ENHANCING SPATIAL CONFIGURATIONS IN INFORMAL LEARNING SPACES: AN EARLY-PHASE DESIGN DECISION-MAKING FRAMEWORK

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ABSTRACT

Traditional design decision-making is usually a process of adapting and reusing the paradigm at the architect's disposal based on intuition and experience, which helps to provide acceptable solutions to known design problems quickly but makes it challenging to generate new spatial types beyond the existing paradigm. The emergence of informal learning behaviors has caused changes in public learning spaces, and traditional design decision-making processes have struggled to provide better solutions. Based on 620 questionnaires, this study combines statistical and space syntax analysis to obtain the relationship between user preferences and space. It uses multi-agent simulation to interpret preferences into spatial forms to assist design in obtaining a more suitable spatial layout pattern for informal learning scenarios. Proposing a design decision-making method to solve complex behavior-driven problems effectively, this research will help to integrate research and design effectively, improve the efficiency and accuracy of design decision-making.

Keywords: decision-making, informal learning, university libraries, space syntax, optimizing design.

1 INTRODUCTION

With the development of pedagogy and the digitization of knowledge media, the acquisition of knowledge is no longer a centralized process revolving solely around teachers or textbooks. Instead, it has become a learner-driven, knowledge exchange process accompanied by various forms of information transmission. Consequently, the concept of informal learning has emerged, leading to a transformation in the usage and construction logic of public learning spaces [1, 2, 3, 4, 5] .The traditional library learning space design based on the scale of book storage units is no longer applicable; research starting from the behavioral and psychological scales of individuals has become essential in the design of library learning spaces.

Unlike general public libraries, the primary behavior of users in university library learning spaces is studying, rather than visiting or borrowing and returning books. This distinction makes the critical objective in evaluating university library learning spaces their ability to enhance the efficiency of knowledge acquisition in various forms of learning activities [6], rather than conventional metrics like the number of stored books, the number of reading seats, or evacuation efficiency.

However, there is a particular lack of analysis regarding the types of behaviors associated with informal learning and the spatial support conditions required. Although the field of library science has long used concepts such as Information Commons and Learning Commons [7, 8], qualitative research methods based

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on case studies and interviews, while able to outline the general characteristics suitable for informal learning spaces, struggle to provide specific conditions for such spaces.

The spatial layout issue suitable for informal learning is fundamentally a matter of the correlation between spatial layout and user behavior. Space Syntax, a method that describes spatial attributes through the simulation of people's fields of vision in space, is a concise tool for studying this issue [2, 9, 10, 11, 12, 13, 14, 15]. It has been extensively used to analyze library spaces. Among these studies, many researchers believe that the main issue with library spaces is the impact of spatial layout on crowd interaction [14, 15, 16] and mutual visibility [17]. Zook and Bafna, in their study of the Seattle Public Library, further noted that the visibility between users on different paths creates varying degrees of publicness, potentially influencing users' perceptions [2, 17]. Marcela Aragüez and Sophia Psarra in their study of the Rolex Learning Centre (RLC) pointed out that public learning spaces with differences in visibility and accessibility might be more favored [18].

However, although existing research has used Space Syntax to establish the correlation between library space layout, user circulation and sightlines, and the sense of public and private, it still has not yielded recommendations and methods for generating layout forms.

1.1 Design Decision-making

The spatial support conditions for informal learning should be a subject of design decision-making. Design decisions can be summarized as the process where designers, in the specific context of a project, determine the key conditions of a plan by synthesizing credible research evidence, considering the client/users' needs, preferences, resources, and their own design experience (Figure 1) [19, 20]. The content of the decision mainly refers to determinations in specific design issues that have advantages, disadvantages, and even right or wrong choices, such as siting, types and layouts of buildings and facilities, massing and programming, furniture specifications, etc. [21]. However, the intuitive and experiential nature of traditional design decision-making is not yet capable of providing satisfactory solutions for new issues like informal learning spaces, which fall outside of conventional design paradigms [22]. It is necessary to study public learning space layout patterns suitable for the characteristics of informal learning, and subsequently propose a design decision-making process oriented towards complex, behavior-driven contexts.

1.2 Paper Overview

To obtain a library space layout pattern suitable for informal learning, this study begins by transforming the sense of privacy into spatial form. We decode privacy as the fulfillment of three conditions: distance

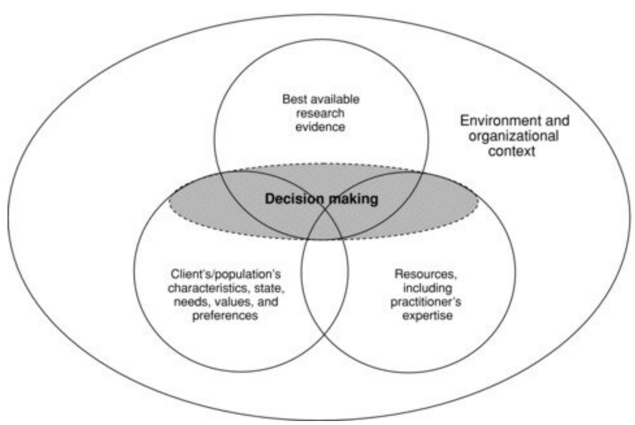

Figure 1: Design decision-making model, [20].

from spatial disturbances, satisfaction of spatial preferences, and allowance for spatial dimensions. This approach allows us to translate psychological perceptions into spatial layout forms relatively faithfully using both quantitative and qualitative methods.

In the process, a combination of tools was used, including statistical analysis, Visual Graph Analysis(VGA) [23, 24], and Multi-agent simulation. This approach facilitated the transformation of research conclusions into design outcomes and provided a design decision-making method that effectively integrates qualitative factors, assessment, and design (Figure 2).

2 METHOD

2.1 Design Decision-making framework

This article presents a design decision framework mainly divided into three stages: analysis, implementation, and optimization (Figure 3).

- In the analysis phase, a combination of case studies, Space Syntax, and questionnaire analysis is used to determine the basic attributes, topological structure, and behavior types of the space.
- In the implementation phase, based on the analysis results, Multi-agent simulation is employed to design the spatial form.
- In the optimization phase, various behavioral needs are integrated to create spatial variants, which are then evaluated using Space Syntax to ensure the design results meet the effectiveness of the initial analysis.

This reverses the traditional approach of first obtaining a design scheme and then using simulation for evaluating the effectiveness of the spatial design. It makes Space Syntax and simulation references for the generation of the design scheme, effectively solving the problem of generating the spatial form.

2.2 Visibility Graph Analysis

The analysis employs Space Syntax's Visibility Graph Analysis (VGA) [23, 24], using the connectivity parameter that directly reflects the visible range from a point in space. This succinctly simulates the sense of privacy experienced by users when they study for extended periods at a certain point in the space, influenced by surrounding lines of sight. Since Space Syntax struggles to represent interface transparency and three-dimensional spatial forms, the study simplified the representation of three-dimensional space based on whether a user's line of sight could pass through, not considering transparent interfaces or open spaces as obstacles.

2.3 Multi-agent Simulation

In the field of Space Syntax, agents can interpret spatial variables or the structured maps derived from these variables. Research in this domain, pioneered by individuals like Penn, introduced local isovists, Visual Graph Analysis (VGA), and measures of spatial integration into agents' decision-making algorithms, particularly for navigation. These agents adjust their direction every few steps based on the dynamic changes in their isovist fields [25]. Concurrently, researchers such as Turner and Hillier have explored the intersections of spatial flow simulation [23], and the interplay between spatial behavior and visibility [26]. These studies have established a correlation between the parameters of Space Syntax within visible spaces and the intended movement patterns in spatial flows. The congruency in the fundamental logic of Space Syntax and

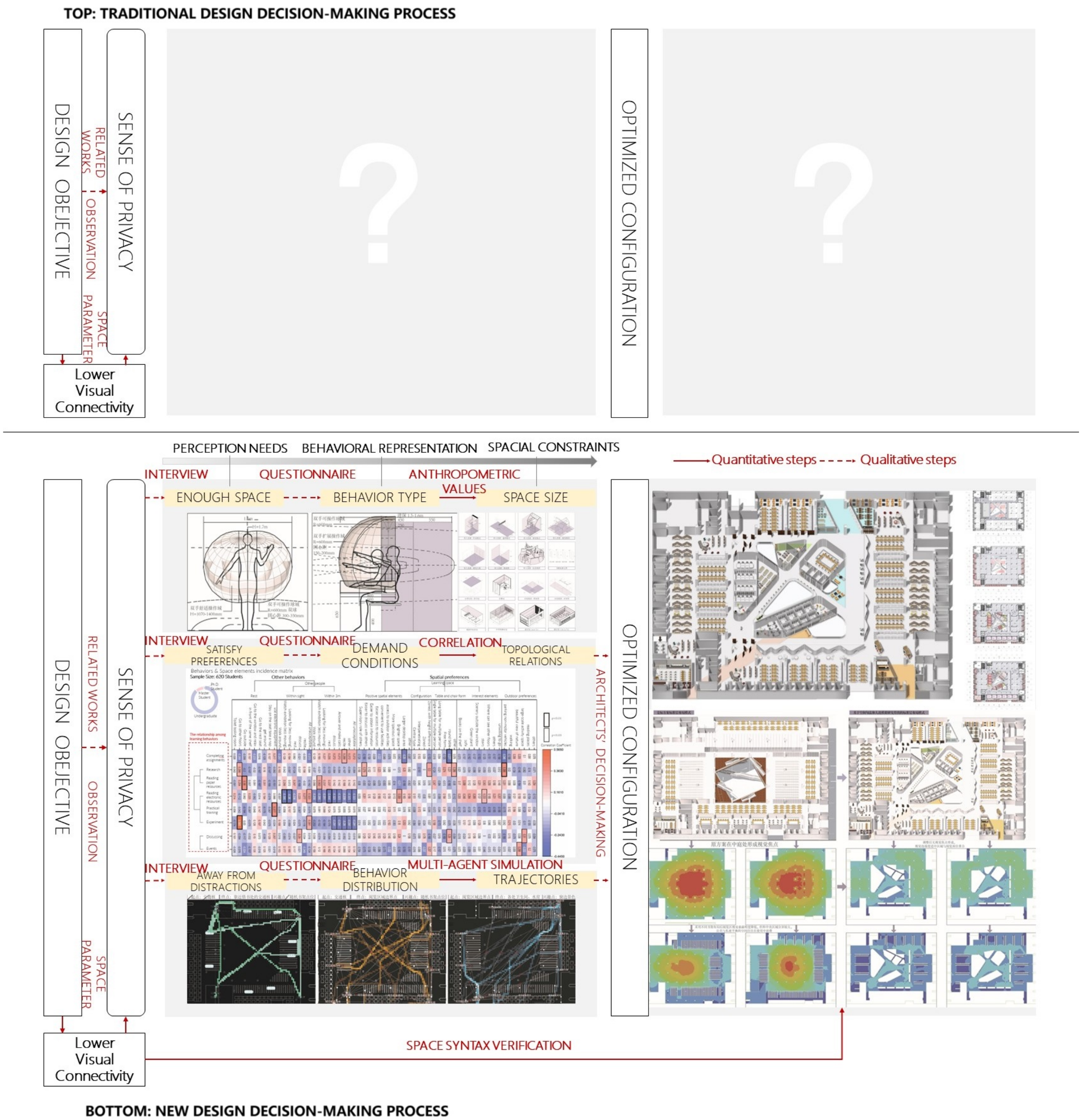

Figure 2: Paper overview.

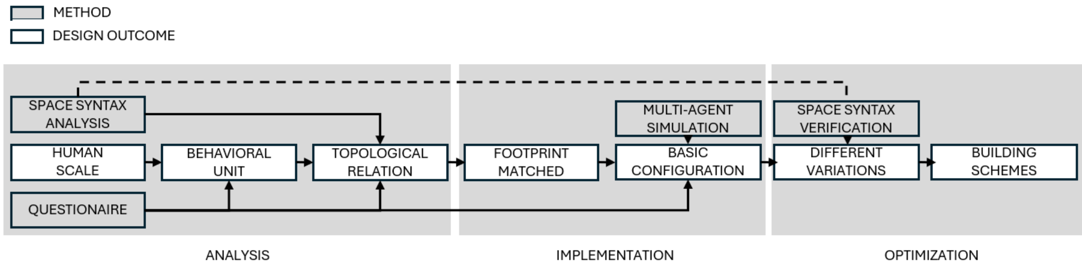

Figure 3: Design Decision-making framework.

Multi-agent simulation justifies their combined use in forming a bridge from analytical assessments to the generation of spatial forms.

In the context of university libraries, where pedestrian movement intentions are shaped not only by visual lines but also by the forces exerted by spatial elements and individual interactions, the study utilizes the PedSim plugin, based on Grasshopper, for Multi-agent simulation. This approach extends the visual analysis inherent in Space Syntax by incorporating elements of social force, thereby reflecting more realistic scenarios. It also enables the depiction of actual crowd movement patterns, as opposed to generalized spatial distributions, enhancing the alignment with practical design objectives. Additionally, Space Syntax serves as a tool for cross-validation, helping to ascertain and optimize the efficacy of the design solutions.

3 CASE STUDY

The study targets the optimization of the open learning spaces (standard floors) in a proposed university library. The library, shaped as a square due to land constraints, plans to situate these open learning spaces across floors 4 to 7. The original design includes a central atrium within the open learning spaces, a classic approach in library architecture. However, feedback collected from some students at the university revealed a lower satisfaction with this design, citing its inability to meet diverse, contemporary learning needs. Given the representativeness of the square layout, this study employs this particular case to apply the explored design decision framework. The aim is to provide reading spaces that harmoniously balance public and private aspects within various combined models of learning spaces.

3.1 Determining the Design Objective

Based on academic research discussing the relationship between library space layout and the sense of privacy [2, 17, 18], this study studied the composition of learning spaces in over 70 learning centers built globally after 2008(Figure 4), and selected representative university library public learning spaces that received positive evaluations for analysis. The chosen cases cover typical layout patterns such as centrally located common spaces, reading areas, and discussion spaces, and possess a moderate spatial scale. The analysis revealed that in the case studies, most learning seats in public learning spaces are positioned in areas with medium to low visual connectivity, i.e., areas with lower visibility and higher privacy (Figure 5).

Transforming the design decision objective into creating learning seat areas with higher privacy is a key point in this study's approach to designing solutions for university library public learning spaces. Further, this decision objective is fulfilled by meeting three design constraints: being removed from spatial disturbances, fulfilling spatial preferences, and accommodating appropriate spatial dimensions, thereby guiding the solution for the design scheme.

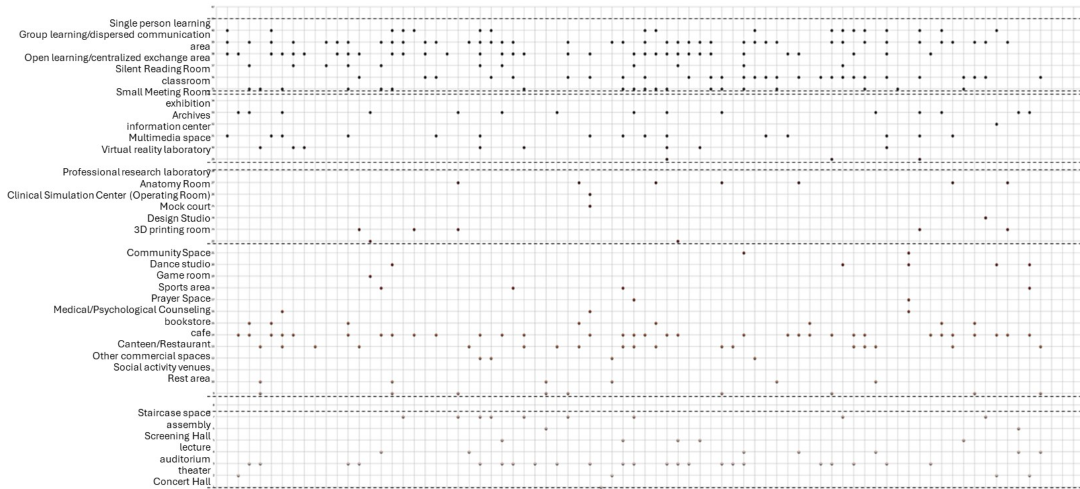

Figure 4: Case studies .

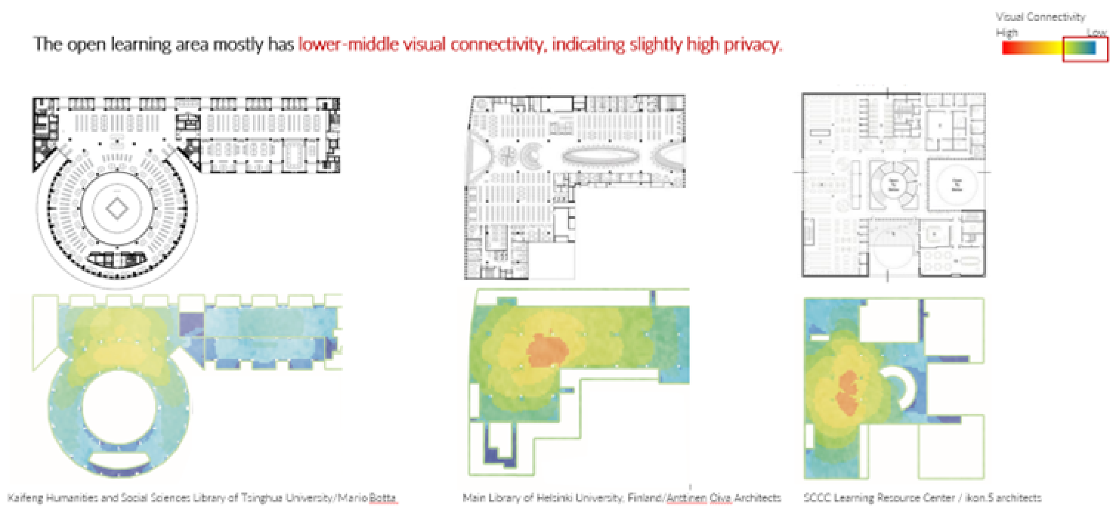

Figure 5: Space Syntax Analysis .

3.2 Design Constraint One: Distance from Spatial Disturbances

The movement of people through the space constitutes one of the key factors affecting the sense of privacy for individuals studying. By simulating the primary movement paths of people, positioning the study seats in areas less traversed by these paths becomes an important decision condition in solving the spatial layout.

The study, based on user surveys, found that the movement of people in library public spaces is characterized by its incidental and spontaneous nature, often influenced by attractions along the way, altering their paths. This characteristic aligns with the nature of informal learning behavior. The PedSim plugin for Grasshopper allows for relatively straightforward simulation of this hypothesis through the setting of start and end points and points of attraction. Hence, the study uses parameters obtained from user surveys to simulate the movement trajectories of people in three high-frequency usage scenarios: borrowing and returning books, entering and leaving the library, and leaving seats for breaks. By superimposing the paths with a higher proportion of people passing through, a reference boundary for the plane form can be obtained (Figure 6), leading to a basic spatial composition.

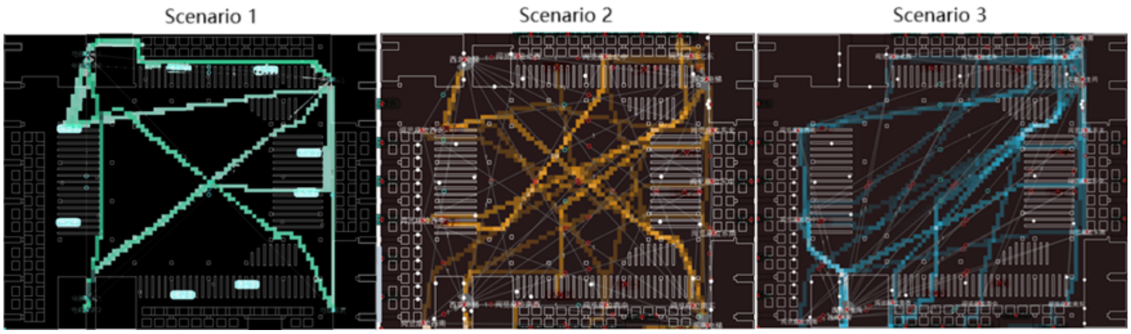

Figure 6: Simulation results.

3.3 Design Constraint Two: Satisfying Spatial Preferences

Although a preliminary planar form has been obtained, understanding the correlation between behavior and spatial preferences is almost essential for functional layout. This study, based on 620 valid questionnaire samples from students of a university in Beijing, investigates the types of behaviors and spatial preferences in the use of public learning spaces in libraries. It utilizes Pearson correlation analysis to examine the relationships among different learning behaviors, and between learning behaviors and design decision points such as spatial layout and types of desks and chairs (Figure 7).

Based on the privacy needs of different learning behaviors, the previously obtained planar form is functionally arranged. Decisions on the spatial characteristics and types of desks and chairs for different functional areas are made according to the results of the correlation analysis.

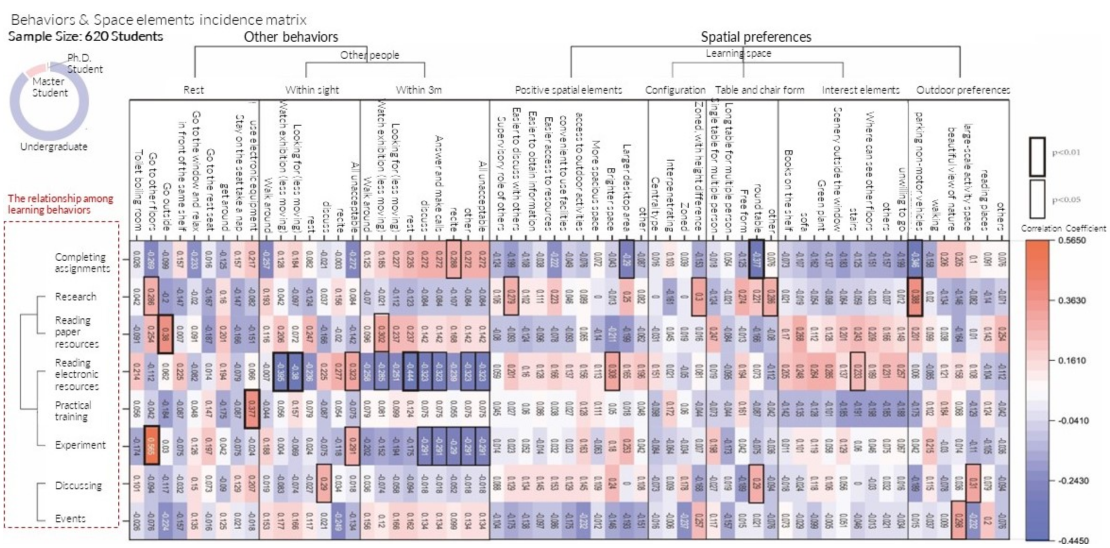

Figure 7: Behaviors and space elements incidence matrix.

3.4 Design Constraint Three: Allowing Spatial Dimensions

To further transform the functional layout into a spatial design that accommodates activities, the study integrates empirical data from ergonomics and environmental behavior studies [27] on embodied behavior and personal space to determine the basic three-dimensional spatial units (Figure 8). Based on the characteristics of bodily movements associated with different learning behaviors, these are translated into the basic allowable dimensions and interface characteristics of their spaces. This process results in a variety of spatial units that allow for these behaviors (Figure 9), which can then be incorporated into corresponding functional divisions to complete the spatial layout pattern.

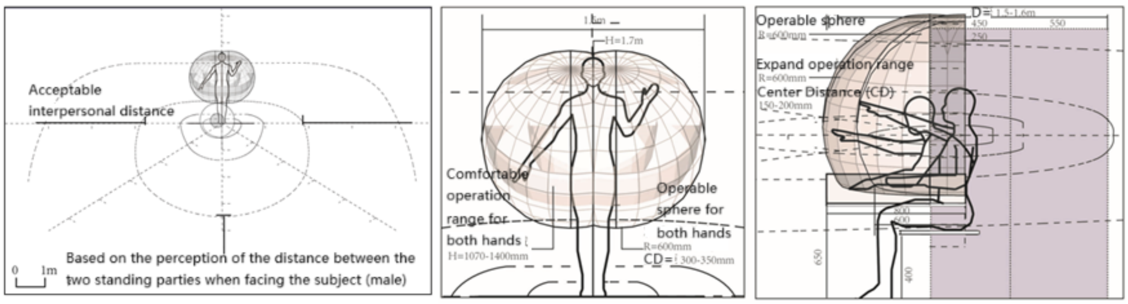

Figure 8: Basic behavioral scale unit.

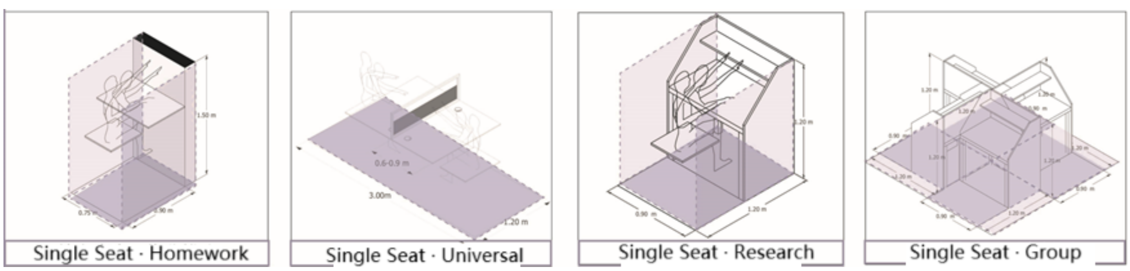

Figure 9: Functional units.

4 RESULT

4.1 Proposing a Preliminary Plan

A planar form is obtained by distancing from spatial disturbances, functionality is assigned to the planar form by satisfying spatial preferences, and function is concretized into space by allowing spatial dimensions. The solution to the plan unfolds step by step through the deciphering of each decision condition, ultimately combining the designer's experience and the user's choices to arrive at a spatial layout scheme.

The central space is arranged for discussion and other knowledge exchange activities, while the periphery is sequentially organized with learning seats characterized by autonomous knowledge acquisition and enclosed study rooms. The layout scheme derived from the decision-making process of this study proposes a model that differs from the traditional "enclosed" layout, suggesting an "inner solid, outer void" pattern (Figure 10).

Considering that as an informal learning space, it may accommodate other activities such as gatherings and exhibitions, this layout pattern can be transformed based on the basic planar form to create different planar

Figure 10: Optimized configurations.

variants. Moreover, by considering the spatial connections in the vertical dimension, a rich overall spatial relationship can be established (Figure 11).

4.2 Validating and Optimizing the Scheme

The scheme is subjected to another round of VGA [23, 24] for verification (Figure 12). Compared to classic layouts with a centralized atrium, the layout scheme derived from the decision-making process of this study offers a higher overall level of spatial privacy. The visual connectivity of each section aligns well with the conclusions of the pilot studies, with the privacy levels at the study seats being appropriate, and the central area also maintains a level of privacy conducive to lingering. This can be seen as an effective realization of the objectives through the design decision-making process.

5 DISCUSSION

This study also has some limitations that warrant further exploration in future research.

Firstly, a complete representation of the dependency relationships among various influencing factors for this design issue has not been achieved. Factors such as the overall configuration of library architecture and the campus cultural context have not been included in the decision-making influences.

Secondly, it is difficult to evaluate the credibility and effectiveness of the design solution in the same way as physical performance assessments are conducted based on absolute performance values [22]. There is still a need to compare simulation data and verification results with actual spatial evaluation data after the project's completion to further improve and calibrate the methodology.

Lastly, the decision-making process still relies to a considerable extent on the designer's experience. In the future, there may be potential to enhance its level of intelligence, such as by integrating artificial intelligence technologies like machine learning to develop quantitative decision support algorithms. Once

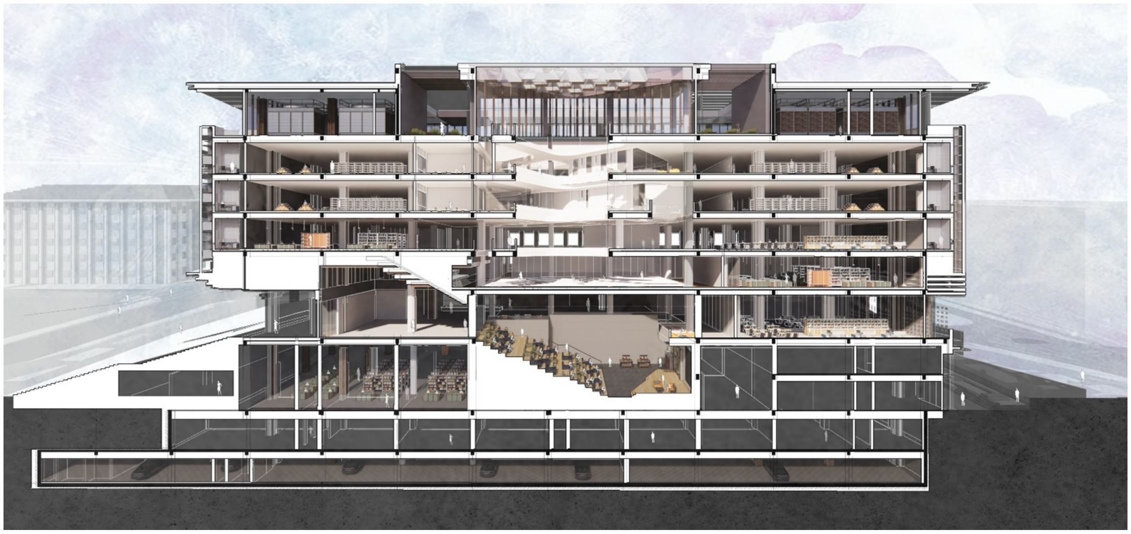

Figure 11: Overall visual connectivity.

developed, behavioral relationships could potentially be automatically transformed and organized into spatial relationships and layouts by the algorithm, significantly reducing the time required and enabling rapid comparison of various design solutions in a short period. This algorithm can be adjusted for subsequent projects with similar objectives and context. Over time, the accumulation of data will also allow the design algorithm to better understand the complex dynamic relationship between behavior and space and to improve the accuracy of the model.

6 CONCLUSION

The layout patterns of public study spaces in libraries have been evolving. The widely used "enclosed" atrium layout has a specific historical context for meeting storage and reading functional needs. However, with changes in knowledge media and exchange processes, its layout, characterized by a strong centrality and high visual exposure of reading areas, is no longer the most suitable spatial model for informal learning, especially when indoor spaces lack appropriate separation and arrangement.

Traditional design decision processes rely on existing cases and the designer's intuitive judgment, which makes it difficult to effectively produce and verify suitable layouts. Tools like Space Syntax, although used for the analysis and evaluation of design schemes [28], usually only provide general principles for guidance in design practice or verify schemes after their completion, enabling relative optimization but not participating in generation. Thus, there has long been a disconnect between problem analysis and design operation, and a lack of scientific rigor in design practice.

This study finds that by identifying key indicators for complex design problems, it is possible to effectively transform design issues into decision problems, and then conduct data collection and correlation analysis of decision elements, thus obtaining potential spatial forms corresponding to decision elements based on simulation in specific scenarios, which serves the formation of design schemes.

The process of setting decision objectives, solving decision conditions, and generating and validating decision schemes in this study also proves that even complex architectural space design solutions can draw important bases and inspiration from both lead and parallel space analysis. This method is very likely to effectively support design decisions and may go beyond the limits of existing experience, discovering new spatial patterns and thereby generating new knowledge.

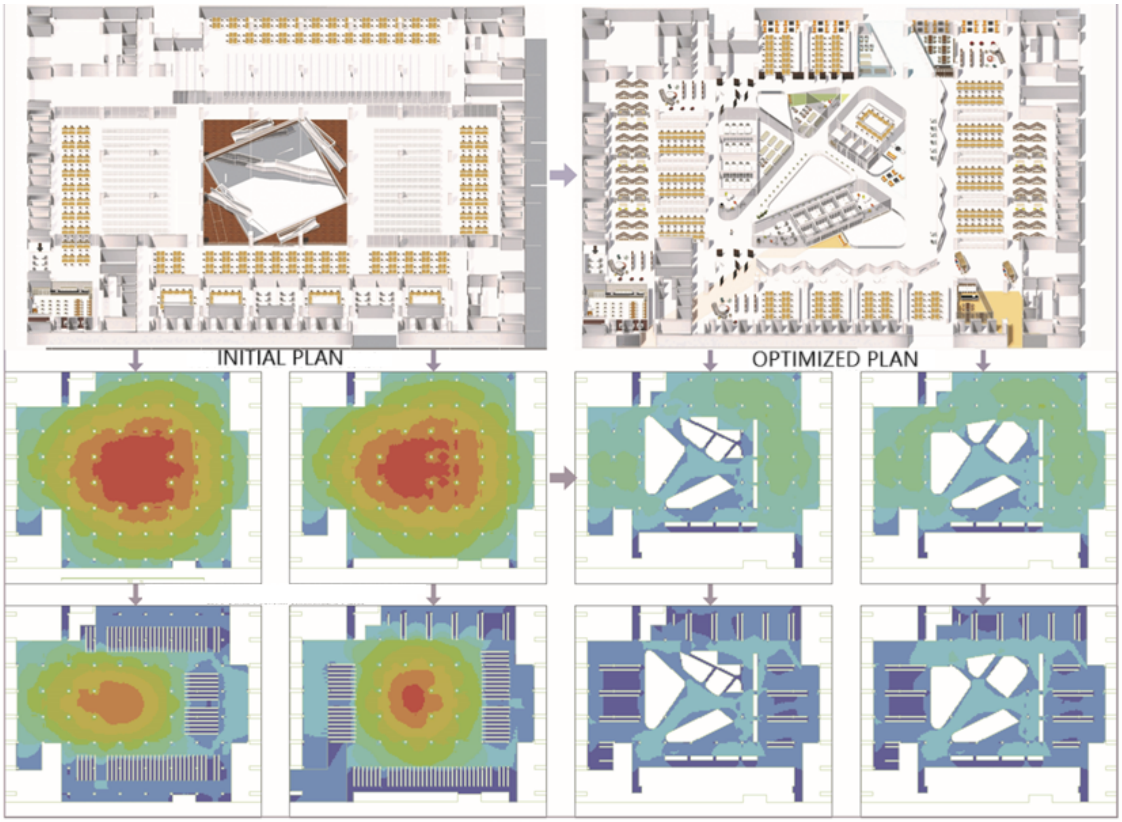

Figure 12: Space syntax verification.

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