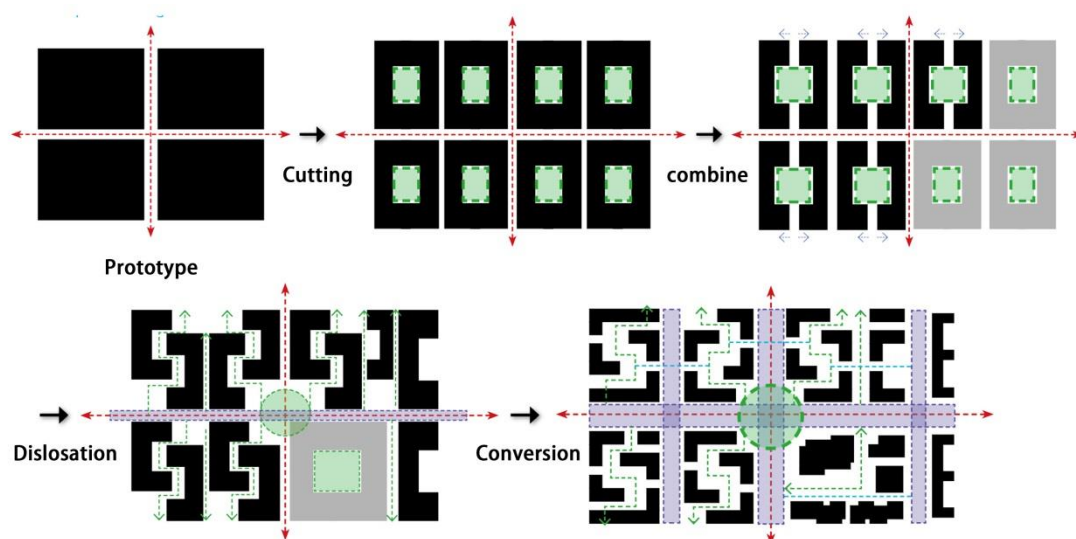


Figure 6. Formation of courtyard form under the concept of modeling space.

2.4. The Possibility of a Combination of Scientific Research, Experiment, and Office

UTIP have many buildings, mainly for research and development and production category [20]. From the point of the high-tech research and product development, the space of R & D lab is not necessarily large, the requirement of lab except special

experimental room is no different from commercial office, but it have a significant ancillary facility requirement such as computer room, library information center, conference office space, auxiliary workshop and warehouse. Due to the diversity and uncertainty of the use function, R & D type of architectural space layout should tend to simplify the structure, in order to provide maximum flexibility to arrange the building space, while providing adequate and pleasant communication space. It should be arranged in the park, which is relatively quiet, comfortable plots, to form a good environment, which is suitable for mental work. In the actual construction and planning process, such functions and the office function often layout in different areas of the same building[20], when the park first start out, such functions are arranged in the same building with incubation and management.

The production of high-tech products generally included pilot production and large-scale industrial production. In the UTIP, the manufacturing function is weakened. This type of building is suitable for the design of a general plant model, that 6m or 8m is appropriate for inter-bay or column network to, and according to production process of different types to flexibly separate the building space. Such as electronic information, new materials, new energy and bio-engineering production, in the architectural design, the feasibility of combining them is a key consideration [21]. Figure 7 shows the possibility of a combination of scientific research, experiment, and office.

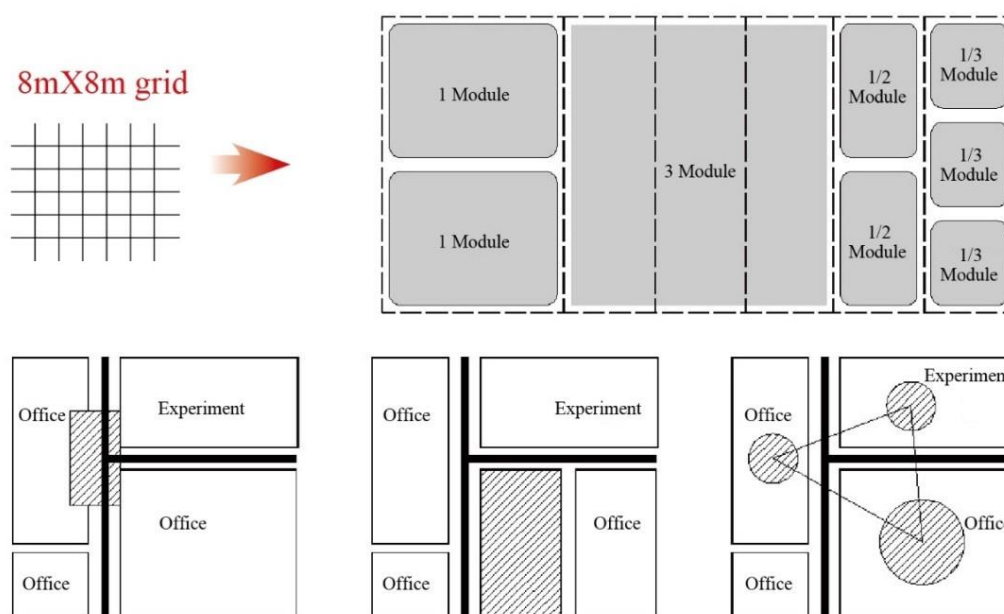


Figure 7. The possibility of scientific research, experiment, office combination.

3. Results

3.1. General Layout and Functional Relationship

Southwest University of Science Park is located in the southeast of Southwest University of Science and Technology, the total planned area of 4.98 hectares, with a total construction area of about 73,000 square meters, shown in Figure 8. The entire park is divided into several major parts, namely, the main park, R & D area, industrial area [22], training area, public construction supporting area, residential area and centralized greening area, shown in Figure 9. Its functional combination mode adopts

the combination of concentration and decentralization, the functional partitioning is relatively clear, the services between functional areas are mutually infiltrated, and the research and development support each other. The delineation of functional areas needs to determine the allocation of various functions of industrial parks. The basic principle of planning is to embody the ecology of hi-tech parks and to intensify the use of land.



Figure 8. The plan of UTIP for Southwest University of Science and Technology and its perspective view.

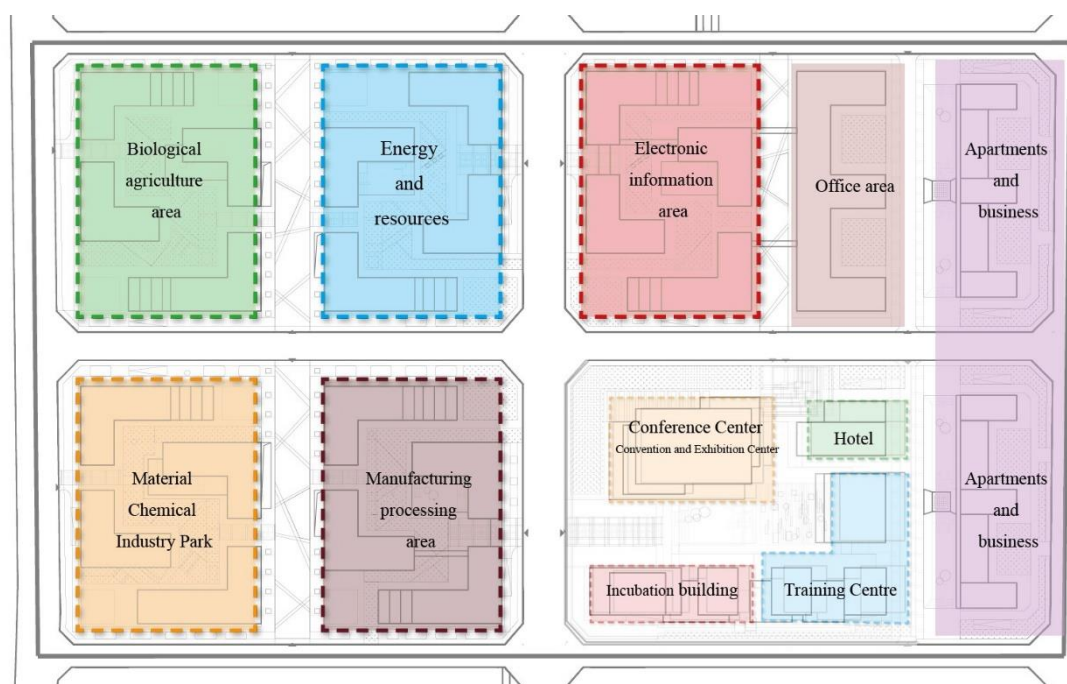


Figure 9. The functional relationship.

The purpose of the planning is to build an industrial park of science, technology and research and development so as to determine the functional allocation proportion of the Southwest University of Science Park.

3.2. Monomer Typical Flat Design

The R & D single building use the modernist architectural vocabulary, exterior design focus on simple and neat, not vulgar detail decoration, reflecting the principle of the times spirit of beyond science and technology park [23], shown in Figure 10. At the same time with the natural environment and climate of Mianyang, as much as possible to take the natural ventilation and sunshine, spatial management emphasizes

the indoor and outdoor close combination and cross-transition, arrange the courtyard, terrace, balcony, rooftop and corridor, and layout local green landscape in the open or semi-open space.



Figure 10. A perspective view of the building.

3.3. Group Morphology

The combination of different volume of construction and large-scale decomposition, contributing to the different size block scattered layout. While to maintain the overall coordination[24], each block which has different characteristics combined different combinations forming a complex with some rules, shown in Figure 11.

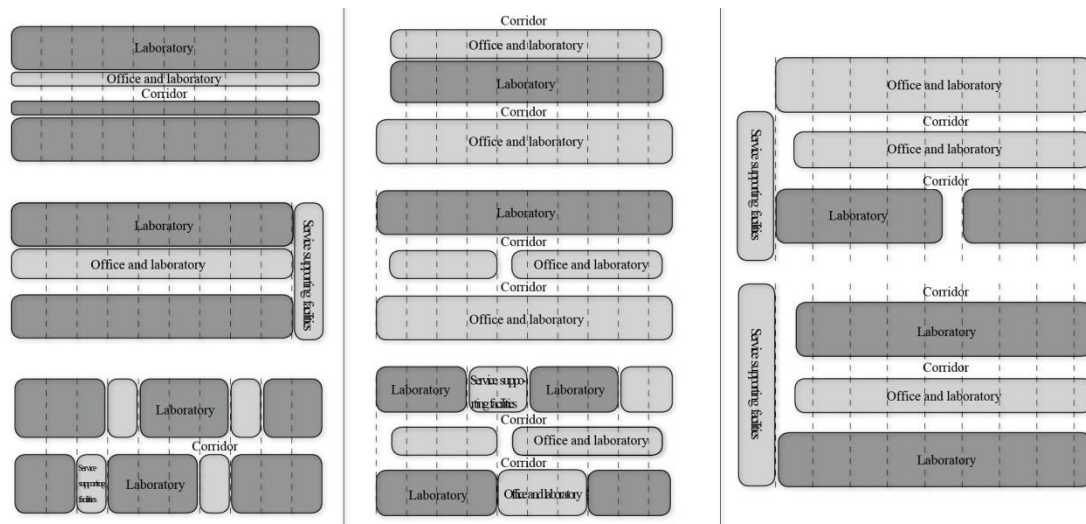


Figure 11. The relationship of the function between Office of Science and Technology Park and R & D.

4. Discussion

4.1. Construction Scale

University Science Park is mainly engaged in research and development activities, as well as the incubation of scientific and technological achievements, the main product is the research report and style. And its research, development and production linkages do not require a lot of material transport, which is different from the conventional industry requires a lot of plant and land [25]. Therefore, the land use scale of the University Science Park is generally not large, too large scale easy to bring management inconvenience, resulting in rising operating costs. At the same time, the high-tech industry itself does not need much land. Instead, it will rather diffuse and divide its work in a wider geographical area without having to concentrate its research and manufacturing enterprises in one place. On the other hand, too small a size would sacrifice some of the features that a complete community should have, resulting in uneconomic investment in infrastructure [26]. Generally believed that, taking into account the requirements of high-tech industries and space, the integrity of the community environment, the best operating efficiency, the size of the Park is generally 3 to 5 square kilometers is appropriate [27]. Of course, this is not absolute. The size of a university science park must also be determined according to the level of economic development, intelligence resources, technological development conditions, and the size of environmental capacity in a given area.

4.2. Architectural Space Morphological Change Optimization Problem



Figure 12. Typical combination of architectural functions.

In the design, the use of Modular space theory is one of social trends nowadays. A corridor and outdoor courtyard provide a good exchange place for different professional and enterprises, which could light up the atmosphere of the park, truly reflects the sharing of resources, and the advantages of interdisciplinary [28]. It also meets the requirements of modern intelligent building in integrated cabling systems

and multipoint access sources. The biggest advantage of this modularity is that it can fully implement the principle of openness, this permit entries in the table to be accessed randomly. The combination of the relationship is shown in Figure 11. At the same time, the combination of building both include the hall space, open space and open-bay inter-building combination, which are well adapted to the needs of research and development and high-tech enterprise production needs, shown in Figure 12.

4.3. The Relationship Between Building Function and Courtyard

Positioning this kind of modular spatial form can also be changed freely to suit different building scale and building combination. Under the basic "Gestalt", you can use different technical methods such as digging, overhead, setting back to form different spatial form, shown in Figure 13. At the same time, though the wrong techniques to form an enclosed, semi-enclosed courtyard form, making the architectural courtyard space changes and interesting, and improving the architectural vision and landscape effects [29]. Figure 14 shows the building function combination and courtyard relationship establishment diagram, you can choose the latter two combinations to form courtyard space.

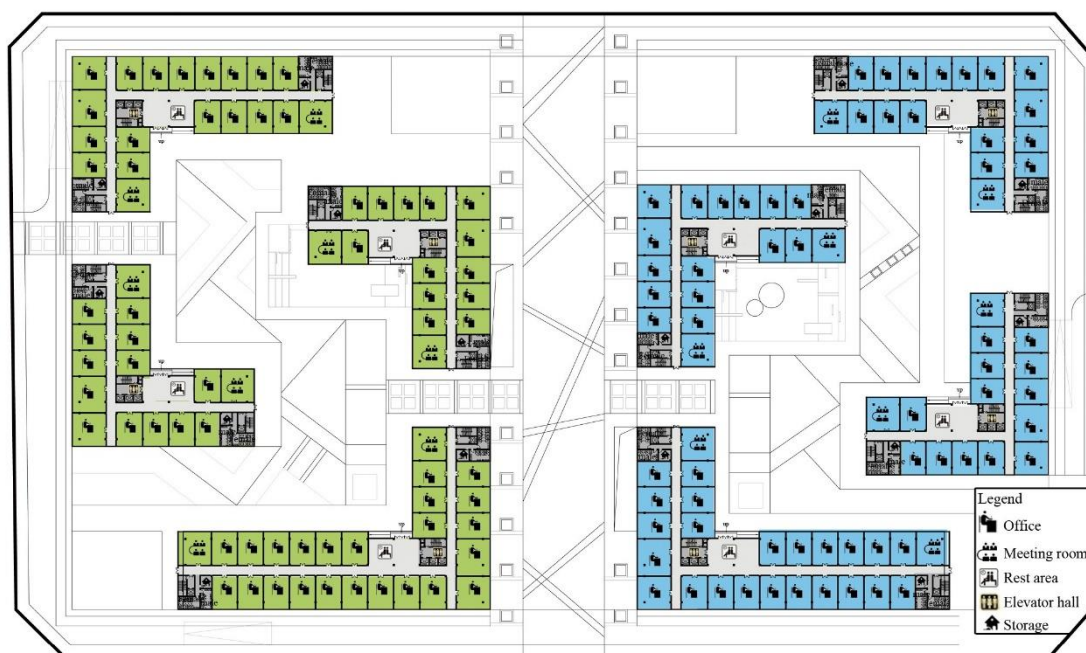


Figure 13. Map of the building on the ground.

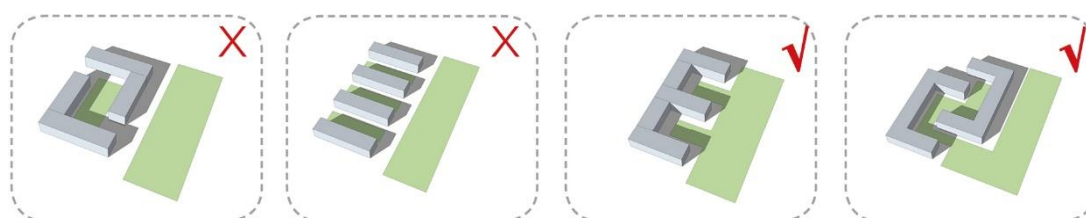


Figure 14. Schematic diagram of the relationship between building function and courtyard.

5. Conclusions

The planning of Southwest University of Science and Technology, whether discuss the structural planning itself or the theoretical research and case reference, have

carried out a certain degree of technological innovation and determined the proportion of functional distribution of industrial parks and the scale of the public construction supporting. Giving a scientific inference and explaining the reasons based on the subjective data in the past industrial park planning, which reflects the scientific planning. The introduction and application of the concept of modeling space is the highlight of the planning of Southwest University of Science and Technology. In the past, some structural plans of industrial parks only put forward the concept of a structure, meaning that planning and design around the circle, axis, nodes etc., little theoretical use and theoretical improvement. Some planning introduced the concept of theoretical depth, such as eco-city, circular economy, but in the real application to the planning layout, it is inevitable that there is a disconnect between theory and practice [30]. For its part, the concept of modeling space study the basic principles of space structure to guide the specific planning and design, both theoretical and practical, achieving the technological innovation and theoretical upgrading. Consequently, it can be very good way to guide space layout of the industrial park.

Finally, on use of the concept of modeling space in planning and design, there are two things should also be noted. One is an adequate venue. Based on geographical characteristics, not any terrain can use this design method, and the perfect combination of the method and the site environment is complied with the principle that need to be followed. The other is that each typical space and plane treatment should avoid monotonous and "unified". Human's emotional needs are always rich and colorful, the spatial positioning is not the same for everyone, which requires a different space to carry the meaning of different events. In the specific design, it's important for us to employ flexible and diverse methods to meet the emotional needs of each individual.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Acknowledgments

We greatly appreciate all the help of the design team of Southwest Architectural Design Institute.

References

- [1] Castells, M.; Hall, P. *High-tech park of the world : the making of twenty-first century industrial complexes*; Routledge: London and New York, 2009; 73-108; ISBN:1317858174.
- [2] Zhong, S.H. *Theory and Practice: on Construction of Science and Technology Park*, 2nd ed.; Economic Science: China, 2014,1-186; ISBN: 9787514143058.
- [3] Yang, J. Research on optimization of university science park in the incubation operation of high-tech enterprises, *Inno. Technol.* 2017, 11, 63-65. DOI: 10.19345/j.cnki.1671-0037.2017.11.016.
- [4] Zhang, L. Advantages and Suggestions of high-tech enterprise incubation and operation in university science park. *Sci. Technol. Chin. Univ.* 2017, 10, 83-85, DOI: 10.16209/j.cnki.cust.2017.10.028.

- [5] Yang, C.; Li, L.; Yong, W. Research on the incubation system construction of university science park. *Chin. Technol. BBS*. 2006, 01, 73-77, DOI: 10.13580/j.cnki.fstc.2006.01.016.
- [6] Chao, Y. Study on the external space design of university science park. M.S. Hunan University, Hunan, China, June 22th, 2004.
- [7] Gao, B. Comprehension on Modelizing Design from a Campus Planning. *Chin & overseas archit.* 2007, (03), 59-60, DOI: 10.13530/j.cnki.jlis.2007.02.009.
- [8] Bao, Y. Study on external space morphology of university science and technology park -- a case study of university science and technology park of Jinling university. PhD, Southeast University, Guangzhou, China, January 1st , 2013.
- [9] Yang, G. Discussion on the architectural design of university science and technology industrial park -- taking the architectural design of the national science and technology park of xiamen university as an example, *Const. Mater. & Deco.* 2016, (7), 91-93, DOI: 10.7666/d.y1714741.
- [10] Liu, Q.; Li, J. Innovative space nuclear design of university science park -- taking national university science park of southwest university of science and technology as an example. *Constr. Mater. & Deco.* 2018, 15, 63-64, DOI: 10.3969/j.issn.1673-0038.2018.15.050
- [11] Lian, H.; Zhu, W. Modern industrial park - History, Trends and Strategies. In *Ideal Space*; Di, H., Lu, S., Eds.; Tongji University Press, Shanghai, China, 2007, 23, 7-9.
- [12] Huang, J. Research on the spatial model of incubator development in national university science park, *Sci. Technol. Chin. Univ.* 2010, 3, 59-61. DOI:10.3969/j.issn.2095-2333.2010.03.021
- [13] Ramaji, I. J.; Memari, A. M. Product Architecture Model for Multistory Modular Buildings. *J. Constr. Eng. Manag.* 2016, 142, 36-47, DOI: 10.1061/(ASCE)CO.1943-7862.0001159.
- [14] Solnosky, R. L.; Memari, A. M.; Ramaji, I. J. Structural BIM processes for modular multi-story buildings in design and construction. 2st Residential Building Design & Construction Conference, Penn State University Park, America, February 19-20; 2014.
- [15] Ramaji, I. J.; Memari, A. M. Identification of structural issues in design and construction of multi-story modular buildings. 1st Residential Building Design & Construction Conference, Sands Casino Resort, Bethlehem, February 20-21; 2013.
- [16] Lawson, R. M.; Ogden, R. G.; Bergin, R. Application of Modular Construction in High-Rise Buildings. *J. Archit. Eng.* 2012, 18, 148-154, DOI: 10.1061/(ASCE)AE.1943-5568.0000057.
- [17] Sharafi, P.; Samali, B.; Ronagh, H.; Ghodrati, M. Automated spatial design of multi-story modular buildings using a unified matrix method. *Autom. Constr.* 2017, 82, 31-42, DOI: 10.1016/j.autcon.2017.06.025.
- [18] Mitterhofer, M.; Schneider, G. F.; Stratbucker, S.; Sedlbauer, K. An FMI-enabled methodology for modular building performance simulation based on Semantic

- Web Technologies. *Build. Environ.* 2017, 125, 49-59, DOI: 10.1016/j.buildenv.2017.08.021.
- [19]Hu, X.; Ma, X.; Dong, X.; Cao, C.; Du, H.; Chen, Z. The prediction of elastic modulus of the mullite fiber network based on the actual structure architecture. *Ceram. Int.* 2017, 43, 16107-16113, DOI: 10.1016/j.ceramint.2017.08.173.
- [20]Bakouros, Y. L.; Mardas, D. C.; Varsakelis, N. C. Science park, a high tech fantasy?: an analysis of the science parks of Greece, *Technovation*, 2002, 22, (2), 123-128, DOI: 10.1016/S0166-4972(00)00087-0.
- [21]Phillimore, J. Beyond the linear view of innovation in science park evaluation. An analysis of Western Australian Technology Park. *Technovation*, 1999, 19, 673-680, DOI: 10.1016/S0166-4972(99)00062-0.
- [22]Farré-Perdiguer, M.; Sala-Rios, M.; Torres-Solé T. Network analysis for the study of technological collaboration in spaces for innovation. Science and technology parks and their relationship with the university. *Int. J. Educ. Technol. High. Educ.* 2016, 13, DOI: 10.1186/s41239-016-0012-3.
- [23]Siegel, D. S.; Westhead, P.; Wright, M. Assessing the impact of university science parks on research productivity: Exploratory firm-level evidence from the United Kingdom. *Int. J. Ind. Organ.* 2003, 21, 1357-1369, DOI: 10.1016/S0167-7187(03)00086-9.
- [24]Albahari, A.; Pérez-Canto, S.; Barge-Gil, A.; Modrego, A. Technology Parks versus Science Parks: Does the university make the difference? *Technol. Forecast. Soc.* 2017, 116, 13-28, DOI: 10.1016/j.techfore.2016.11.012.
- [25]Wright, M.; Liu, X.; Buck, T.; Filatotchev, I. Returnee Entrepreneurs, Science Park Location Choice and Performance: An Analysis of High-Technology SMEs in China. *Entrep. Practice Theory.* 2008, 32, (1), 131-155, DOI: 10.1111/j.1540-6520.2007.00219.x.
- [26]McAdam, M.; McAdam, R. High tech start-ups in University Science Park incubators: The relationship between the start-up's lifecycle progression and use of the incubator's resources. *Technovation*, 2008, 28, (5), 277-290, DOI:10.1016/j.technovation.2007.07.012.
- [27]Chan, K. F.; Lau, T. Assessing technology incubator programs in the science park: The good, the bad and the ugly. *Technovation*, 2005, 25, 1215-1228, DOI:10.1016/j.technovation.2004.03.010.
- [28]Zou, Y.; Zhao, W. Anatomy of Tsinghua University science park in China: Institutional evolution and assessment. *J. Technol. Transf.* 2013, 39, 663-674, DOI:10.1007/s10961-013-9314-y.
- [29]Jang, H.; Lucy, J.; Kang, J. Prioritisation of old apartment buildings for energy-efficient refurbishment based on the effects of building features on energy consumption in South Korea. *Energy Build.* 2015, 96, 319-328, DOI: 10.1016/j.enbuild.2015.03.027.
- [30]Špegelj, T.; Žegarac, L. V.; Premrov, M. Application of the timber-glass upgrade module for energy refurbishment of the existing energy-inefficient multi-family buildings. *Energy Build.* 2016, 116, 362-375, DOI: 10.1016/j.enbuild.2016.01.013.



© 2018 by the author(s); licensee International Technology and Science Publications (ITS), this work for open access publication is under the Creative Commons Attribution International License (CC BY 4.0). (<http://creativecommons.org/licenses/by/4.0/>)