Journal of Civil Engineering and Urban Planning (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/jceup.2024.060410
ISSN 2616-3969 Vol. 6 Num. 4

Exploration of University Planning and Design under the Concept of Multi Objective Optimization

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Keywords: Multi-Objective Optimization Idea; College Academy; Planning and Design

Abstract: In recent years, with the continued increase of university enrollment, the contradiction between insufficient campus space capacity and infrastructure and the increasing number of university students has been increasingly apparent. In this context, Dalian Polytechnic University has issued a campus expansion plan for the bidding of the North Campus, on which the design of this building is based. To secure design results, this project provides a multi-objective hierarchical system based on the existing circumstances and design aim, consisting of four components: functional composite distribution, spatial multi-level perception, cultural inheritance and innovation, and academy style architecture. Balance optimization is applied to the target layer using the multi-objective optimization principle to maximize the total result. Finally, a subjective satisfaction evaluation was performed on the planning and design outputs, yielding an overall satisfaction rate of 86%. This was used to assess the effectiveness of the multi-objective architecture, which is based on the multi-objective optimization principle.

1. Introduction

Since 2000, China's Ministry of Education has developed a construction strategy to fiercely develop higher education, resulting in increased popularity of higher education. With the continuing expansion of enrollment over the years, the disparity between existing campus space and infrastructure and the growing student population has become more apparent. This contradiction drives campus space renewal planning and design to become a trend in development. This contradiction drives campus space renewal planning and design to become a trend in the evolution of university planning and design. Renovation and enlargement projects face more complicated and diversified difficulties than new campus construction, with sharper conflicts that necessitate multidimensional adaptation to the old site[1].

2. Dalian Polytechnic University North Campus: Current Situation and Engineering Overview

2.1. Current circumstance analysis

According to the current situation and long-term planning, Dalian Polytechnic University adheres to the principle of strict and tight, and does its best. Dalian Polytechnic University adheres to serving the development of the university and meeting the needs of talent training. Dalian Polytechnic University insists on highlighting its school-running characteristics and coordinating the North and south campuses. Dalian Polytechnic University formulated the overall plan, implemented the construction step by step, and drafted the overall plan of the North campus. The basic situation of the venue is shown in Figure 1.

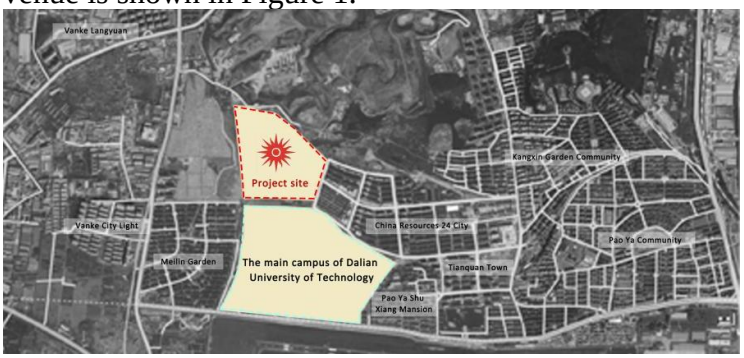

Figure 1: Overview of the surrounding area of the site

2.2. Project overview

The area of Dalian University of Technology's North Campus is approximately 481.65 mu. The area covered by the red line is 296793 ㎡, while the area after the line is withdrawn is 277000 ㎡. The road system encircling the property is still undeveloped. In the foreseeable future, the existing Songjiang Road and Zhangqian Road will continue to be used for the municipal planning of ZhangQian Road, Qianshan Road, and No. 1 Road. The University of Technology's new and old campuses are easily accessible for external communication and travel, and the excellent planning has created the ideal regional transportation infrastructure. The current, unfinished river channel is located on the west side of the north campus. The current cement plant mining area is located on the northeast side. Total construction area: 192300 ㎡, phase I construction area: 97400 ㎡.

3. Design Considerations

3.1. Design concept

The overarching planning and design concept for the North Campus of Dalian Polytechnic University is characterized as "foundational, innovative, coordinated, and human-centric." This development concept seeks to provide a contemporary campus characterized by cutting-edge science and technology, an aesthetically pleasing environment, and vibrant energy for the northern campus. The integration of the "mountain and sea city" concept establishes the comprehensive planning framework of "one axis, one belt, and three areas," so contributing to the development of a premier institution in Dalian.

3.2. The concept of multi-objective optimization

When there are many objectives in the optimization problem that must be optimized simultaneously, it is referred to as multi-objective optimization as opposed to single objective optimization. It is challenging to identify a single optimal solution in multi-objective optimization because of the inherent conflicts between several objectives. Rather, to reach the best ultimate goal, a thorough and well-coordinated comparison of several aims is required. Multi-objective optimization is currently widely employed in a variety of domains, including Internet algorithms and engineering design[2].

3.3. Building a multi-objective hierarchical structure

The multi-dimensional optimization design of the suggested plot is carried out under the design concept's tone with the aid of the multi-objective optimization concept in the hopes of eventually achieving the maximum of the comprehensive objectives, including the composite distribution of functions, reasonable spatial structure, cultural inheritance and innovation, and college architecture. Table 1 illustrates the construction of a multi-objective hierarchical system based on this. The following are the specific contents[3]:

Table 1: Multi Objective Hierarchical System

Primary target	Secondary target	Tertiary target
Function compound distribution	land function structure analysis	land function structure analysis
	Single function configuration	food center
		dormitory
Spatial multi-layer perception	planning Spatial structure	planning structure
		Traffic network structure
		Roaming walking road structure
		Vertical elevation structure
	Courtyard space sequence	single courtyard space
		Combined courtyard space
	"Point, line and plane" landscape sequence	"point" landscape
		"linear" landscape
		"Face" landscape
Cultural inheritance and innovation	Combination of square and square	Overall planning
		Planar form
		Facade decoration
	Selection of materials and colors	Selection of materials and colors
	The orientation of the dormitory is uniform	The orientation of the dormitory is uniform
	Physical environment simulation	Sunshine simulation analysis
		Noise simulation analysis
		Wind field simulation analysis
Academy architecture	Spatial layout	Spatial layout
	Landscape construction	Landscape construction
	Architectural decoration	Architectural decoration
	Cultural atmosphere	Cultural atmosphere

4. Planning and Design

4.1. Composite Distribution Function

4.1.1. Analysis of the Structure of Land Use Functions

The property is segmented into four sections: teaching and research area, comprehensive exchange area, student dwelling area, and sports activity area, as illustrated in Figure 2. The initial phase of construction will prioritize the food discipline teaching building, the majority of student apartments, the student canteen, the comprehensive teaching building, and the scientific and technological achievements transfer and incubation base, along with other significant ancillary facilities. Subsequently, the library, art education facility, international exchange and cooperation center, and gymnasium will be constructed in succession[4].

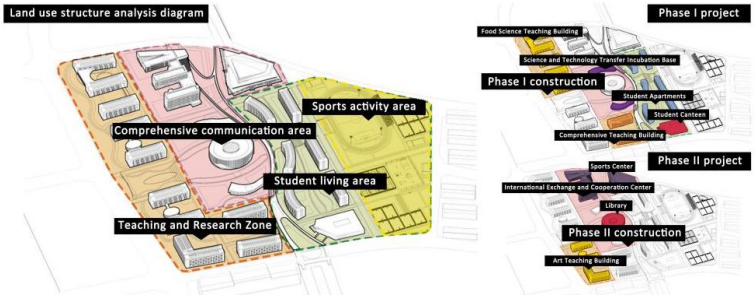

Figure 2: Plan group analysis

4.1.2. Primary Unit Function Configuration of Phase I Project

(1) Culinary Center

The design incorporates a logical arrangement of students' service facilities, including supermarkets, banks, postal services, and barber shops, while the functional zoning and spatial configuration of the canteen are thoughtfully aligned with the site's elevation variations. The designated construction space of 45,000 square meters for student housing on the north campus may accommodate 4,500 students, and a canteen of 8,000 square meters is suggested, as illustrated in Figure 3.

(2) Building for the instruction of food subjects

The educational facility will amalgamate contemporary pedagogical principles with the specialized attributes of food science to establish a holistic learning environment that encompasses knowledge dissemination, skill development, and research innovation,as depicted in Figure 3.

(3) Comprehensive educational facility

The design of the educational facility will thoroughly account for the integration and connectivity among various functional areas, ensuring that the classroom, autonomous learning center, lecture hall, and other spaces can operate independently while also facilitating convenient transformation and collaboration, thereby accommodating diverse teaching activities, as illustrated in Figure 3.

(1) Student accommodations

The apartment is designed in a courtyard configuration, with the main structure separated by the courtyard prototype. Despite minor variations in their shapes, the essence of the functional structure remains consistent, as illustrated in Figure 3.

(2) Incubation platform for the dissemination of scientific and technological advancements

The design highlights the intimate connection between colleges and universities, businesses, and markets. The construction of collaborative R&D centers and internship and training bases fosters

collaboration among industry, academia, and research, thereby expediting the transformation and implementation of scientific and technological advancements, as illustrated in Figure 3.

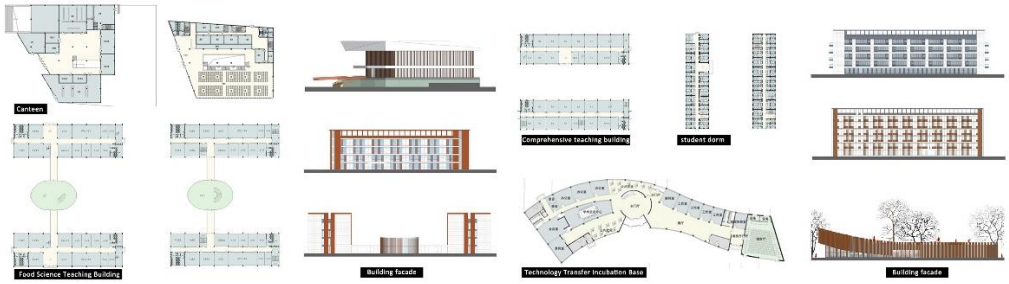

Figure 3: Plan and elevation of individual buildings

4.2. Spatial multilayer perceptron

4.2.1. Spatial Structure Planning

(1) Planning framework

The "One Axis" core spindle space represents a cohesive connection between the East and West campuses, governed by the center main axis. The primary axis extends from east to west, creating a conventional main square in front of the school. "One Belt" embedded space: centered on the theme of "embedding," it draws from Chinese Taoism, investigates local culture, links international exchange and cooperation centers, facilitates transfer and incubation bases for scientific and technological advancements, libraries, and multifunctional educational facilities to create an integrated spatial environment that intertwines humanity and nature, ideals and romance, as seen in Figure 4.

(2) Traffic Network Configuration

The traffic planning for the North Campus of Dalian Polytechnic University primarily relies on the North-South Elevated Walkway and the circular road network. Four primary vehicular entrances and exits are strategically positioned around the campus, while the elevated walkway to the south effectively utilizes the topographical features to link with the southern campus, as illustrated in Figure 4.

(3) Landscape pedestrian pathway

The landscape belt enhances the axial relationship of the new campus. The design prioritizes the viewing pleasure and rest during the continuous and rapid flow of traffic. The design intentionally enhances the variation in surface breadth, incorporates a central resting area, and transforms the pedestrian landscape belt into an extension and expansion of space, as illustrated in Figure 4.

(4) Vertical elevation

The topography of the North Campus of Dalian Polytechnic University is predominantly elevated in the east and declines towards the west. The base exhibits a significant slope. The road gradient is maintained at a maximum of 3% in the design to optimize the route's straightness and accessibility, as illustrated in Figure 4.

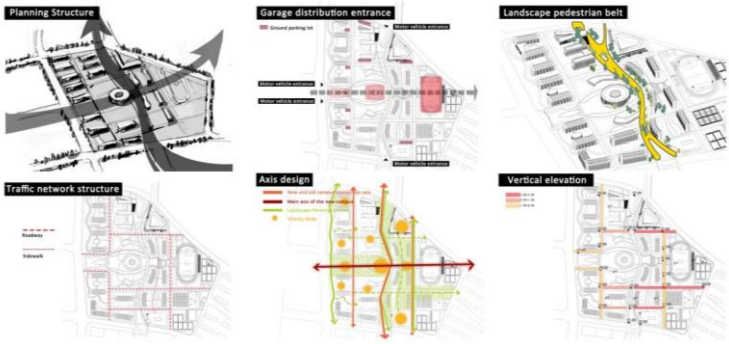

Figure 4: Plan the spatial structure

4.2.2. The spatial succession of the courtyard

(1) Single-seat courtyard area

The primary area of the solitary courtyard is confined by the structure acting as the interface and bordered by the screen wall[5]. The focal area is the central green space, as depicted in Figure 5.

(2) Compound courtyard area

The single-seat courtyard space generates an organic topology, resulting in four distinct forms. In the context of site limitations, a multi-layer spatial configuration continues to be developed, as illustrated in Figure 5. The sections 1-2-3-4-5-6-7 of the courtyard constitute an area surrounded by the building and the screen wall, establishing a distinct and robust link between the courtyard space and the courtyard itself. Furthermore, five prospective courtyard spaces, labeled a through e, have been progressively developed behind the active courtyard design[6].

4.2.3. Multilayered Landscape Sequence

The campus landscape design primarily emphasizes the East-West waterscape and the North-South greenery axis, along with three green zones encompassing the teaching and dormitory sections. The design comprehensively addresses students' physical and mental health requirements to establish a comfortable and aesthetically pleasing ecological campus, as seen in Figure 5.

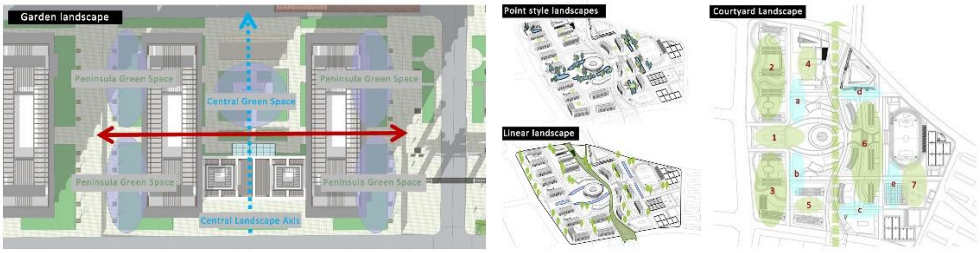

Figure 5: Courtyard and landscape sequence

4.3. Cultural legacy and innovation

4.3.1. Square Circle Combination

(1) Comprehensive planning

The interface at the base is almost square, which is the salient feature. The notion of "round sky and place" is integrated and executed at the planning stage to establish a configuration of "inner circle and outer side," so ensuring the form retains continuity with traditional culture while the space exhibits a degree of cohesiveness. Ensure the shape, space, and culture are interconnected, as

illustrated in Figure 6.

(2) Two-dimensional shape

The singular plane form maintains the spatial configuration within the overarching design, achieving external uniformity in shape and internal coherence in the design concept, as illustrated in Figure 6.

(3) Facade embellishment

The campus gate's front is adorned with an "inner circle and outer side" design to enhance the spatial tonality and cultural ambiance of the Academy, as illustrated in Figure 6.

4.3.2. Material Selection and Color

The selection of building materials and primary color considers the site context, resulting in the adoption of a warm tone. Simultaneously, given the building's location, the landscape pedestrian belt is predominantly constructed of red bricks in the northeastern area, as illustrated in Figure 6.

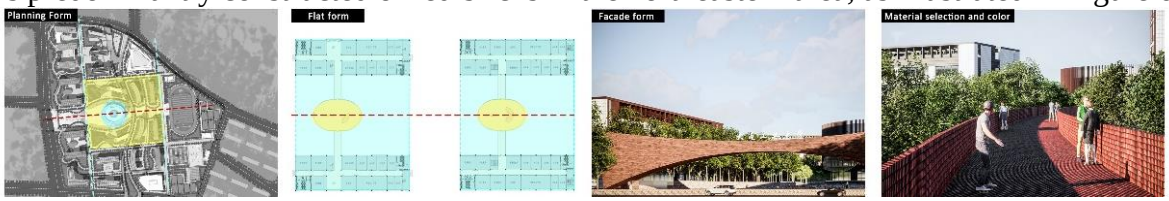

Figure 6: Planning formation

4.3.3. Dormitory orientation uniformity

The conventional dormitory rooms include a north-south functional configuration. The design pursuant to this technique will result in rooms occupying around fifty percent of the overall area oriented towards the north. Consequently, the south-facing rooms get excessively warm during summer, while the north-facing rooms remain frigid in winter. The primary structure of the building will result in a suboptimal experience for individuals, exemplified by the annual relocation of students between dorms. To circumvent the issues associated with the aforementioned plan while maintaining the same area index, the primary structure of the dormitory is oriented from east to west. This method can guarantee that every room receives sunlight. The issue of western sun exposure can be addressed by adjusting the window orientation and utilizing a sun visor, as seen in Figure 7.

4.3.4. Simulation of the Physical Environment

As seen in Figure 7, the overall sunlight simulation analysis of the dormitory area using Lvjian software indicates that the building's storey height and spacing satisfy the 2-hour sunshine standard specified in the Code for Dormitory Building Design.

The simulation of a household setting during the day is shown below. The dormitory serves mostly as a quiet place, and as Figure 7 illustrates, it is a class 1 acoustic environment functional area with a daily environmental noise limit of 55dB.

Figure 7 illustrates how the amplification factor of wind speed in pedestrian areas in the winter and summer monsoon environmental cloud map data is less than 2, meeting the green construction criteria.

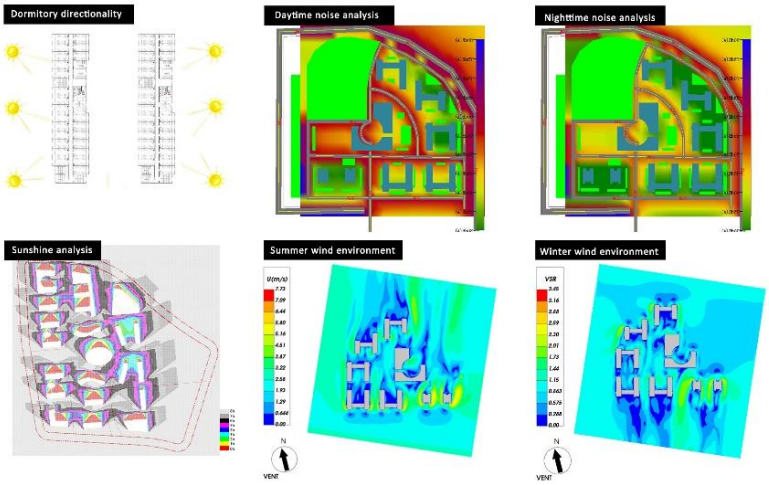

Figure 7: Physical environment analysis

4.4. Academy-style architecture

4.4.1. Space Layout

The primary content of the early target layer, represented by the composite distribution of function and space, is space layout, a characteristic of academy architecture. The single buildings that are planned and developed are all structures that serve various purposes, and the internal space layout is cohesive in terms of functional space. The courtyard element, such as the single courtyard or the combined courtyard, primarily reflects the arrangement of the outdoor space. The academy-style spatial arrangement is made up of the layering of internal and outdoor functional spaces.

4.4.2. Building a landscape

In this planning and design, the landscape—an essential component of the academy—runs through it as surfaces, lines, and points. The landscape design incorporates the site elevation, planning arrangement, building yard layout, and other multifaceted outcomes in addition to the landscape itself.

4.4.3. Architectural embellishment

Decoration is an integral aspect of architectural design. The architectural facade design incorporates horizontal moldings, vertical frame segmentation, and wooden grid decoration to convey a synthesis of modern and traditional freehand brushwork. Furthermore, the library facade design employs the concept of bamboo slips to embody the academic culture comprehensively, as illustrated in Figure 8.

4.4.4. Cultural Atmosphere

The timber-hued structures are harmoniously merged with the adjacent trees, bushes, and the overall landscape. The central tenet of the Campus is encapsulated in the phrase: "There exists a road amidst the mountain of books, and diligence is the pathway." The steady expansion of the primary axis road illustrates the introspective cultural disposition of the garden campus, as depicted in Figure 8.

Figure 8: Renderings

5. Contentment with the Outcomes of the Planning and Design

This time, 32 students, 8 teachers, and 4 support workers received 44 questionnaires. Following the collection of the surveys, the number of surveys received by each rating is calculated and utilized as the judgment matrix, as indicated in Table 2. There is a high level of satisfaction because the quantitative findings of the simulation analysis of the sunshine, noise, and sound fields all meet the required design standards.

As illustrated in Figure 9, the comprehensive evaluation results demonstrate that the weight of the overall satisfaction score and the single objective satisfaction score is inclined toward satisfaction, with the satisfaction weight accounting for 86%.

Table 2: Satisfaction Evaluation of Planning and Design Results

goal	Very dissatisfied	dissatisfy	normal	satisfaction	Very satisfied
land function structure analysis	**0**	2	10	22	10
food center	**0**	2	12	20	10
dormitory	0	0	2	30	12
planning structure	0	0	6	28	10
Traffic network structure	0	0	6	26	12
Roaming walking road structure	0	0	8	20	16
Vertical elevation structure	0	0	6	22	16
single courtyard space	0	0	0	32	12
Combined courtyard space	0	0	4	30	10
"point" landscape	0	0	4	30	10
"linear" landscape	0	0	6	28	10
"Face" landscape	0	2	4	26	12
Overall planning	0	0	8	26	10
Planar form	0	0	6	28	10
Facade decoration	0	2	8	22	12
Selection of materials and colors	0	2	12	22	8
The dorm's orientation is consistent.	0	0	2	30	12
Sunshine simulation analysis	0	0	0	0	44
Noise simulation analysis	0	0	0	0	44
Wind field simulation analysis	0	0	0	0	44
Spatial layout	0	0	2	28	14
Landscape construction	0	0	4	26	14
Architectural decoration	0	2	10	18	14
Cultural atmosphere	0	2	6	18	18

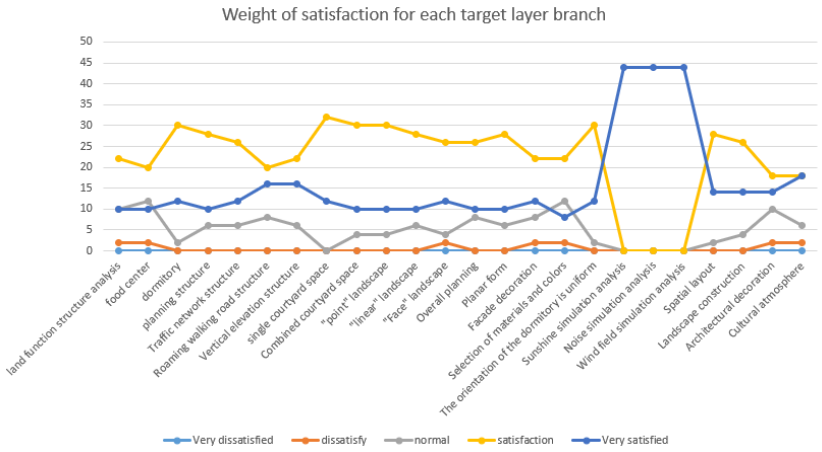

Figure 9: Target layer satisfaction weight

6. Conclusion

In order to establish Dalian Polytechnic University's North Campus, it is necessary to assess the state of affairs now, deal with real-world problems, and lead the way in future developments. By utilizing technology, the design strives for excellence, functionality, and worldwide influence. Harmonious development is ensured by coordination. Human nature favors designs that are easy to use and environmentally friendly. Multi-objective optimization enhances engineering design by going beyond technological limitations.

Acknowledgement

This paper was supported by the project "the Fundamental Research Funds for the Central Universities" DUT19RC (3) 044.

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