Analysis on the Influencing Factors of the Reform Design of the Teaching Building of Design College Based on ISM

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Abstract. Background The renovation design of the teaching building of Design College of South China University of Technology needs to achieve the design objectives of function replacement, space reorganization and improvement of space quality. Problem The space utilization rate of the existing teaching building is low, which cannot meet the teaching efficiency; and because the teaching building was originally used as a public classroom which is a teaching space without college characteristics. Technology This paper summarizes the influencing factors by means of literature inquiry, field investigation and interviews, and uses Interpretative Structural Model (ISM) to analyze the hierarchical relationship among the factors obtained in the investigation, so as to help people understand the logical relationship within the complex system at a more hierarchical level through this method. Target With the help of this method, the key factors affecting the renovation design of teaching buildings are summarized, and the ISM is constructed to provide guidance for an effective solution strategy. Conclusion the ISM method is used to extract the relevant design elements and form the design model of the system, which provides a useful reference for the smooth implementation of the reform project.

1. Introduction
The first and second levels of teaching building A5 in the University Town Campus of South China University of Technology are facing the needs of function replacement and space reorganization. Because it needs to accommodate multiple functions under the condition of limited site area, there is a contradiction between area and function. At the same time, this area was not originally used as a design college classroom, model room or other places with professional characteristics. Now, after the renovation and design of this space, there is a contradiction that the existing facilities do not meet the new functions.

In order to design a transformation plan that can not only solve these two contradictions but also improve the quality of space, we need to make a deep analysis of the logical relationship among the factors and put forward an effective solution strategy.

Through on-the-spot investigation, user interviews, questionnaires and other research methods, many factors affecting the renovation design of teaching buildings are obtained. There is a complex relationship of interdependence and mutual restriction among the factors. ISM method is used to analyze the hierarchical relationship among the factors obtained in the investigation, and an interpretative structural model is constructed, which provides a clear guiding idea for the follow-up design practice, and maximizes the solution of the two contradictions to achieve the design objectives.
2. Overview of Interpretative Structural Model Method

Interpretative Structural Model (ISM) was developed by Professor J. N. Warfield in 1973 to analyze the structural problems of complex social and economic systems [1]. ISM is a method specializing in the study of the correlation structure between complex elements in system analysis technology. Its connotation is that it can make use of the known complex relationship among the elements in the system and form a multi-level hierarchical structure model under people’s practical experience and computer-aided calculation [2].

In the whole process of analysis, through various research methods such as literature research, induction and summary, questionnaire and so on, the constituent elements from the key issues to be studied are summarized and extracted. With the help of directed graph, adjacent matrix, reachable matrix and computer technology [3], the complex relations among the elements can be dealt with scientifically. Finally, the interdependence, mutual restriction and interrelation of elements are expressed through structural diagrams, which can be used as a tool to determine the order and direction of the complexity of the interrelationship among elements in the system [4]. The advantage of ISM is that it does not need explicit statistical data to support it. It mainly expresses the interrelationship of elements among systems and has strong explanatory function. It is suitable for the situation that there are a large number of elements in the system and the relationship between them is complex and the structure logic is not clear. It helps people understand the logic relationship within complex systems by making the relationship between elements more hierarchical [5].

3. Using ISM Method to Analyze the Design of Teaching Building Renovation

3.1. Extracting Representative Elements

In order to construct ISM model, the factors affecting the design of teaching building renovation are analyzed through field investigation, user interviews and literature research. From the five aspects of natural and human environment, resources and technology, laws and regulations, and overall objectives, 10 representative elements are extracted, and the set of elements \( S = \{S_1, S_2, S_3, \ldots S_{10}\} \) [6] (see table 1).

| Factor type                  | Influencing factor                  | Code |
|-----------------------------|------------------------------------|------|
| Natural and Man-made Environment | Location Conditions | S1   |
|                             | Site Status                        | S2   |
|                             | User Requirements                  | S3   |
|                             | User Experience                    | S4   |
| Resource Technology         | Cost of Capital                    | S5   |
|                             | Design Content                     | S6   |
| Laws and Regulations        | Codes of Architectural Design      | S8   |
| Overall objective           | Conflict resolution                | S9   |
|                             | Improving Space Quality            | S10  |

3.2. Establishment of Relation Map between Elements

The complex elements in the system are interrelated, and are generally based on the binary relationship between the two elements. The binary relation is a kind of relationship between two elements existing in the system which needs to be discussed according to the nature of the system and the purpose of the research. Usually there are influence relation, causality relation, inclusion relation and so on. In the establishment of the relationship between the elements, “X” is used to indicate the strong connection between the two factors; “A” to indicate that the following factors have a direct
impact on the above factors; “V” to indicate that the above factors have a direct impact on the following factors (table 2); and “O” to indicate that the two factors are not interrelated.

Table 2. Relationship diagram of influencing factors of teaching building renovation design.

| O | O | O | V | O | A | O | O | S10 |
|---|---|---|---|---|---|---|---|-----|
| O | O | O | O | A | O | O | S9  |
| O | O | O | O | V | V | O | S8  |
| O | O | A | O | X | X | S7  |
| O | O | O | S4  |
| O | O | S3  |
| O | S2  |
| S1  |

3.3. Establish an Adjacency Matrix

From table 2, the binary relation graph 3 of the system can be obtained. The “0” indicates that there is no relationship, the “1” indicates that there is a direct connection, and the adjacency matrix A can be obtained (see table 3); then the M reachable matrix is obtained by Matlab software operation, and the program is omitted (see figure 1).

Table 3. Binary relationship diagram of influencing factors of teaching building renovation design.

| S  | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 |
|----|----|----|----|----|----|----|----|----|----|-----|
| S1 | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0   |
| S2 | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0   |
| S3 | 0  | 0  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0   |
| S4 | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0   |
| S5 | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0   |
| S6 | 0  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 1   |
| S7 | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0   |
| S8 | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 0   |
| S9 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0   |
| S10| 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1   |

Formula A =

Formula M =

Figure 1. Adjacency matrix A and reachable matrix M.

3.4. Decomposing the Reachable Matrix and Establishing the Structural Model

The antecedent set and the reachable set must be analyzed before the reachable matrix is decomposed. In the row corresponding to the element Si in the reachable matrix, a set of column elements corresponding to the matrix element of 1 is represented, and represents a set of elements reachable by Si in the reachable matrix or the directed graph, and is denoted as R (Si); the antecedent set of system
elements Si is a set of system elements that can reach Si in the reachable matrix or directed graph, denoted as A(Si); the common set of system elements Si is the common part of Si in the reachable set and the antecedent set, that is, the intersection, denoted as C(Si), and the common set C(Si)=R(Si)∩A(Si) [7]. In order to decompose the reachable matrix, we first list the reachable set and the antecedent set and their intersections on the table, as shown in table 4 below.

**Table 4. Reachable set and antecedent set and intersection.**

| Number (i) | Reachable set R(Si) | Antecedent set A(Si) | Intersection C(Si)=R(Si)∩A(Si) |
|-----------|---------------------|----------------------|-------------------------------|
| 1         | 1,2,4,5,6,9,10      | 1                    | 1                             |
| 2         | 2,4,5,6,9,10        | 1,2,3,5,6,7,8        | 2,5,6                         |
| 3         | 2,3,4,5,6,9,10      | 3                    | 3                             |
| 4         | 4                   | 1,2,3,4,5,6,7,8,10   | 4                             |
| 5         | 2,4,5,6,9,10        | 1,2,3,5,6,7,8        | 2,5,6                         |
| 6         | 2,4,5,6,9,10        | 1,2,3,5,6,7,8        | 2,5,6                         |
| 7         | 2,4,5,6,7,9,10      | 7                    | 7                             |
| 8         | 2,4,5,6,8,9,10      | 8                    | 8                             |
| 9         | 9                   | 1,2,3,5,6,7,8,9      | 9                             |
| 10        | 4,10                | 1,2,3,5,6,7,8,10     | 10                            |

In order to have a clearer understanding of the hierarchical relationship between the various elements in the system, the top level represents the ultimate goal of the system, and the next layer represents the reason for the upper layer. With this method, we can scientifically establish the teaching process or other. The structural model of the problem. The hierarchical decomposition method is based on the R(Si)∩A(Si)=R(Si) condition for hierarchical extraction. Thus, table 5 is obtained.

**Table 5. The structure of the influencing factors of the teaching building renovation design.**

| Level | Element |
|-------|---------|
| 1     | S9      |
| 2     | S4      |
| 3     | S10     |
| 4     | S2, S5, S6, |
| 5     | S1, S1, S7, S8 |

By decomposing the reachable matrix, the hierarchical structure of the factors influencing the design of the teaching building was obtained [8], so a hierarchical structural relationship model was drawn according to table 5 (see figure 2).

### 3.5. Summary and Interpretation of Structural Model

Through the calculation and analysis of 10 factors affecting the renovation design of teaching buildings, the structure model of 5 levels in figure 2 is obtained, and the following conclusions are drawn from the analysis.

1. It can be seen that location conditions, user needs, implementation technology and architectural design specifications are influencing factors in the fifth level, are the root factors affecting the renovation design of teaching buildings, and are the fundamental factors to achieve the ultimate goal. The implementation of technical and architectural design specifications is the basis of the implementation of the entire renovation design. Whether the design can be realized depends on the construction and specifications. These two factors also restrict the design content and the cost of funds. Location conditions and user needs restrict the content of the design. Location conditions here refer to
the geographical location, traffic conditions, surrounding environment and people flow line of the teaching building site. The design itself is to meet the needs and to be suitable for the situation of the site.

Figure 2. Teaching building reconstruction design influencing factors interpretation structural model.

(2) The interfering factors including design content, site status and capital cost are in the fourth level. The three factors interact and restrict each other, which is the most important link in the process of achieving the ultimate goal and plays a connecting role. Because the location conditions and user needs of the fifth-level factors affect the design content; user needs, technology and specifications affect the design content and capital costs; and these three factors also affect the factors of the first, second and third levels, so they are the key link between the preceding and the following. Therefore, the process of site investigation and design and the budget of cost in the initial stage of design are important links in the whole process. It is necessary to pay attention to the coordination with the whole, and to make the design come true and try again and again.

(3) Improvement of space quality and user experience are the factors in the third and second levels, showing a progressive relationship. Whether space quality is good or not will affect user experience, and whether space quality is high is directly affected by the factors in the fourth level. User experience will also be constrained and affected by design content. So it is an important step to simulate the user’s experience space in the design, which affects whether the results can be achieved.

(4) Resolving contradictions is the ultimate goal of the whole process. It is not only affected by the following levels, but also directly affected by the design content. It is obvious that the design content is the core of the whole transformation design. Therefore, in order to achieve the main goal of resolving contradictions, it is particularly important to solve and coordinate the relations and contradictions among all levels.

Through the analysis of each level, we find out the core factors and fundamental factors, which play a guiding role in our follow-up design, let us have a clearer idea in the design, make corresponding solutions to the problems, and achieve the ultimate goal.

4. Rebuilding Design of Teaching Building

The ISM model is obtained through the analysis of the factors affecting the design in the previous part. The later design will follow the structural model for design analysis. The design project is located in the University Town Campus of South China University of Technology. At the end of the north-south axis of the campus, the east side is close to the landscape waterway, covering an area of about 1222 square meters. Its originally functioned as the public teaching building, later used as a design institute. Therefore, the primary task of the project is to re-divide the space and transform the function. Pre-understanding of location conditions and user needs is fundamental to the design. The comparison of the design plan before and after modification is shown in figure 3.

The author mainly adopts the design method of “Motion Viewpoint”. That is to say, using the difference of pictures produced by human movement to form a complete observation of the scene,
which is a method of gradually changing from one point perspective to multi-point perspective [9]. This design method can help the author to perceive the details of the design. Design from the perspective of user experience strengthens the connection between interior design and human beings as well as the embodiment of humanization. This is the design idea realized under the interaction and restriction of design content, site status and user experience.

![Diagram](image1)

**Figure 3.** Comparison of plane drawings before and after renovation.

At the entrance of the site, the existing doors and windows are replaced by glass-revolving doors and floor windows to achieve the continuity and integration of indoor and outdoor vision and space. The outdoor landscape is introduced into the interior with the help of large-scale transparency treatment to increase indoor and outdoor connectivity (see figure 4a). With the shift of view, we have observed the treatment of the larger academic report area, which was originally used as a hall, but now for external reasons it is closed to a larger ladder as a public area of the college. According to ISM model, user needs and site status and design content interact, so the design of large ladder meets the needs of students in Design Institute for academic discussion, lecture report and works exhibition. The current situation of insufficient site area makes the design content have to merge functions, while the form of large ladder can achieve functional unity in limited sites (see figure 4b). The author unifies the decoration of the larger elevator room and staircase room as fair-faced concrete, and wraps a white cork exhibition wall with a height of 2.5 meters from the ground outside. This design maximizes the exhibition area, improves the space utilization ratio and realizes the functional transformation of the site. At the same time, the large continuous interface unification increases the integrity of the site, and the texture of fair-faced concrete and cork surface is combined, which makes the large area of the same interface less boring, richer and more ornamental (see figure 4b).
Where the academic ladder is closely connected with the corridor, a white floor steel grille is designed. Because of the particularity of the form, there is no complete division of two functional spaces. The translucent design method increases the mobility of the space. The sunlight penetrating the steel grille will form a rich and changeable shadow effect in corridor and other areas, enriches people’s experience and perception in space and causing use emotional changes of people. This reflects the relationship between design content and user experience in ISM model. Users are the long-term users of the site. Therefore, designers need to start from the user’s point of view, fully simulate and think about their experience of using environment, so as to make the designed space have emotional and human characteristics (see figure 4c).

![Figure 4. First floor rendering](image)

The second floor of the building is mainly classrooms, model rooms and studios. The design of the model room uses floor glass in a large area. On the one hand, it plays the role of displaying the works and their production process. On the other hand, it reduces the visual connection with the stairwell [10]. Because the stairwell and elevator room occupy too much room in the whole space, if the model room still uses solid wall, it will cause users to have depressive experience in the site. Therefore, after repeatedly considering the user’s feelings and the degree of conformity of design content, the author designs the model room as a transparent floor glass, which solves the user’s needs while creating a high space quality (see figure 5).

![Figure 5. Second floor rendering.](image)
During the whole design process, the project implements the observation method of the motion viewpoint from beginning to end, so that the observation point can be separated from the perspective of God, and the model can be observed and designed from the perspective of the human eye, so as to achieve the most real observation situation [11]. This is precisely the designer’s goal to move from abstract space to place perception, in such a way to increase people’s perception of place. It is an application of the hierarchical structure derived from ISM model. Under the ultimate goal of resolving contradictions, repeated attempts are made to achieve the design content, site status quo and user experience so as to achieve the best quality of space and the best user experience, truly establish the internal relationship between people and the environment, and mobilize more human senses to experience indoor space.

5. Summary
In this paper, through the literature research, induction and summary, questionnaire and other methods to obtain the elements of the 10 systems, the operation structure is obtained to explain the structural model, the factors affecting the design are divided into five levels and the relationship between the levels is drawn. Providing guiding ideas for subsequent design, focusing on the degree of conformity between design content and site status, as well as the control of capital cost and human experience in space, design results and “sports perspective” The design approach reflects the importance of the design content and user experience in the structural model. The final result is not only harmonious with the environment around the venue, but also maximizes the quality of the space and resolves the contradictions within the budget, so that the experience of people in space is optimal and humanized design is in line with the humanity.

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