Influences of Spatial Configuration Learning on Spatial Behavior

Ref 031

Focused on the shortest distance and visibility

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Keywords
spatial configuration; spatial learning; spatial behavior; spatial usage; shortest distance; visibility

Abstract

This study aims to investigate factors on spatial behaviour. We consider two factors; one is the shortest distance, and the other is visibility. The effect of these variables are compared by analysing on the relationship between both spatial configuration and spatial learning on spatial usage. Coex, which is a representative for mixed-use mall, is selected for the case study.

The research is carried out as follows; firstly, visibility is analysed quantitatively using Space Syntax software of Depthmap. ; secondly, the shortest distance is examined using DEM (Discrete Element Method); thirdly, observation is conducted to measure actual spatial behaviours by following users; fourthly, the degree of spatial learning is measured using questionnaire, and especially, spatial cognition is surveyed based on sketch maps; fifthly, the relationship between spatial configuration and spatial usage is analyzed; and finally, the relationship between spatial learning and spatial usage is investigated.

It is found that both the shortest distance and visibility is closely related with spatial usage, while visibility has much influence than the shortest distance. In addition, in the case that people lack sufficient spatial knowledge, they show a dominant tendency to prioritize visibility in a way to minimize trials and errors.

1. Introduction

The process of how people recognize spatial configurations and use them is the important subject for understanding the relationship between people and environment.

Lynch (1960) said that in the built environment, organization of building factors plays an important role in representing spatial cognition. Among those factors, spatial configuration is considered as an important element that influences people spatial experiences (Steadman, 1983; Hillier, 1996). Similar to that context, Golledge & Stimson (1997) also insist that spatial layout is an essential element in people's understanding of their spatial surroundings. However, little is known about the correlation among spatial configuration, learning, and behavior. Although Yoon et al (2005) investigated the correlation among them partially, there is no study in the comprehensive perspective.

Downs & Stea (1973) insist that basic information of environment that people need to know are place, distance and direction, and they also said that not only metric distance but also cognitive distance plays an important role to recognize the space for people. Sadalla & Staplin (1980) talk about the change of direction as an important characteristic on the cognitive distance paradigm.

They prove that people feel the road longer as they see more intersections on the path, and they also prove that the number of direction change influences people's distance-cognition. Hillier (1996) explains on change of direction using the term, "Syntactic depth". Depth is a relative idea, meaning the change of direction that occurs when people move from one space to another. Hiller insists that the influence of the depth is the essential factor for people to decide how to use a space in a certain spatial configuration.

Visibility and spatial cognition on the shortest distance is an important factor in architecture that deals with spatial configuration. It hasn't been studied the intensity of the impacts of the two factors with regard to spatial behavior. However, there is no report on interrelationship between spatial configuration and space-use behavior and learning on environmental information in the process.

The purpose of this report are, (1) to investigate whether the visibility and the shortest distance are related to spatial use, and if there is a relationship, which factor influence more on spatial use, (2) to investigate the relationship between the degree of learning on environment and people's spatial use, and it there is a relationship, to examine the influences of learning focused on visibility and the shortest distance, and (3) to figure out the interrelationships among spatial understanding, spatial cognition and spatial use.

The steps of the study are, (1) analyzing visibility on the case study area and the characteristics of spatial configuration on the shortest distance using space syntax and DEM, (2) examining space users' actual behavior using subject following investigation from a selected origin to a selected destination, (3) conducting a questionnaire survey by analyzing people following in a study site. Analyzing the degree of users spatial learning by using the questionnaire and investigating a cognitive map by using sketch map. Analyzing the characteristics of the spatial cognition associated with spatial configuration. (4) analyzing the interrelationships between spatial configuration and spatial usage, and (5) Fifth, investigating the correlation between spatial learning and spatial behavior in a perspective of the spatial configuration. Thoroughly, this report examines the influences of spatial configuration and the degree of spatial learning on people's spatial usage using investigation on people's behavioral and psychological characteristics.

2. Theoretical Background and Preceding Research

Spatial configuration, spatial cognition and spatial use are the most important issues in understanding the relationship between human beings and their environments. Lee and Choi (2001) has argued that people experience buildings differently as they move in space and the configuration of spaces, rather than individual spaces, will play a decisive role in drawing a strategic line of movement from this experience. The people's cognition of distance in metric space is also a very important factor in architecture concerned with spatial configurations. From this point of view, Yoon (2005) has first regarded both metric distance and depth as important factors in spatial cognition, but found that depth becomes more influential than metric distance as the spatial scale of cognition expands. Therefore, this study investigates spatial configurations and human movements with a focus on metric distance and visibility.

2.1 DEM Theory

DEM theory is a type of traffic flow in a broad sense, and it is designated as a program to analyze flow of pedestrians or flow of passengers in the field of architectural engineering and communication engineering. It divides structures' plain molds like VGA analyzing method, construct potential map putting direction vector on each cell-when it puts direction vectors; the direction is decided as the direction vector of the shortest copper wires from an inlet to the closest outlet.

The basic concept of the potential map is that when the potential value of an exit cell is given as 1, the potential values of surrounding cell is increasing gradually to 2, 3, 4, and so on. The user of the program moves from starting cell to another cell that has lower value, and if there is another user in the cell, he or she moves to other cell that has the same value to the cell that he or she wants to move. In Fig 1, starting from the circled cell (value 6), the user searches other cells that have the lower values, and there are 3 potential value 5 cells. In this case, the user has to compare each potential value of the next steps to move. Cells to right-lower direction go 5, 4, 3; cells to right direction go 5, 4, 4; and right-upper direction goes 5, 6, 7. In other words, the user has the main vector direction to the right-lower direction. Figure 1 show the main vector direction on each cell. In order to identify the shortest path from a particular origin point and the destination, in is necessary to find out the path based on the main vector direction between two points.

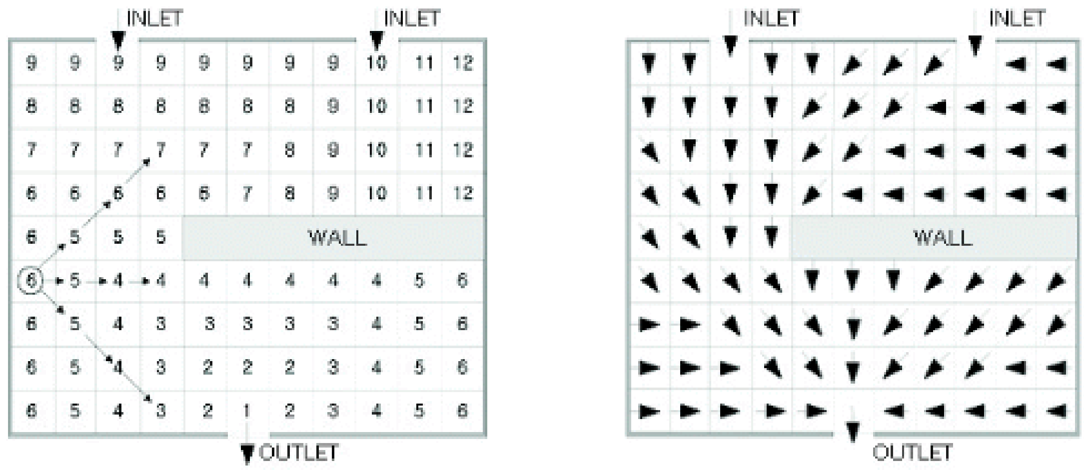


Figure 1
Direction vector of cell

3. Methodology

3.1 A Case Study Area

To complete this study, we chose "Seoul Samsung Coex" as a case study area. The reasons are: (1) main place of Coex, underground arcade, is the main path connecting surrounding buildings and subway station, and is the area for shopping and hanging out. Moreover, Coex is a large public place that numerous people use intensively so that it is easy to observe diverse space-using behaviors. (2) Event court located in the center of Coex at the aspect of spatial configuration. It is regarded as the center for spatial usage by connecting facilities and stores in Coex as well. Therefore, it is reasonable to designate the court as the objective standard for analyzing visibility and shortest distance. (3) Coex building is comparted by surrounding roads so that we can present objective standard to investigators and subjects.

This study is for examining space-using behaviors, the above fact-Coex has the obvious boundary characteristic-is reflected in limiting study site. So, a questionnaire survey was conducted. For the questionnaire survey, total 52 facilities from B2 floor to 1st floor (total 3 floors) are selected for the mainly used areas. Also, by considering Coex and adjacent facilities and streets, the spatial characteristics of Coex is investigated in the urban context.

3.2 Analysis on Spatial Configuration Utilizing Space Syntax Theory and DEM Theory

To understand the spatial configuration of the study site, visibility and shortest distance of the study site are analyzed by using Depthmap and DEM. Depthmap and DEM have the similar analysis structure. Both assign the value of cell by randomly selected grid value. The cell represents the spatial characteristics. So, to compare and analyze the spatial characteristics of the visibility and shortest distance, spatial configuration is interpreted based on the identical analysis boundary and grid value.

In establishing analysis boundary, users' spatial behavior and information map are referenced and reflected in the analysis boundary to accurately capture spatial behavior. Most of public spaces allowed to pedestrians are included in the analysis boundary except for facilities and stores in the study site. The grid with the resolution of 1500mm is used for the Depthmap based visibility analysis. The grid is also employed for the DEM based shortest distant analysis. A people Following to put direction vectors on each cell is performed, and the main paths that has grade 5 of final destination are drew out. Using the paths form inlets to outlets, the shortest distances are examined.

3.3 A Survey on Spatial Behavior Using a People Following

People following was conducted to investigate users' spatial behaviors. A user was randomly selected at the station and monitored from Millenium Plaza to a particular destination the user decided. The user's path was marked on the map. Monitoring was carefully proceeded to prevent the randomly appointed user to recognize that one was in monitoring. In general, spatial behavior might be influenced by monitoring. In people following, toddlers or group users were excluded in monitoring because their choices tend to be made by others.

3.4 A Survey on Spatial Learning and Spatial Cognition Using a Visitors' Questionnaire

To figure out people's spatial learning degree, survey is performed. The questions were asked to the monitored user at the point where monitoring was done. The questionnaire is composed of the questions asking people's basic spatial usage and people's degree of spatial learning.

To examine people's spatial cognition level, surveys for cognitive map (the same method as above) using questionnaire and sketch of their path. We introduced the survey as for more efficient usage of Coex, and asked people to draw every part of the area they recognized on an A4 size paper. After that, we provided the map of Coex and asked them to check the main area of Coex they considered. The cognition survey minimized the hesitation and helped people draw easier letting them know scale of the area and direction by putting station and Cinema on the paper.

4. Correlationship among Spatial Configuration, Spatial Usage and Degree of Learning

4.1 The Spatial Configuration

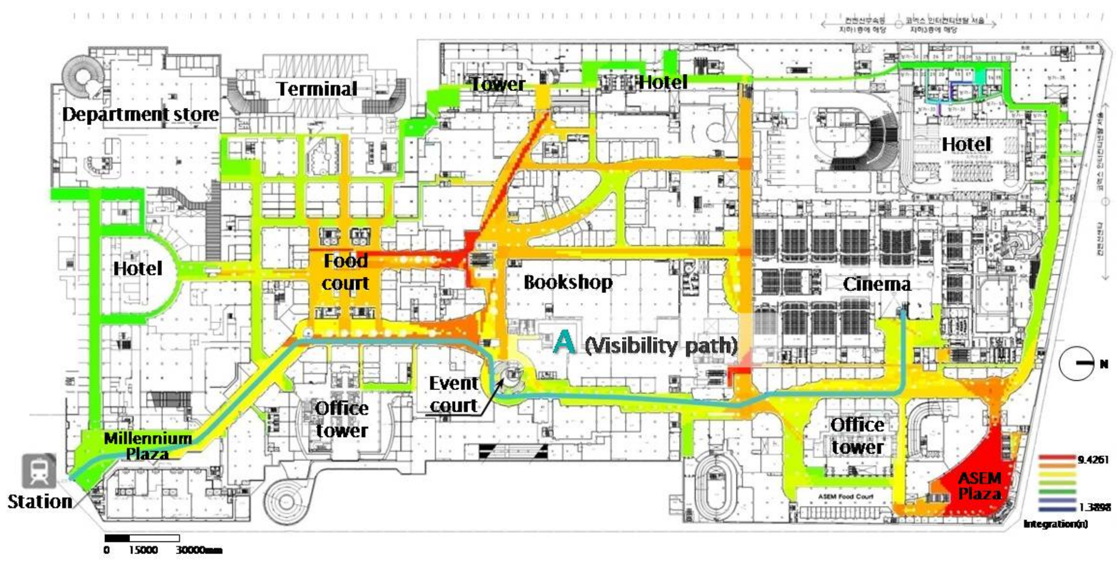


Figure 3-a

Paths to Cinema destinations - Visible path to cinema vs spatial usage (global integration)

The spatial configuration of Coex is examined focused on visibility and the shortest distance. Fig 3-a shows the global integration indicating the result of the visibility analysis at the arcade in the basement of Coex. The integration shows the properties of spatial configuration in view of the whole logical connection considering not only the Coex but also the surrounding areas, indicating visibility and permeability in the whole ranges of space. ASEM Plaza has the highest integration score (4.64) the escalator area located in the north of food court show 4.29. The lowest score is found in the escalator area near the Event court (3.93). Such impact is connected to the main path in Coex while low integration score is found in the path way to the department store in the west and the way to hotel, and the way to tower (2.15). The result show that the visibility and accessibility decrease at the sub-areas away from the main areas where most facilities are located.

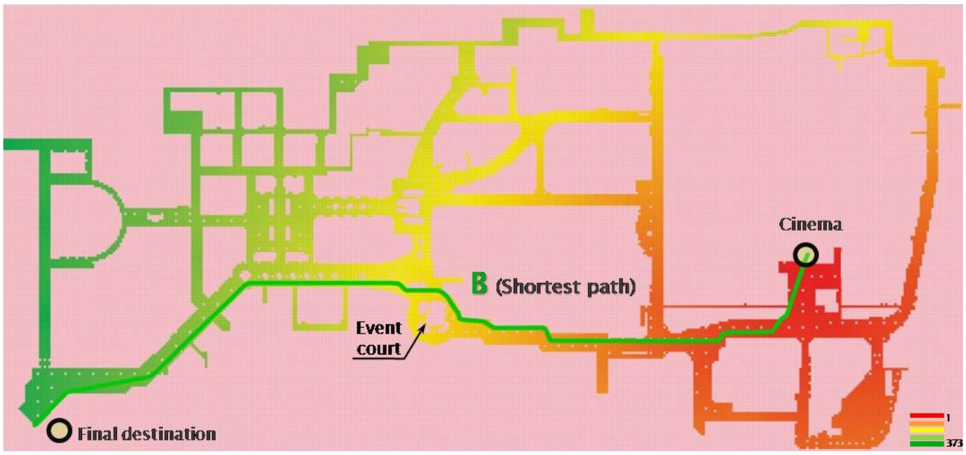


Figure 3-b
Paths to Cinema destinations - Shortest path vs spatial usage

Fig 3-b is the examination on the shortest distance of the main path (Station-Cinema). 3 levels of spectrum (red, yellow, and green) are used to make the comparison of the result to Depthmap easier. The lower the cell value, the shorter the distance from the destination, and it is represented by color red. On the other hand, the larger the cell value, the longer the distance from the destination, and it is represented by color green. It is found that cinema has the value of 1. The surrounding cell value increase in the order of 2, 3, and 4 with green.

4.2 The Spatial Behavior

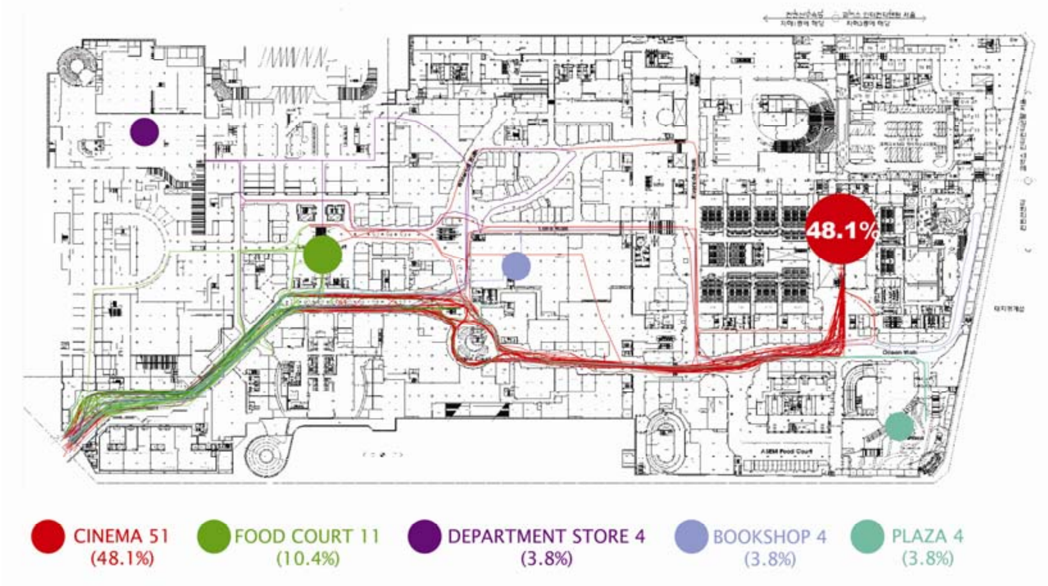


Figure 2.
Spatial usage paths of main 5 destinations

To understand users' spatial behavior, spatial behavior pattern and general spatial pattern were investigated. Total 106 people were monitored to examine spatial behavior. We grouped the people according to their destination point, and the path that has the highest frequency value was the path to the cinema (48.1%, n=51). The following paths were food court (10.4%, n=11), department store, bookshop and Plaza (3.8%, n=4) Few data were ignored due to the lack of sample numbers.

To see the general spatial use pattern, a quetionnare was conducted to the monitored users. As a result, it has the most case of came to the movies (28.22%, n=46), the main place people visited was Cinema (29%, n=78), and most people tended to remember names of the stores rather than constructional characteristics such as an open hall or an escalator as their mainly hanging out places.

4.3 The Spatial Learning and Spatial Cognition

Visiting frequency and experience were examined to see the degree of spatial learning. As a result, according to the investigation, 42.45 percent of the users have visited the place more than 20 times (n=45). It means that most of the users have visited Coex continuously over a long period of time, and we can infer that the facility users have a certain degree of spatial learning of Coex based on the fact.

To examine the degree of the spatial cognition, we investigated facility users' degree of the path cognition and cognition map. As a result, 71.69 percent of the users answered that their cognition level is higher than the average (n=76).

Total number of visit		**Level of path cognition**		**Value of recognition**			
Frequency	Persons	Cognition	Persons	Number	Persons	Number	Persons
First time	1(0.94%)	Utter unknown	6(5.66%)	34	1(0.94%)	10	1(0.94%)
2~4	14(13.2%)	Unknown	24(22.64%)	33	1(0.94%)	9	2(1.89%)
5~10	23(21.7%)	Normal	39(36.79%)	25	2(1.89%)	8	5(4.72%)
10~20	23(21.7%)	Known	28(26.42%)	21	1(0.94%)	7	6(5.66%)
20 and up	**45(42.45%)**	Very well known	9(8.49%)	18	1(0.94%)	6	4(3.77%)
				17	2(1.89%)	5	9(8.49%)
				15	2(1.89%)	4	9(8.49%)
				14	3(2.83%)	**3**	**14(13.2%)**
				13	2(1.89%)	**2**	**12(11.32%)**
				12	2(1.89%)	**1**	**19(17.92%)**
				11	1(0.94%)	0	7(6.6%)
Total	106(100%)	106(100%)		106(100%)			

Table 1
Level of spatial learning and spatial cognition of Coex users

Facility users' degree of cognition is analyzed applying a fixed quantity based on their expression degree and their way of expression. The expression level is analyzed based on (1) the expression degree of all the places on the cognition map and (2) the expression degree of essential places on the cognition map. As a result, the expression degree of cognition map (49.04 percent (n=52) of people said that they only knows 0~3 places on the map) shows difference from the result of the path cognition degree (28.3 percent (n=30) of the people said that they totally don't know the path or don't know the path very well). It shows that people feel it difficult to draw the cognition map even though they don't feel any difficulty on using the place. In other word, actual map and the map in people's head are somewhat different. The main area people mostly go was Cinema (14.6%, n=91), and the main place people use showed the similar tendency. It means that people tend to recognize the space based on their main using space.

5. Influence of Spatial Configuration and Learning on Spatial Usage

5.1 Correlation between Spatial Configuration and Spatial Usage

To analyze the correlation between spatial configuration and spatial usage, we investigated the visible path and the shortest path, and we compared the result to the actual space-using path. For this, Cinema destination path was selected for the representing path. Individual paths were analyzed based on Station and Cinema. Visible path was analyzed based on global integration indicating visibility and permeability. Visibility increases as the value in the global integration increases. The Visible path is defined as the path following cells with the highest integration values in this study. The fig 3-a shows the results of the visibility analysis between Station and Cinema.

Fig 3-b shows the results of the shortest path by using the similar method in the visibility analysis. Based on the DEM result, paths were analyzed in the direction of low value cells between Station and Cinema. The path A and B show the different pattern at the point of Event court. The actual distance was measured in AutoCAD and it is found that A is 12000mm longer than B.

Fig 3-c compares the visible path and spatial usage path to the most active destination area, the Cinema. For spatial usage path, people whose destination is the Cinema (n=51) used Event court (92.1%, n=47). Therefore, we analyzed correlation between the visible path and the shortest path focused on their spatial usage.

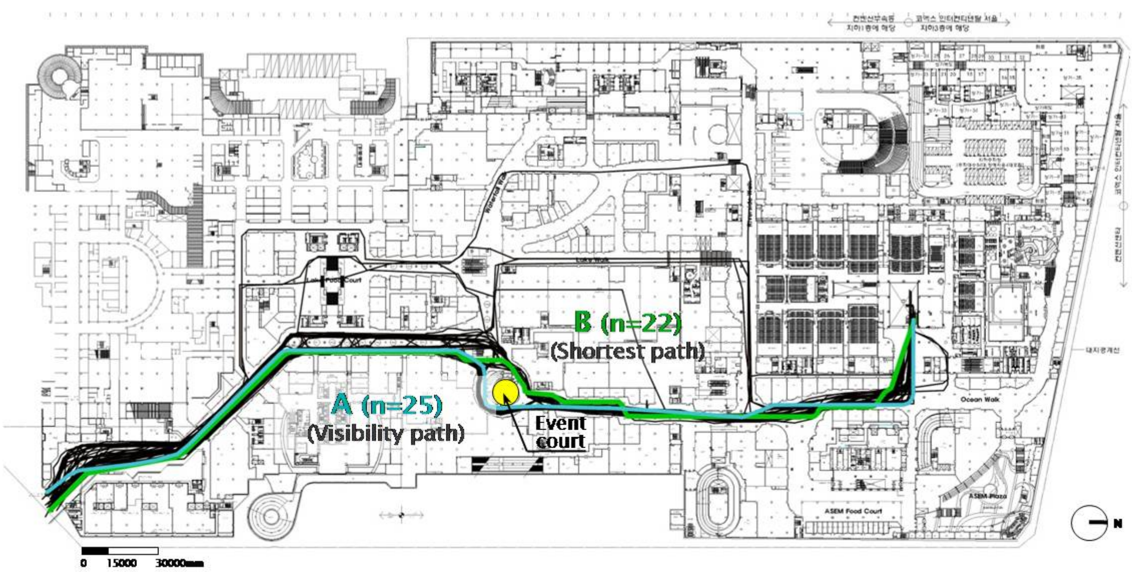


Figure 3-c

Paths to Cinema destinations - Visible path vs shortest path vs spatial usage

As a result, 53.2 percent (n=25) of the people among the people who use the total spatial usage path (n=47) utilized A, and 46.8 percent (n=22) used B. It shows that the relationship between Coex users' spatial usage and visibility is more closely connected than the relationship between the user's spatial usage and the shortest distance. Although A is 12000 mm longer and 6.4% higher than B in distance and usage, users were not much influenced by the physical distance. Moreover, in the aspect of spatial design, Event court is located in the center of underground arcade, and A and B have different inner environments: A is the place that has stair seats so that people can appreciate many events, and it also secures visibility and accessibility. On the other hand, B limits visibility and accessibility by the stage and wall, and it is dark. Therefore, based on the regulation that Peponos, Zimring and Choi (1990) insists that people prefer more on the place that is brighter and wider or that has more visible access, and also people used place A more than B.

5.2 Correlation between Spatial Learning and Spatial Usage

In this section, the study analyzes the relationship between spatial learning and spatial usage in these steps: (1) analyze the relationship between spatial learning and spatial cognition (2) analyze the relationship between spatial cognition and spatial usage (3) analyze the relationship between spatial learning and spatial usage. Validation was proceeded to see the correlation in the order of the degree of spatial learning, spatial recognition, and spatial usage.

5.2.1 Correlation between Spatial Learning and Spatial Cognition

In this section, it is explored the impacts of users' visiting frequency and experience level on users' cognition level. For that, the following method was employed: (1) the point range of the frequency of visit is set from 1 to 5: first time gets 1 and more than 20 times scores 5 points. Coex users'(n=106) average score was 3.92, and it shows that they have the frequency more than average and relatively have high level of spatial learning (2) the point range of familiarity of the path is also set from 1 to 5: totally utter unknown gets 1 and very well known scores 5 points. The average score people earned was 3.06, and as a result people had an average familiarity on the space (3) the number of main spot on the cognition map was varied from 1 to 34, and converse the number to object value and analyze the relationship using STAT VIEW.

As a result, we found that the positive relationship among total number of visit-and-degree of path recognition (0.523), frequency of visit-and-expression level on cognition map (0.415) and expression degree on cognition map-and-degree of path recognition (0.366).

Correlation Matricx						
Section	Total number of visit		Path recognition		cognitive map expression value	
	R	P-Value	R	P-Value	R	P-Value
Total number of visit	1	-	**0.523**	4.42502E-09	**0.415**	4.86259E-06
Path recognition	**0.523**	4.42502E-09	1	-	**0.366**	5.70928E-05
cognitive map expression value	**0.415**	4.86259E-06	**0.366**	5.70928E-05	1	-
106 observations were used in this computation / p-value < 0.0001						

Table 1
Comparison on total number of visit, path recognition and cognitive map expression value

5.2.2 Correlation between Spatial Cognition and Spatial Usage

In Fig 4, (a) shows the rainbow spectrum that is used to compare and contrast the expression degree on the cognition map and space use. It is consisted of total 7 levels showing from number 1 to 91, and the red is for the highest level of expression. (b) is the design that shows the spatial usage path of the users, and both (a) and (b) are similar in frequency. For example, in the case of the path A, the main path in Coex, shows yellow, orange, red type colors are found in the areas near the major path(a) and shows that the path has the most dense usage(b). Also city airport tower and convention center around Coex has '0' in expression frequency (a), and also has '0' in spatial usage (b).

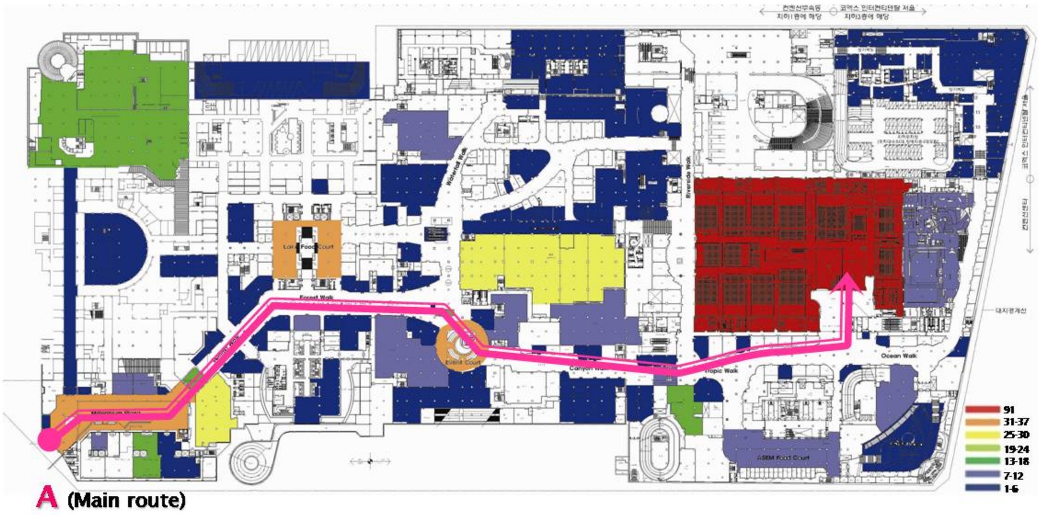


Figure 4-a
Analysis on spatial cognition on cognitive map

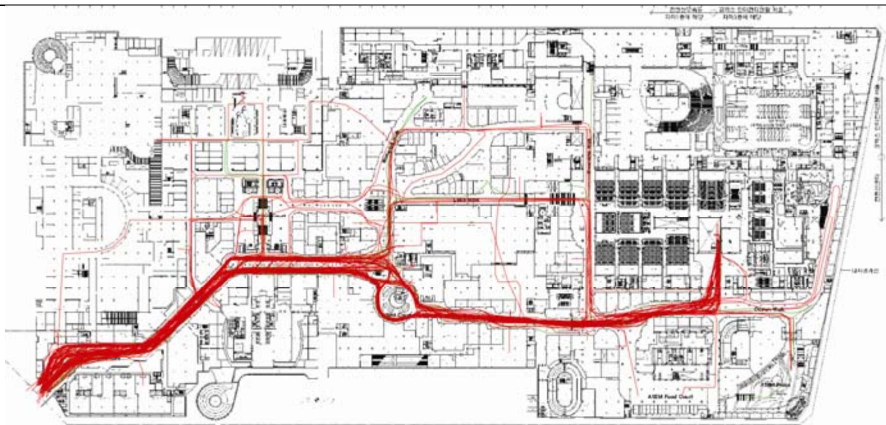


Figure 4-b
Spatial behavior of Coex users

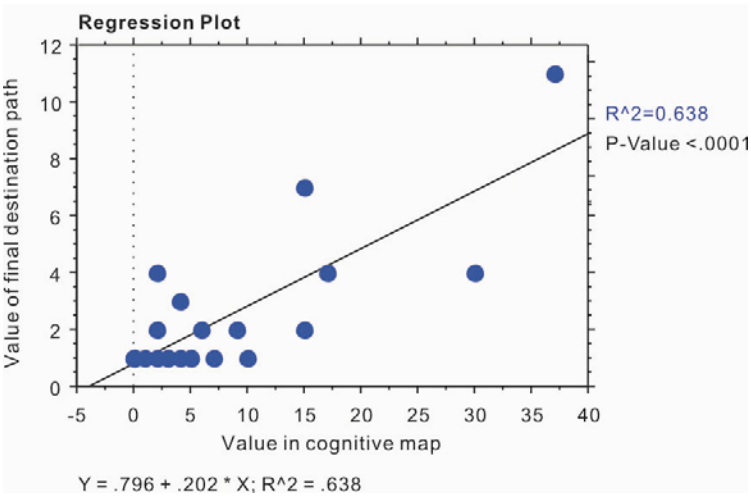


Figure 5
Expression value in cognitive map vs value of final destination path

To analyze the relationship more objectively, we used SPSS. As a result, independent variable represented cognition expression value and dependent variable represented final destination value, and there is positive relationship between the two (63.8% of the relationship). It says that users' spatial usage is formed based on the spatial cognition (Fig 5).

In sum, as fig 6 shows, the correlations between the spatial learning and spatial cognition were 41.5 and 52.3 percent. 63.8 percent were found in the between the spatial cognition and spatial behavior. These indicate that there is a strong relationship among the three factors.

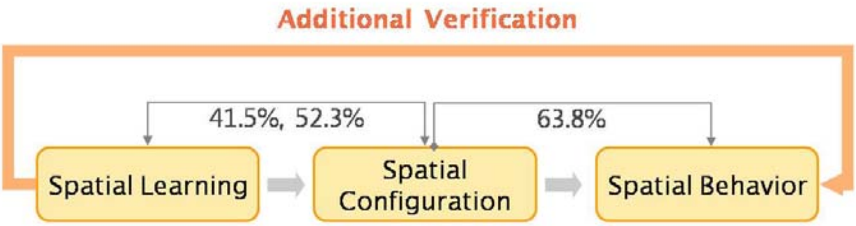


Figure 6
Correlation among spatial learning, spatial cognition and spatial behavior

5.2.3 Correlation between Spatial Learning and Spatial Usage
In Fig 7, we analyzed 25 users' path using visible path based on the Event court to investigate relationship between degree of learning and space use.

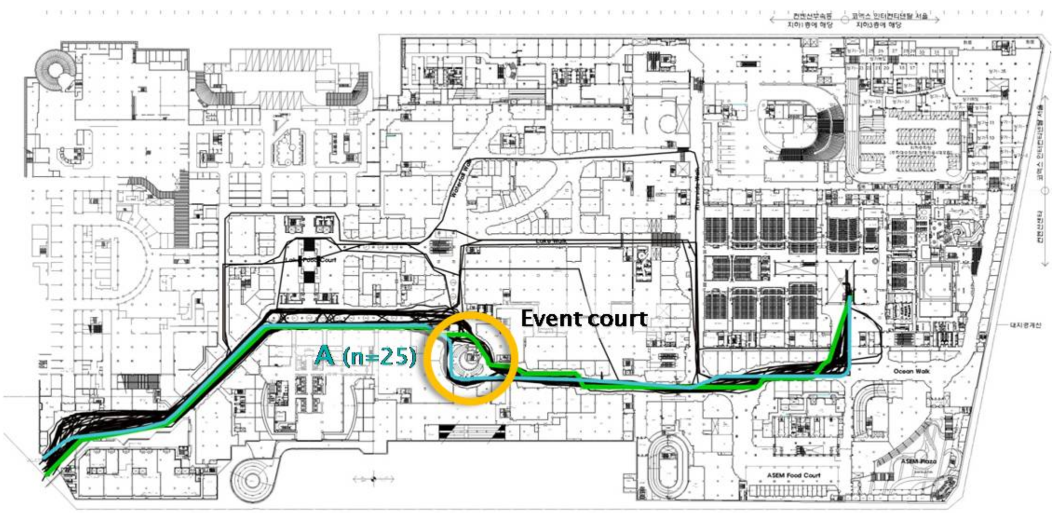


Figure 7-a
Visible route of Cinema vs the shortest route vs behavior

15 users among 25 (60%) didn't recognize the event court when they draw the cognition map while other 10 users did. However, 4 among the 10 didn't precisely recognize the event court but just remember the location (Fig 7-b). Like this, 19 users among 25 (76%) who didn't concisely recognize the Event court were the people who draw path A with straight lines and diagonal lines. It shows the relationship between the two factors when Coex users' spatial cognition and spatial usage. Path A in users' minds is straight or diagonal lines, and the movement from the entrance of Coex to the location that has visibility means moving straight or diagonal in spatial cognition to users.

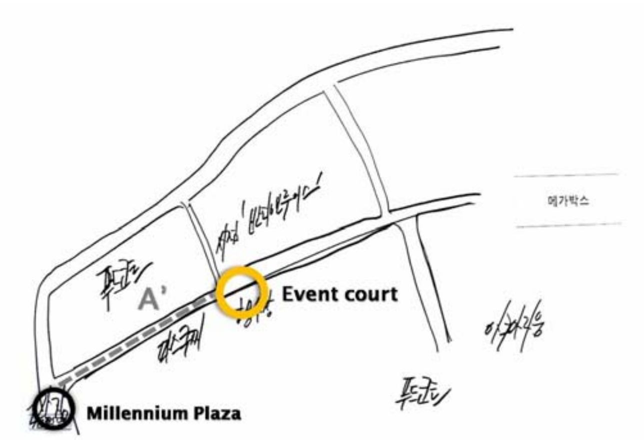


Figure 7-b
Correlation between spatial learning and spatial behavior - Sample of the cognitive maps on Coex

5.3 Correlation among Spatial Configuration, Spatial Learning and Spatial Usage
Shown in Tab 3, we analyzed user's paths to find out their connection between spatial configuration, learning degree and spatial usage on the main usage path reached to the Cinema (n=47). We compared each user's paths classifying visible path and the shortest path based on their learning degree.

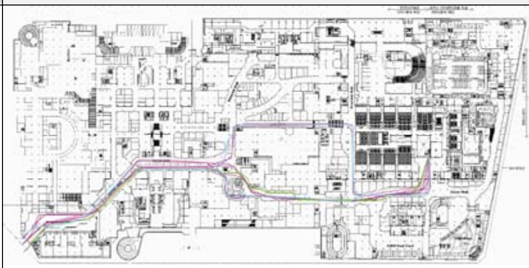
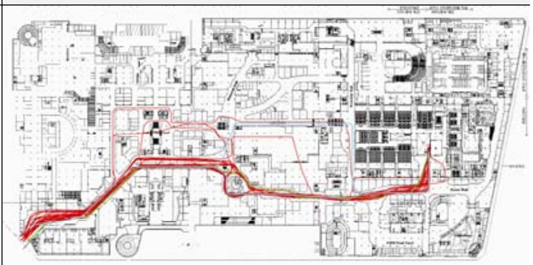
Section	2~4 times		5~10 times	
	Total 7 persons		Total 8 persons	
				
	Visibility route	**4**	**Visibility route**	**3**
	Shortest route	**3**	**Shortest route**	**5**
Section	**10~20 times**		**20 and up**	
	Total 5 persons		Total 27 persons	
				
	Visibility route	**2**	**Visibility route**	**16**
	Shortest route	**3**	**Shortest route**	**11**

Table 3
Spatial learning and spatial behavior of Cinema users

We has graphed (Fig 8) on that matter, and found out that in case the user learn 2 to 4 times, it make closer the interrelationship with visibility. However in case they learn 5 to 10 times or 10 to 20 times, interrelationship with the shortest distance become closer. Furthermore, in case they learn over 20 times, the interrelationship with visibility has been closed again.

The result of the analysis shows that the degree of learning influences spatial cognition, and spatial cognition influences spatial usage. It shows that as learning degree increases spatial recognition increases. Not spatial learning but spatial recognition influences users' choices. Users tend to choose shortcuts. Also, it is found that people tend to use not busy paths as spatial learning level increases.

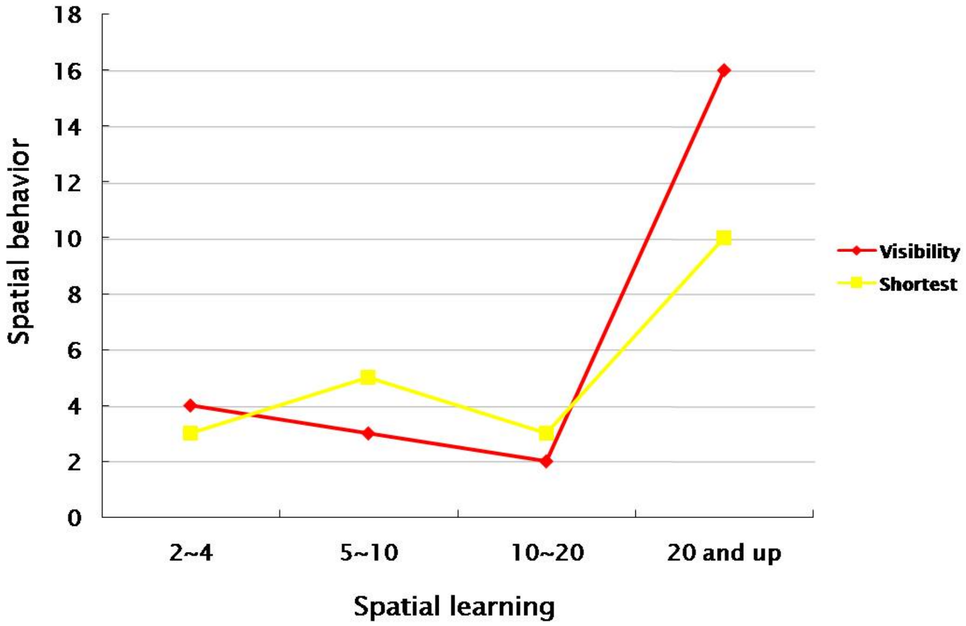


Figure 8
Relationship between spatial learning and spatial behavior

6. Conclusion and Discussion

This study shows the relationship between spatial configuration and spatial usage, and analyzes the relationship based on visibility and the shortest distance. In this process, we compare and analyze the relationship between learning on environment and spatial usage. Finally, we analyze the process and figure out the correlation of all the factors.

First, we make the spatial configuration value and spatial usage value objectively. As a result, spatial usage has 53.2% with visibility and 46.8% with the shortest distance. Through this, users find out that spatial usage has close relationship with visibility.

Second, to investigate correlation, we researched on (1) correlation between spatial learning and spatial cognition (2) relationship between spatial cognition and spatial usage (3) spatial learning and spatial usage. As a result, (1) we found that the positive relationship among total number of visit-and-degree of path recognition (0.523), frequency of visit-and-expression level on cognition map (0.415) and expression degree on cognition map-and-degree of path recognition (0.366). (2) Fig 4 shows similar frequency on both cognition expression frequency model and spatial movement path. We used rare analysis to prove the objectivity. Also a result, we found the relationship between spatial cognition and spatial learning (R^2=0.638). (3) In the relationship between spatial learning and spatial usage, we figured out the essential relationship through analyzing the path to Cinema from inlets.

Third, we make the relationship between spatial configuration and learning mathematically. The result is: in case the user learns 2 to 4 times, it makes closer the interrelationship with visibility. However in case they learn 5 to 10 times or 10 to 20 times, interrelationship with the shortest distance become closer. Furthermore, in case they learn over 20 times, the interrelationship with visibility has been closed again. We came up with the result that as learning degree gets higher, the range of spatial cognition gets wider, and because users' make their movement based on their cognition, we figured out that users try to find shortcuts as they learn about the space more.

This study analyzes the whole process of spatial configuration, spatial cognition and spatial usage to understand the relationship between people and environment. Moreover, it is significant that the study is focused on visibility and the shortest distance on spatial use based on the degree of learning.

Considerations of spatial layout based on this study is like this:

First, subject reports show that people remember particular store name more than architectural factors like a location of a square or escalator as their main using place. It means that when a particular store is put on a particular location, spatial layout can make people's spatial usage more efficient when they design the inner space.

Second, the study shows that the subjects are tend to recognize the space based on their main using space, and they do not consider the passing space with any particular purpose as their main using space even though they use the space many times. It means that spatial layout have to seek functions and diversities of space applying particular themes when they design the inner space.

Third, subjects tend to recognize the space more simple when they have wider range of visibility, and as the visibility range is wider, the space has more accessibility and utility value. It means that if the main functional space secures the maximum visibility, it can contribute to the simplicity and active usage.

This study is not enough to characterize all the factors. Hereafter, topological numeral value analysis on inspecting the interrelationships among spatial usage, spatial visibility and the shortest distance is needed based on this study.

Acknowledgements

This research supported by a grant (07UrbanRenaissanceB03) from High-Tech Urban Development Program funded by the Ministry of Construction & Transportation of Korean Government.

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