Production of spatial complexity in an educational building

Xiaoling Dai
Architecture Department, Zhejiang University of Technology
dai_xiaoling@hotmail.com

Qi Dong
Art and Design College, China Academy of Art
dongqi00@gmail.com

Junhui Guo
Architecture Department, Zhejiang University of Technology
guoqunhui123@163.com

Abstract
No.18 building in the Xiangshan Campus of China Academy of Art is a four-story building designed by the 2012 Pritzker Prize winner Shu Wang. The first part of this paper explored users' perception of this building by three data collection methods. By questionnaire, it is found out that majority of its users no matter how familiar or unfamiliar they are with the building, encountered difficulties in way-finding behaviours. By cognitive map sketch, it is found out that 60% of users' mental maps have obvious discrepancy. By way-finding experiment, it found out that more than half of the detour behaviours are related with the design feature of vertical connections. Therefore, it is an unusual case which can enlarge our understanding for indoor navigation in overwhelming spatial complexity conditions.

The second part aims at uncovering the spatial features which made this building distinctive from normal educational buildings. Two sets of analytical methods are used. First, this building is examined by basic architectural analysis, j-graph analysis and, decision point density analysis, then comparing its various measures with an ordinary educational building. Second, several remodelled scenarios is created to compare with the original design. VGA analysis is used to show the effort of straightening the elongated twisted floor plan.

At the end, a comprehensive explanation for the spatial complexity and navigation problems is concluded. Three vertical spatial features and four horizontal features are summarised. In addition, this paper discusses the overwhelming problem of complicated buildings in a contemporary era, and suggests there is a need to refine tools for measure legibility of spatial layout. Four tools applied in this case study have shown their potential and should be tested in further studies. Finally, simple design suggestions are made for designers to utilise the findings from this empirical study.

Keywords
Spatial complexity, navigation, legibility, j-graph, educational building.
1. Introduction

Background of case selection

Although space syntax community has accumulated a great amount of building cases through the recent few decades, there is a particular type of buildings out of this database. They are the buildings which contradict to Hillier’s concept of “generic function” (1996, p.258). This concept refers to the following three aspects of human occupancy of buildings that is prior to particular functional programmes or activities: (1) to occupy space means to be aware of the relationships of space to others; (2) to occupy a building means to move about in it; (3) and to move about in a building depends on being able to retain an intelligible picture of it.

Generally speaking, buildings are commissioned by either developers or its future users. So, architects can only design within a certain framework embedded with culture and social background. Therefore, common buildings always fit in the definition of “generic function” to meet functional requirements. However, what if the client fully trusts the architect and the architect takes full advantage of the trust and let his imagination run freely without restriction of conventional rules? Then exceptional case may appear such as the No.18 building located in Xiangshan Campus of China Academy of Art, Hangzhou, China, designed by Shu Wang, the 2012 Pritzker Prize winner.

This building shows a genius architect’s creativity and his understanding of the poetical attribute of Chinese Garden. While, it is complained by its users as too complicated and bring difficulty for navigation. This attribute is well known by the locals, and even a TV series show “Running Man” thought they can utilise the unusual building for treasure seeking game. This building was selected as their first shooting site and achieved great success.

Therefore, it is conjectured that No.18 building is an un-intelligible building which contradicts to the definition of “generic function”. It is a precious case for researchers to explore people’s perception and way-finding behaviour in extreme circumstance.

Basic description of the case

It is the main building of Art and Design College, located in the second phase of campus construction project, and in the south side of the Xiang Hill (Figure 1). It is a four-story building, covering an area about 4,000 square meters. The floor plan is actually a replication of the No. 11 building in its east, but in an upside down way (Wang & Lu, 2008a).

Figure 1: No.18 Building’s (a) site plan (source: Wang & Lu 2008a); (b) photo
Shu Wang classified this building as the “courtyard” type. While it could also be viewed as an elongated rectangular shape with 300 meters length is twisted into a serpentine shape. It has a semi outdoor ground floor for parking and storage, and coped with the changing elevation of the site. Above it are the three main floors, where the classrooms and offices are located. Part of the roof is elevated, forming three small office rooms and the top of a staircase. The surface of the building volume is outstanding with the so called “flying way”, which goes in and out the building. It is a ramp, a special type of vertical connections.

By reading the articles written by the architect and the interviews he accepted, the design ideas of this building can be summarised in four parts. First, the relationship of the buildings with the Xiang Hill is important. The artefacts are inserted into nature. Therefore, the buildings are in the form of half nature and half artefact. This particular building is turning its back to the hill, implying a posture of silent and peep. Second, the “flying way” is inspired by the “Buddhist grottos caves on cliff” in the Thousand-Buddha Crag in front of Lingyin Temple in Hangzhou. The architect appreciates the place and believes that this kind of space is the proto type of university of Asia. When the “flying way” goes in and out the mass, it creates caves – the architecture interior. A series of poetic places appear abruptly when walking through the building in the rhythm of Chinese calligraphy (Wang & Lu, 2008b). Thirdly, there are various educational spaces in the building with different spatial qualities, such as the under the overhang roof, cave, flying way, courtyards in upper levels, and a roof platform. Therefore, the teaching activity can take place freely (ibid). When users criticised the insufficient light condition of the classrooms, he defended himself that “there are plenty of light outside the classroom. You can have a class in the corridor or on the roof” (Anon., 2012). Finally, responding to the doubt of over complication, he said, to find an exit in a maze liked building is the source of delight for the people in the 17th century’s litterateur such as Yu Li (ibid).

Research questions and methods

This paper is focused on three questions as follows. First, is it possible to describe user’s perception of this building systematically? Therefore, we can confirm the legibility problem as a fact, which made the case study significant. Three data collection methods were applied: questionnaire, cognitive map sketch, and way-finding experiment. Second, can we elaborate the distinctive spatial features of this building which are outstanding from ordinary educational buildings? The study chooses a common education building as a comparison case. By architectural analysis, j-graph and decision point density analysis, the differences are clarified in a quantitative manner. A further “remodelling scenarios” analysis is carried out to explore the effect of the main corridor twisting. VGA analysis is used to compare these scenarios. Thirdly, can we obtain a comprehensive understanding of the production of complexity for the No. 18 building? And is it possible to transform the spatial measures for spatial complexity into rules or patterns that architects can understand?

2. Report from user’s investigation

Three data collection methods were applied to describe user’s perception of this building: questionnaire, cognitive mapping sketch, and way-finding experiment. 2

General assessment from questionnaire data

74 valid samples are collected and covered four types of users: students, staff, visitors from other departments in the same campus, visitors from outside the school (Table 1). As many literatures suggested that level of familiarity have great influence on users’ way-finding behaviour (O’Neill,

1992), these participants are subdivided by level of familiarity. Statistically speaking, it is found that 85% of familiar users and 92% of half familiar users reported that they have navigation problem in this building.

**Table 1: Questionnaire samples**

<table>
<thead>
<tr>
<th></th>
<th>Occupants: students</th>
<th>Occupants: staff</th>
<th>Visitors: from same campus</th>
<th>Visitors: from outside</th>
</tr>
</thead>
<tbody>
<tr>
<td>familiar</td>
<td>35</td>
<td>14</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Half familiar</td>
<td>0</td>
<td>1</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>novice</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12</td>
</tr>
</tbody>
</table>

*Data from open-ended question*

It is found out that the No. 18 building does not only confuse the new comers, but it also frustrates the people who studies and works inside it for a long period. What are the users’ explanations for this unusual way-finding difficulty?

According to the questionnaire, we designed an open ended question, asking “what do you think is the main reason account for way-finding problem of this building?” The collected answers can be sorted into two types. The first group describes the troubles they experienced in detail, such as unable to locate the room; unable to identify which level they’re in; gone to a dead-end and can’t find a way out. The second group tried to elaborate the reason. The popular opinions can be summarised into five sets: (1) signs and room numbers are not clear, it’s difficult to find a room; (2) too many change of directions; it’s like you’re stuck in a maze and this can cause the feeling of uncertainty; (3) if someone is using the ramp to move vertically in the building, it is very difficult to figure out which level he is in; (4) although there are a lot of routes that can be used, but their accessibility is in doubt, many of them end up in a dead-end; (5) the layout is not at all like ordinary design, and do not coherent with peoples thinking habits. These five sets of opinions are both excellent evidence for this paper’s hypothesis that it is a “contra-generic function” building, and clues for further spatial analysis to explore the “production of spatial complexity”.

*Cognitive map*

At the end of the questionnaire and way-finding experiment, the participants were asked to draw the floor plan of this building by their best memory. Within the valid samples, 57 drawings are done by familiar and half familiar participants, another 6 drawings are produced by novice subjects from way-finding experiment.

According to the accuracy of the drawing, these 63 sketch maps were rated into 4 levels: correct (6 samples), almost correct (19), minor mistake (24), and huge mistake (14). Figure 2 gives typical examples for all the types. “Almost correct” type includes three circumstances: can represent the twisting shape of the plan, but with few detail (Figure 2b); do not express the folding shape enough by losing one or two turnings (Figure 2c); express the folding shape too much by adding one or two turnings (Figure 2d). “Minor mistake” type is much simpler: most drawings of this type represent the plan as a C shape (Figure 2e). “Huge mistake” type has more varieties: it could be a complete mess (Figure 2f), or only represent a tiny part of the building (Figure 2g), or express the folding shape excessively (Figure 2h).
There are 60% of users whose cognitive map have obvious discrepancy compare to the real plan. Even if we exclude the 6 participants who are first-time visitors of this building, the proportion is still a striking value (57%), which illustrates the legibility problem of this building strongly alongside the data we have gain from questionnaire.

These drawings can also help us to understand the origination of way-finding problems. For example, Figure 2h is a precise illustration for the above comment: too many change of directions, feels like you’re stuck in a maze. This content will be discussed with the help of spatial analysis tool afterwards.

Way-finding experiment

In order to understand the spatial detail of “getting lost” behaviour, way-finding experiment was designed and carried with 26 subjects in total. Two tasks are designated with different starting points and targets, in order to achieve various routes. Both target rooms are on the third floor and should be sought with only room number information. The investigator followed the subject and recorded he/she actually route on isometric perspective map (Figure 3). Then, data was input to cad program for the purpose of display and further quantitative analysis.
The parameter PAO [the distance (in % of the optimal route) that was walked additionally to the length of the optimal route] is calculated to assess way-finding performance of participants (Hölscher, Buchner, Meilinger, & Strube, 2009). The mean value of PAO for the familiar group and novice group is 1.25 and 1.45 respectively (Table 2).
By comparing the real traces of way-finding and the optimize routes of 26 subjects, 46 single occasions are found as obvious detour behaviour. They can be sorted into three types: (a) caused by incidental reason (33%), such as select the opposite direction of the goal; (b) management related reason (9%), such as a closed staircase, which will change a possible route into a dead-end; (c) design related reasons (59%). This type “C” can be further subdivided into three groups. In total, 68% of the non-incidental detours are related with the design of vertical connection, such as mistakenly take the wrong ramp and go to another level or cannot find a staircase lead directly to target level.

This finding in together with the questionnaire and cognitive mapping data suggested that, in very complex spatial layout, even the great familiarity cannot help people to cope with navigation tasks. This finding contradicts to O'Neill’s (1992) argument - “environmental complexity has less of an impact on way-finding as familiarity increases”. While, it does consist with Moeser’s (1988) observation in a very complicated hospital building.

This again suggests the “contra-generic function” building conjecture may be correct. It is hoped that a thorough spatial analysis and empirical study of this building can broaden our understanding on indoor navigation behaviour and its relationship with spatial configuration.

### 3. Comparative study

After a thorough user’s investigation, it is clear that No.18 building is a contra-generic function building, which is too complex to be memorized and navigated. This section tries to elaborate the distinctive spatial features of this building by comparing it with an ordinary educational building. East Building of CCEA, ZJUT is selected. It is a two-story building with a “C” shaped main corridor, and has rooms along both sides. This is a simple and pragmatic spatial arrangement that is common for educational buildings. The two buildings are compared with only one floor each at this time.

In the following sections, three methods are used to illustrate how and why the No. 18 Building is much more complicated than ordinary educational buildings. Please bear in mind that East Building is used as a benchmark of ordinary building.

#### Basic Architectural analysis

By visual inspection on their plans, two main differences can be figured out. First, No. 18 building has more vertical connections (convexes in red). Second, No. 18 building has a more complex horizontal circulation system (convexes in green). Quantitative comparison is then conducted to check this visual observation. As the two buildings have different floor area, normalized values should be calculated for comparing purpose (Table 3). Besides, as the “flying way” system which could be viewed as an additional attachment to the main structure, in order to understand its effort to the whole building, we also calculated every measure for the spatial system without flying way.

---

### Table 2: PAO data of way-finding experiment

<table>
<thead>
<tr>
<th>Level of familiarity</th>
<th>N</th>
<th>mean</th>
<th>SD</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>familiar</td>
<td>12</td>
<td>25%</td>
<td>.492</td>
<td>168%</td>
</tr>
<tr>
<td>novice</td>
<td>14</td>
<td>45%</td>
<td>.409</td>
<td>136%</td>
</tr>
</tbody>
</table>

---

3 The comparing floors are the ground floor of east building and the first floor of No.18 building are selected here, because the latter building has a fragmentary ground floor.
Figure 4: Single floor plan of (a) East Building (b) No.18 Building

Table 3: Architectural features of two buildings

<table>
<thead>
<tr>
<th></th>
<th>total area (m²)</th>
<th>length of corridor(m)</th>
<th>No. of vertical connections</th>
<th>vertical connections per 1000m²</th>
<th>length of corridor per 1000m²</th>
<th>proportion of corridor area</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Building</td>
<td>2236</td>
<td>152</td>
<td>3</td>
<td>1.3</td>
<td>68</td>
<td>18.0%</td>
</tr>
<tr>
<td>No. 18 Building</td>
<td>4739</td>
<td>531</td>
<td>13</td>
<td>3.3</td>
<td>112</td>
<td>35.0%</td>
</tr>
<tr>
<td>No. 18 Building</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| without flying   | 3983            | 269                   | 11                         | 2.3                             | 67.5                          | 22.6%                      | way/porch
The result confirmed the observation: (1) No. 18 building has more vertical connections no matter taking account of the flying way or not; (2) No. 18 building has almost twice of the length of East Building’s corridor; while if removed the flying ways, two of them are equivalent.

Besides, by reviewing the user’s investigation, another two outstanding features of the No.18 building are found. First, there are many ramps in this building. Actually, the architect has stated that all the corridors should be ramps, and that the users can be able to ride a bicycle from ground floor up to the top floor (Wang & Lu, 2008a). The ramps give novelty experience for the users, while bring a major way-finding difficulty in the same time. There are two types of ramps, the ones connecting spaces on the same floor; and the ones linking different floor plans. As these two types of ramps look very similar with each other (Figure 5a), the user could not tell whether he/she is in the same floor after going up or down with a ramp. There is five such confusion spots in the whole building, and their location are shown in Figure 5b from the top view. As for the first floor, convex elements 44/46/78 are all traps of way-finding task.

The second outstanding feature is the discontinuity of stairs in vertical dimension. For the whole building, there are 15 stairs in different positions (Figure 6). However, only one stair (G) can connect the ground floor continuously to the roof; more than half of the stair (53%) can only connect adjacent two floors, which force the user must find another vertical connection if he wants to overcome more than one floor.
**J-graph analysis**

By j-graph analysis, the differences between two buildings’ layout can be uncover more clearly (Figure 7). The two j-graphs are both drawn starting from the deepest space of the system. For east building, the root node is the northern entrance (convex 3); for No.18 building, the root node is the starting steps of flying way (convex 1). In order to do an easier inspection, both j-graphs are sorted in the way that the nodes belongs to the main corridor are kept straight in the middle. And in order to embedded the single floor within the whole building, the vertical connection nodes are all indicated by special symbols.

![Diagram of j-graph analysis](image)

**Figure 7:** Single plan j-graph with programmes of East Building and No.18 Building

J-graph of East Building is a tree like structure, with three little rings (rings that extend not more than three levels). It is easy to visualize its plan structure by reading this j-graph, rooms are located on both sides of the corridor. It is a common configuration of an educational building.

Contrarily speaking, j-graph of No. 18 building is somehow “out of control” – it is no longer a simply tree, but a tree with two parts of big rings attached to it. By big ring, we mean rings that extended to levels more than five layers. The lower rings are simple to figure out, but the higher rings are very complex. They are actually a set of rings overlapping with each other and across different levels. Once the users are in these rings, it is easy to lose their sense of direction, and therefore encounter way-finding problems.

Another unusual situation is the functional constitution of the rings. In normal building, a big ring is usually the circulation system which should be displayed as green nodes - “corridor”. But these rings are consisted by three colours of nodes: green represents corridor, purple represents flying way and yellow represents classrooms. This reflects the exact problem the users experienced in way-finding process – the route is very difficult to follow. A room or a segment of the flying way could become a
part of the route; when following a flying way, you don’t know what is waiting for you ahead, it could be a new possible route leading to another part of the building, or a dead-end.

**Decision point density analysis**

The above analysis has suggested that the circulation system of No. 18 building is very different from an ordinary educational building. The vertical connections in it are much denser and disconnected; the horizontal corridor in it is not only denser, but also very difficult to follow. It could lead the user to another floor without even noticing it (as the ramp in the same floor and to another floor looks the same); it could lead the user to a dead-end or to a long ring corridor with so many diverge directions to choose freely with less clue. This finding reminds us the “maze like” comment reported by many users.

This descriptive image may able to be captured by a quantitative measure: decision point density analysis. This measure should able to tell whether there are too many decision should be made when a user is entering a building and have a navigation task. Obviously, too many crossing points will cause the feeling of nervousness or even anxiety; too less crossing point means boring and less functional.

Both O’Neill (1991) and Peponis (1990) have developed their own definition of decision point. While, this paper modified their definition by absorb the idea from Hillier’s (1996) statement on a/b/c/d topological type classification. In the old analysis, a junction at the corner of “L” shaped corridor is regarded as a decision point. While, viewing it following the a/b/c/d classification, this junction should be a “b” or “c” space, in which people can only go forward or backward. In way-finding, people normally go forward instead of backtracking. Therefore, in an “L” shaped corner, the effort for making a decision is almost nothing compared to a crossing with many directions. So in this paper, only “d” space is regard as a decision point, where the forward route choice is more than one direction, that is to say the directions at that point is more than two. In Figure 8, decision points of No.18 building are noted down as yellow spots, a number is assigned to the spot represented the number of directions at this point (including the directions to another floor). This calculation can be conducted easier with the help of the correspondent J-graph.

---

**Figure 8:** Decision points of No.18 building
By this analysis, a significant difference is uncovered (Table 4). In No. 18 building, users encounter at least twice as many decision points as in a normal buildings with similar size (5.3/2.2). And in the main corridor of it (without the flying way), with a speed of 300meter/5minute, every 16 seconds (100 meter/6.3), the user will meet a new point to make an annoying decision.

Table 4: Comparison of decision point density

<table>
<thead>
<tr>
<th></th>
<th>total number of decision point</th>
<th>decision point area density (per 1000m2)</th>
<th>decision point linear density (per 100m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Building</td>
<td>5</td>
<td>2.2</td>
<td>3.3</td>
</tr>
<tr>
<td>No. 18 Building</td>
<td>25</td>
<td>5.3</td>
<td>4.7</td>
</tr>
<tr>
<td>No. 18 Building</td>
<td>17</td>
<td>4.3</td>
<td>6.3</td>
</tr>
</tbody>
</table>

4. Floor plan remodelled scenario analysis

Scenario construction

In the analysis above, the spatial system of No. 18 building has been compared with a normal building as benchmark. A detailed understanding of how to construct an extremely complicated circulation system is then achieved. It is mainly about how you design the vertical connections and horizontal corridors. However, one obvious feature of No.18 building’s layout is missed. It’s the twisted main corridor. By creating a series restoring scenario, we can straighten the elongated building step by step (Figure 9). By a simple visual inspection, human instinct tells us that version III is a much simple structure then the original version I because it has a continuing of line of sight instead of abrupt turns.

Figure 9: Straighten the plan step by step

VGA analysis

Then the VGA analysis is brought in to give quantitative measures. It will give us the mean visible area in every position of the spatial system for each scenario. The data map is drawn in the way that every door and window is open to line of sight; the grid in depthmapX program is set as 500mm*500mm. By dividing “connectivity” value by 4, a measure “visible area” for each grid is achieved. It is found that by straightening the floor plan, the mean visible area of the system gain a significant increase (Table 5).
Table 5: VGA analysis of three scenarios

<table>
<thead>
<tr>
<th>scenario</th>
<th>mean visible area (m²)</th>
<th>ascend %</th>
<th>total elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>114.3</td>
<td>100.0%</td>
<td>17033</td>
</tr>
<tr>
<td>II</td>
<td>144.2</td>
<td>126.1%</td>
<td>17258</td>
</tr>
<tr>
<td>III</td>
<td>151.4</td>
<td>132.4%</td>
<td>17370</td>
</tr>
</tbody>
</table>

By examining the visibility distributing in the three scenarios, a trend is discovered - the visibility of the main corridor improving dramatically along with the straightening of the plan. In the originally design, the main corridor has no visual advantage than other spaces. By straightening the plan, the main corridor begins to capture its visual importance (more red is shown in Figure 10), and therefore, it is transformed to a normal building which people can understand and memorise, that is to say, gains a legible spatial system.

Figure 10: Connectivity measure display for three scenarios

5. Conclusion and discussion

Spatial explanation for navigation problems

By empirical data collection, this study identifies the No. 18 Building as a complicated building which brings to severe navigation problems for its users. By two sets of analytical methods, a comprehensive understanding of why No. 18 building has such a complex spatial system is obtained. Generally speaking, the explanation can be summarised as the following two categories: vertical and horizontal features.

As the current knowledge about way-finding str

ategies suggested, in a typical way-finding process, a user most probable either start from vertical search for the right floor or move horizontally to the right direction of the target (Hölscher, Meilinger, & Vrachliotis, 2006). In the first type of occasion, he/she will encounter with three main vertical spatial obstacles as shown in Table 6. In the right column of the table, the analysis tool used for identify the particular problem is given alongside. Actually, as we have shown the result of the way-finding experiment, 68% of the non- INCIDENTAL detours are related with the design of vertical connection. This finding is consistent with Hölscher’s argument (2006), that staircase design is identified as a major way-finding obstacle.
Table 6: Vertical spatial features account for navigation problems

<table>
<thead>
<tr>
<th>spatial feature</th>
<th>consequence for navigation</th>
<th>analysis tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 similarity between ramps in the same floor and cross floors</td>
<td>Mislead the user to other floor</td>
<td>architectural analysis</td>
</tr>
<tr>
<td>2 too many vertical connections</td>
<td>abundant decision making points, difficult for memory</td>
<td>architectural analysis</td>
</tr>
<tr>
<td>3 discontinuity of vertical connection</td>
<td>cannot reach the target floor directly</td>
<td>architectural analysis</td>
</tr>
</tbody>
</table>

After the user reached the right floor successfully, there are another four horizontal spatial obstacles which him/her may meet as shown in Table 7.

Table 7: Horizontal spatial features account for navigation problems

<table>
<thead>
<tr>
<th>spatial feature</th>
<th>consequence for navigation</th>
<th>analysis tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 overlapping big rings</td>
<td>challenge for memory, feel like mass</td>
<td>j-graph</td>
</tr>
<tr>
<td>2 topology of space and function type do not match</td>
<td>unusual design, unexpected routes and dead-ends</td>
<td>j-graph</td>
</tr>
<tr>
<td>3 too dense of decision points</td>
<td>great effort to select the way, may miss the right crossing</td>
<td>decision point density analysis</td>
</tr>
<tr>
<td>4 too many turns of directions of the main corridor</td>
<td>cannot tell the right way in a single vision; lose of direction</td>
<td>VGA</td>
</tr>
</tbody>
</table>

Discussion about “over” complexity

This paper gives a thorough explanation for the production of spatial complexity for a special building. This effort is in line with many other studies – aiming at providing an objective, quantitative approach to validly predicting way-finding performance during the early planning stages of a building (Werner & Schindler, 2004).

In the contemporary era, this kind of research is even more important, because encouraged by the following three aspects of conditions, “over complexity” gradually become a significant problem for many multi-level buildings. These are: the advancement of technology development in construction; the multi-functional architectural programming; and the pursuing of design creativity and novel spatial experience.
However, beyond a certain extent, complexity becomes a negative attribute. Legibility problem of buildings will lead to inefficiency for usage, causing the feel of uncertainty, anxiety and even panic. Take this building as an example. The original design put great attention to the interrelation of indoor/outdoor spaces. It is an effective method to foster educational atmosphere as many literatures has suggested (Ünlü et al., 2009; Tanner, 2008). However, the great idea of free spread learning spaces is resolved by the over freedom of circulation system apologetically. The over complicated spatial layout made the simple task of moving around the building difficult, not to mention exploring the scattered and ample learning places. This building do not have a “clear and comfortable pathways allow freedom of movement and orientation among structures” if use the criterion in Tanner’s Design Appraisal Scale (2008).

**Measuring the legibility of spatial layout**

So there is a need of tools to help the Architects to test whether the legibility of their design is acceptable, in other words control the spatial complexity of their design. In this case study, four tools are introduced to uncover the production of complexity. These tools are: basic architectural analysis (to map the condition of vertical connections), j-graph, decision point density analysis and VGA analysis. Importantly, not a single tool can explore the level of complexity by itself. They are more effective when working together. Within them, “decision point density analysis” is a new tool improved by the authors. It is derived from ICD analysis, but altered in two aspects. First, enlightening by the a/b/c/d space’s definition, it regards the “D” space as the only type that requires decision making; Second, human perception is considered in the measure by calculating the time interval for encountering a new decision point.

Regretfully, this measure is relying on manual computation. Is it possible to do it by computer program in the future? The current j-graph related programs are jass and the convex analysis function in depthmapX. Neither of them can give a/b/c/d value automatically. A software upgrade is urged to facilitate this type of analysis.

**From research finding to design guides**

To transforming research findings to simple design suggestions or even a few reader-friendly guides is always a challenge. However, this effort is important as only a very few design schemes have the chance to get advice from researchers.

This paper on the one hand gives an extreme example of achieving un-legibility for the readers, hoping that if a new design requires a well-organised spatial system, it should intentionally avoid the vertical and horizontal spatial obstacles the example has shown. On the other hand, two guidelines are summarised for achieving an intelligent building as follows. First, the vertical system should be simple and easy to form a clear survey picture for the users. That is to say, the number, location and connectivity of the vertical connections should be carefully designed. Second, the main corridors system in the horizontal level should also be clear, continuous and recognizable. It is suggested that the designers could utilise a simple version of j-graph, something similar as the bubble diagram, to examine the decision making point density and whether there are “big and over lapping rings” in the spatial structure, then control the level of complexity by compare the design proposal with familiar existing cases with similar function, such as this paper select East Building for get a benchmark. By these efforts, the designers may able to cope with spatial complexity with higher controllability.

**Acknowledgements**

This work is financially supported by Natural Science Foundation of China (51208465).
References


