# Spatial Structure Analysis in Accordance with the Mode of Interconnection between Surface and Underground Pedestrian Networks

Ref 050

## Dongdaemun Stadium Neighborhood

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**Keywords**
underground space; intermediary space; pedestrian network; visual influence; enclosing balance; weight

**Abstract**

*Studies with relation to underground space and pedestrian networks overlook the issue of interconnection between the surface and underground network of pedestrian; a majority of studies base their analyses on mere recognition of underground space, design-related issues, or underground signs for directions. Although the use of underground space in Seoul is focused on pedestrian purposes, studies usually fail to go beyond issues such as entrance facilities to the underground space or pedestrian traffic, lacking comprehensive analyses concerning, for instance, pedestrian passage structure from underground to the surface.*

*As such, this study aims to suggest an effective way of integrating the surface and underground network of pedestrian through analyzing various methods and effects of interconnection. There is no specified, or distinctive, way of evaluating spatial changes between the surface and underground that is different from evaluation methods for changes within the surface level in the present space syntax model. In other words, it is difficult to grasp the network structure of the surface and underground though factor analysis of the space for vertical movements. Thus the purpose of this study is to analyze the space for vertical movements with visual cognition, the concept which the present model fails to incorporate.*

*Stairs mostly interconnect the surface and underground in the subject area, and such intermediary spaces are categorized based on the extent of information recognized visually. Each categorized space is, then, ranked in terms of the amount of visual influence, and maximum weighted values are assigned. Correlation analysis between the current pedestrian traffic volume and MD leads to the possible range of maximum weighted values; Ways in which pedestrians cognize the surface and underground pedestrian networks are speculated through correlation between the pedestrian traffic volume and depth of space.*

*When weighted value is applied to the current network of pedestiran rather than depth of space, the depth of space becomes more correlated to the pedestrian movement. Also, underground space that is utilized as much as the surface level space prevails to have the same weighted value as that of surface level. Such result implies that pedestrians in Dongdaemun Stadium neighborhood perceive the depth of the surface and underground spaces to be the same, being independent of each other.*

*The relevance of pedestrian traffic volume is increased and the weighted value is decreased when ascending from underground to the surface, according to calculations of sequential weighted values depending on the amount of information visual information. The perception of depth associated with the escalating movement, from underground to the surface, is less than that associated with the deescalating movement, from the surface to underground.*

*The main concern of this study lies on the effort to provide basic ideas to selecting weighted value.*

## 1. Introduction

### 1.1 Background & Purpose

For a large city like Seoul, where land use is intense, a maximum utilization of underground space to secure sufficient areas for integral modern life activities is imperative. As the underground space in Seoul has been largely utilized as pedestrian networks, further attention needs to be drawn to the issues of vitalizing its functions, in particular, in regard to pedestrians.

However, most studies concerning underground space tend to overlook the issue of interconnection between the surface and underground pedestrian networks; a majority of studies base their analyses on the cognition of underground space, design-related issues, or signage systems for way-finding. Although the use of underground space in Seoul is set mainly for pedestrian purposes, studies usually fail to go beyond issues such as entrance facilities to the underground space or the amount of pedestrian traffic, lacking comprehensive analyses of pedestrian movements from the underground to the surface.

In this respect, this study aims to suggest an effective way of integrating the surface and underground pedestrian networks through classifying and analyzing various methods and effects of interconnection.

### 1.2 Scope & Method

#### 1.2.1 Scope of Study

The subject area for analysis is Dongdaemun Stadium neighborhood, in which underground pedestrian networks are actively utilized due to limited space and condition of the surface pedestrian networks Lacking crosswalks across main streets, underground space connect various surface points on the streets. This neighborhood is heavily affected by underground pedestrian networks that are expected to go through a series of changes as the underground spatial network evolves. The scope of study is set around areas where a large volume of pedestrians can be observed, namely the underground space, entrance and exits facilities, and main streets. In addition, an area highly related with a large pedestrian volume is chosen as the space syntax model area to analyze changes related to interconnection and its methods.

#### 1.2.2 Method of Study

Based on the current status of interconnecting underground and surface spaces, weighted pedestrian network analysis will be applied to study the correlation between pedestrian network and modes of interconnection.

There will be four methods of study: the first method is to establish a pedestrian network model for the subject area and to analyze the existing system; the second method is to categorize modes of interconnection, analyze characteristics, and construct a methodical way to assign weight to categorized modes; the third is to present a space syntax pedestrian network model to each interconnection mode. Models will go through a series of inspection and modification based on the interconnection modes; and finally, the fourth is to conduct a comparative analysis between the current space syntax model and the weighted space syntax models based on the various interconnection modes. Based on the results, the relationship between interconnection modes and pedestrian network will be analyzed.

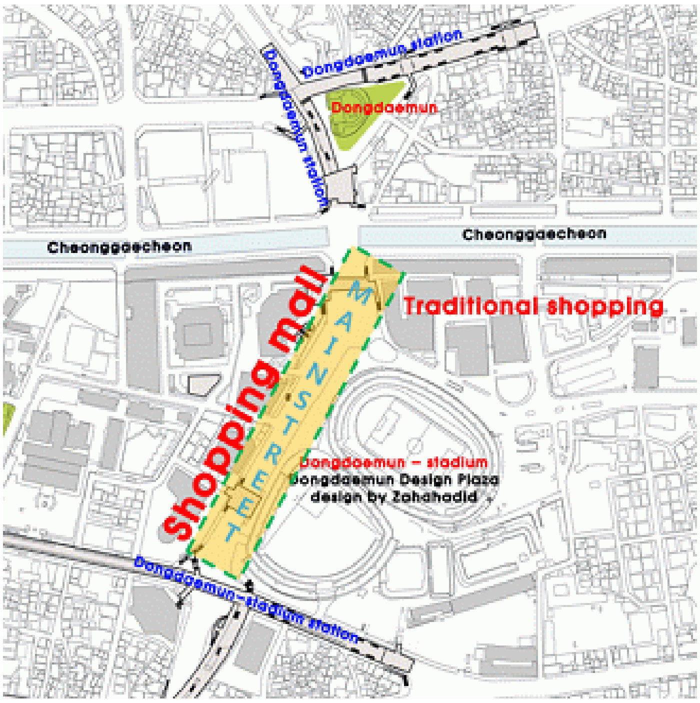



***Figure1***
*Selected subject area in Dongdaemun-Stadium neighborhood*

## 2. Theoretical Consideration

### 2.1 Underground Pedestrian Space

#### 2.1.1 Underground Pedestrian Environment

Necessary information to understand the direction and current position of oneself is visually provided from outer space, so that one has an opportunity to self-correct onés coordinate. Thus an underground space where one can form a coordination system identical to the one on the surface is required as one directly applies the coordination system constructed on the surface level.[1]

Such confusion in the coordination systems begins as one enters and navigates the underground space. In order to reduce such disorientation, openness of entrance facilities to the underground space needs to be increased, and careful consideration should be given to the interconnection with the surface as furnishing the interior of the underground establishment. Furthermore, minimizing changes in direction and use of straight-run-stairs in lieu of spiral stairs may be effective in mitigating the confusion.

Amongst many, vertical interconnection space has a profound influence on the pedestrians conception of logical space orientation, as the surface and underground spaces are perceived as completely separated from one another. The degree of spatial orientation depends on media by which visual link between the surface and underground spaces and also within the underground space can be secured.

#### 2.1.2 Intermediary Space: Connection Between Surface and Underground

Intermediary space creates spatial abundance by including two contradictory phenomena within a single space. Such space may be defined as a link between spaces with opposing characteristics - inside and outside, for example; it may be re-interpreted as a place having communicational and transitional values. Entrance to the underground, vertical pedestrian passage, and underground squares are deemed as typical intermediary spaces within the underground.

Rather than simply linking two opposing spaces, namely surface and underground, psychological connection between the two needs to be secured to the degree to which the surface level environment can be predicted from the underground. Visual connection, too, needs to occur as pedestrian progresses into the underground from the surface. The existence of intermediary space enables smooth and harmonized transition from one opposing space to the other.[1]

The property of entrance to the underground, having dual identity of being part of both the surface and the underground, is altered by spatial quality of the entrance itself, which, precisely, is the reason why a particular attention needs to be drawn to it. As intermediary space is considered important in terms of pedestrian networks, the mode of interconnection also bears a significant influence over it. Observing changes imposed upon pedestrian networks due to various methods of interconnection, therefore, may provide critical foundation and serves as a guideline in designing future underground spaces.

## 2.2 Spatial Cognition in Space Syntax

### 2.2.1 Limitation of Space Syntax in Convex Segmentation

As discussed above, variations in pedestrian environment arises from opportunities to correct one's coordinate while walking on the surface and the underground. The degree of pedestrians' spatial cognition differs from one area to another, and such difference needs to be met with different analytical procedures.

In general, convex space in convex analysis is defined as an area where a person may have a visual confirmation and experience of the entire area.[2] If the surface-underground interconnection was based on this concept, analytical procedures would rely on how we define interconnecting space. Conventional models identify vertical intermediary space, that is, stairs, as a unit space, resulting in the insertion of the interconnecting space between the surface and the underground.

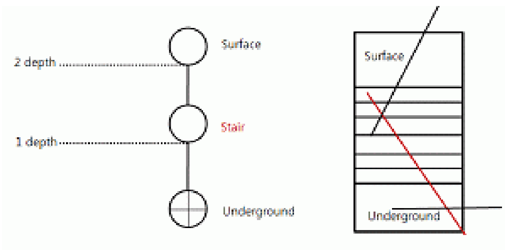



***Figure2***

*General Model Structure, J-graph(left), Axial line(right)*

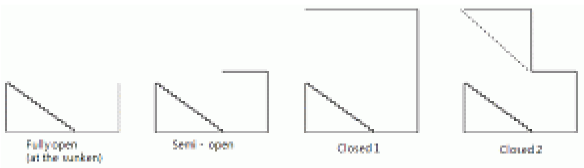



***Figure3***

*Sectional diagram of various types of stairs*

The conventional model seems, hence, to yield a high level of correlation with pedestrian movements. Such method, however, ignores the notion that pedestrians' visual perception and conveyed information may vary depending on the degree of openness of the stairs. For instance, the amount of information visually conveyed is limited when using closed stairs, the ones that can be seen in subway stations. If vertical movements using open stairs occurred, however, more comprehensive information would be communicated to pedestrians.

The analysis of intermediary spaces which grounds its thesis on the mode of interconnection and visual correlation between the surface and the underground attempts to determine how much of visually perceived information is to be utilized. The space syntax analysis theory, however, fails to provide a quantitative analysis of the difference in perceived information which results from vertical movements.

Also, despite the lower level of space cognition when situated in the underground than on the surface, variables mentioned above are not reflected in the analysis. Simple counting of the number of depths existing from the ground level to the underground axial line may be done, but there is no methodical way of including the spatial difference between the surface and underground pedestrian networks.

### 2.3 Space Cognition Theory

2.3.1 Interpretation of Enclosing Balance Theory

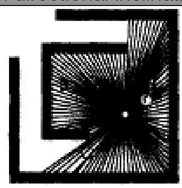
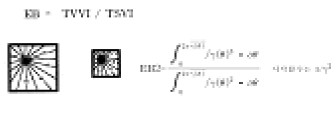
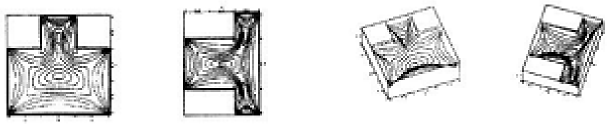
| Enclosing balance | |
|---|---|
| Illustration of perception on directional inclination | Homeostasis of enclosing balance |
|  |  |
| Examples of natural segmentation of space due to enclosing balance | |
|  | |

***Table 1***
*Illustration of the Visual Influence*

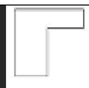
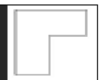
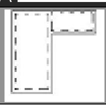
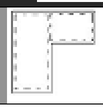
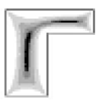
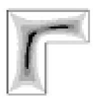
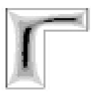
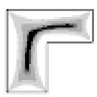
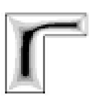
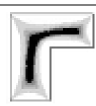
| Type | | A  | B  |
|---|---|---|---|
| | unit space |  |  |
| enclosing balance field | weight 0.15 |  |  |
| | weight 0.2 |  |  |
| | weight 0.3 |  |  |

***Table 2***
*Comparison of segmentation method and enclosing balance on convex area*

Enclosing balance theory asserts that, similar to the concept of gravity, enclosing balance for a point on a wall is visually influenced by all points on the wall; just as gravitational force is emitted throughout space, visual influence is emitted throughout the wall.[3]

From an intuitive perspective, it is plausible to assume that points located nearby the origin have greater influence on deflection stress. Enclosing balance field is derived from gravitational field, and its algorithm contains simplicity and tentativeness while providing a set of standards capable of representing characteristics of any two-dimensional diagram.

## 3. Types of Underground Interconnection

### 3.1. Classification of Underground Interconnection

Enclosing balance discussed above assumes pedestrians' spatial cognition process to be one related to walls of space, two-dimensional planes as opposed to three-dimensional ones. Such a procedure can be regarded as a visual analysis excluding the ceiling and the floor.

For the sake of classification of modes that visually interconnect the surface and the underground spaces, enclosing balance theory will be modified. Let's assume, when classifying intermediary spaces from a visual perspective, walls of intermediary space have identical visual property, as convexity of convex space does not recognize horizontal aspects such as width. It may be concluded, therefore, that variance in visual recognition of intermediary space is dependent on the shapes of perpendicular planes. Greater level of space orientation can be obtained as visual interconnection between the surface and underground increases; on the contrary, decreasing visual interconnection between the two will result in lower level of space orientation.

Ultimately, variance in visual domain that pedestrian perceives from each point is inevitable as enclosing balance is utilized as a component of perpendicular analysis. Similar to the case when enclosing balance is applied to horizontal planes, such discrepancy in visual domain can also explain the degree of segmentation of space from visual perspective when connecting the surface and underground.

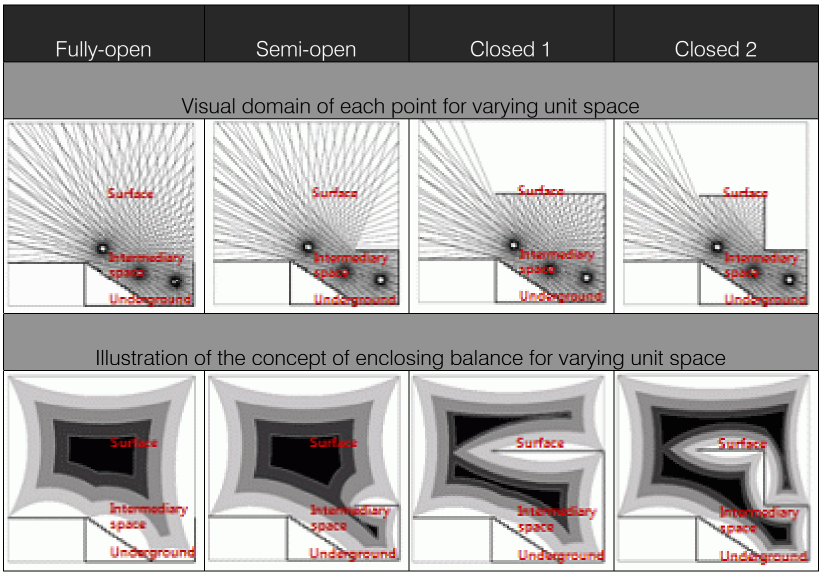



***Table 3***
*Illustration of the Visual Influence*

The surface level space, stairway intermediary space, and underground space are set as three standard spaces and classified based on methods of visual segmentation. Fully open type recognizes all three standard spaces' visual domain as one; Semi-open type recognizes intermediary space's and the surface space's visual domain as one; Closed type1 and 2 have decreased level of interconnection with the surface, and visual space recognition of intermediary space differ as progressed further underground.

As illustrated on Table 3, discrepancy among each type occurs as the number of independent segmented spaces is determined within intermediary space. Depending on the existence of independent space, the highly interconnected surface and underground spaces can be interpreted as a single space.

In essence, a relation between the amount of visually perceived information and weighted value needs to be established in order to implement a relation coefficient of the two in the space syntax model.

The amount of visually perceived information ( I ) = f (w) weight applied, I iØ 1/w

It is assumed that the greater the amount of visually perceived information, the smaller the weight being applied. I and W are inversely proportional. The rank in terms of weight assigned is fully open type, semi-open type, closed type1, and closed type2, fully open type having the highest interconnection level. Additionally, as visual interconnection gradually decreases within intermediary space as progressed further downward, underground space has the lowest level of visual interconnection. In conclusion, final ranking of weight assigned is, in the order of decreasing level of visual interconnection, fully open type, semi-open type, closed type1, closed type2, and underground level.

1. Value of I Underground( i0 ) < Closed2( i4 ) < Closed1( i3 ) < Semi-open( i2 ) < Fully open( i1 )

2. Value of W (Mean Depth applied) Fully open(w1) < Semi-open(w2) < Closed1(w3) < Closed2(w4) < Underground(w0)

### 3.2 Method of Weight Assignment Based On Type

3.2.1 Establishment of Current Model

Selection of areas with high levels of pedestrian traffic and integration is conducted in order to establish a current model before assigning weight to subject areas. Starting from the main avenue with the greatest pedestrian traffic volume, the scope of selection closed in from one-kilometer radius. Axial analysis includes Dongdaemun Stadium neighborhood's main avenue, underground subway station, underground plaza, and passages linking underground level of surrounding buildings.

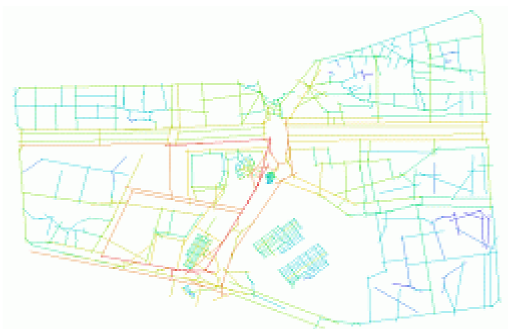
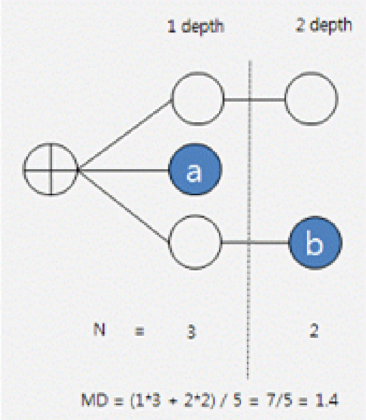


***Figure 4***
*Axial analysis model*

***Figure 5***
*Subject area pedestrian traffic data*

### 3.2.2 Selection of Weight Range

Classifications by type and assigned weight ranking of visual domain have been conducted above, and assigned weight ranking is incorporated in axial analysis. Standard value is obtained through analysis of correlation between changes in mean depth (MD) and pedestrian traffic volume with assigned weight on each one of them with respect to unit space.




| Mean Depth | weight | Mean Depth_wgt |
| --- | --- | --- |
| MD = (1*3 + 2*2) / 5 = 7/5 = 1.4 | a=0.5<br>b=1.5 | MD_wgt = (1*2+0.5)+(1*2+2*1.5) / (1+1+0.5+1+1.5)<br>= 7.5/4 = 1.875 |
| | a=10<br>b=5 | MD_wgt =<br>(1*2+10)+(1*2+2*5) / (1+1+10+1+5)<br>= 24/18 = 4/3 = 1.333.. |
| | a=5<br>b=10 | MD_wgt = (1*2+5)+(1*2+2*10) / (1+1+5+1+10)<br>= 29/18 = 1.6111.. |

***Table4***
*Illustration of changes in MD value*

Based on each unit space, weight has been assigned in values: type 1~4 = w1~w4, underground = w0. Types that are applied in the subject area's axial analysis are calculated as sums of convexities, yielding 1 = w1+w1, 2 = w2+w3, 3 = w3+w3, 4 = w3+w4, with underground having the weighted value of w0.

Five measurement values, four stairway types of unit space and underground, and its approximate range is selected, with the range being 0<(minimum value, maximum value) as a space with the value of depth being zero cannot exist. Weighted value has been assigned to stairway types only, and highest correlation value for MD and pedestrian traffic for each stairway type is selected as the maximum value.

At first, maximum assigned weights were estimated to be: [w1 < w2 < w3 < w4

Assumption of the underground space having no weighted value, lack of depth, presents decreased relevance to the pedestrian volume. What was originally speculated to have a large depth actually yielding the contrary can be interpreted as a phenomenon due to the large pedestrian volume, similar to that of the surface.

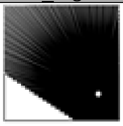
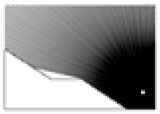
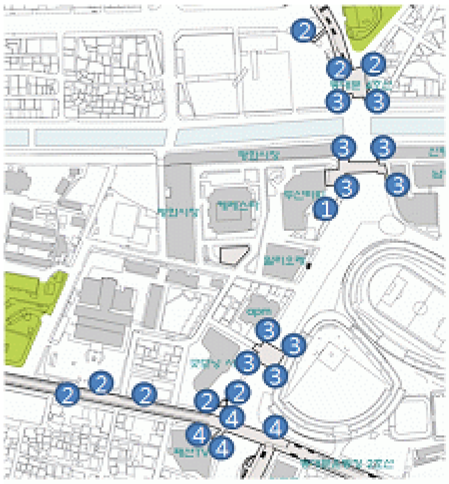
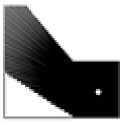
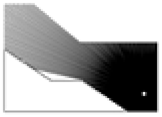
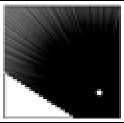
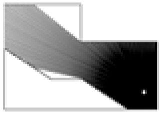
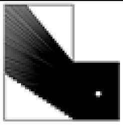
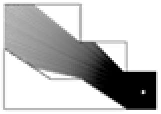
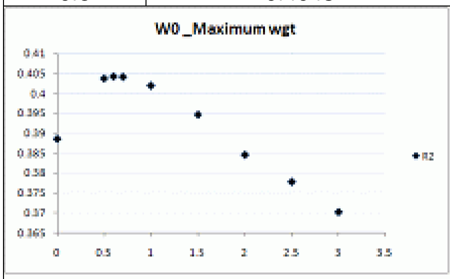
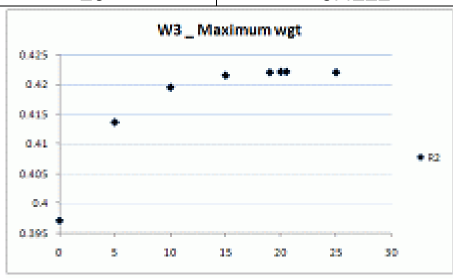
<table>
<tr><th colspan="5">Weight applied</th></tr>
<tr><th colspan="2">unit space_wgt</th><th colspan="2">site applied type_ wgt</th><th>Subject area types</th></tr>
<tr><td>fully open = w1</td><td></td><td>① type = w1+w1</td><td></td><td rowspan="4"></td></tr>
<tr><td>semi open = w2</td><td></td><td>② type = w2+w3</td><td></td></tr>
<tr><td>closed1 = w3</td><td></td><td>③ type = w3+w3</td><td></td></tr>
<tr><td>closed2 = w4</td><td></td><td>④ type = w3+w4</td><td></td></tr>
</table>

***Table 5***
*Illustration of weight assignment*

<table>
<tr><th colspan="2">w0 (underground)</th><th colspan="2">w3 (closed1)</th></tr>
<tr><td>wgt</td><td>$R^2$</td><td>wgt</td><td>$R^2$</td></tr>
<tr><td>0.6</td><td>0.4043</td><td>20</td><td>0.4222</td></tr>
<tr><td colspan="2">
</td><td colspan="2">
</td></tr>
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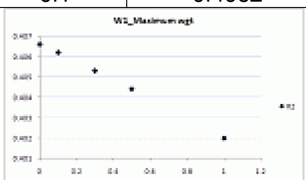
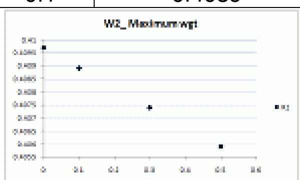
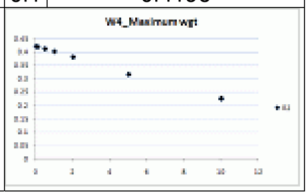
<table>
<tr><th colspan="2">w1 (fully-open)</th><th colspan="2">w2 (semi-open)</th><th colspan="2">w4 (closed2)</th></tr>
<tr><td>wgt</td><td>$R^2$</td><td>wgt</td><td>$R^2$</td><td>wgt</td><td>$R^2$</td></tr>
<tr><td>0.1</td><td>0.4062</td><td>0.1</td><td>0.4089</td><td>0.1</td><td>0.4196</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
</table>

***Table 6***
*Assigned weight for each type*

Assuming independence of the surface and underground from one another and the same depth, it is concluded that the change in depth is amplified in intermediary space, confirming its significance and importance.

## 4. Analysis of Walkway Network Based On Interconnection of Underground Space

In this chapter, weight range will be applied, differences it yields from the current network will be analyzed, and the maximum weighted value having high correlation between MD and the traffic volume will be calculated.

First, correlation of MD and the pedestrian traffic volume is studied without considering weight. Then the correlation is examined in conjunction with the maximum weight value. Factors having high level of correlation with the surface and underground will be gradually adopted in the calculation as well as an attempt to examine the relation between the surface level and underground.

### 4.1 Verification of Weight Assignment

#### 4.1.1 Present (without weight application)

This is a correlation analysis of the pedestrian traffic volume and MD values, without considering weighted values. A number of large shopping malls and countless wholesalers stand alongside the main avenue in the neighborhood. The core of axial analysis model is not densely populated with large multi-complexes near the main avenue, but, rather, more development is observed as being farther away from the center. Plus, there is a low level of integration due to disproportionate development of pedestrian networks in the surface level and underground, underground being dominant. A large volume of pedestrian traffic in underground regardless of spatial integration, or lack there of, leads to an analysis, focusing on the correlation between depth of spaces and traffic volume, in effort to understand the surroundings of the main avenue.

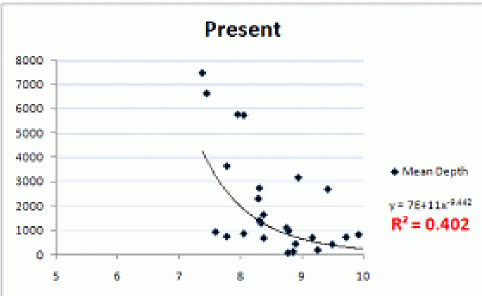



***Figure 6***

*Correlation analysis of present pedestrian traffic volume and MD*

#### 4.1.2 Application of the Maximum Weighted Value for Each Factor

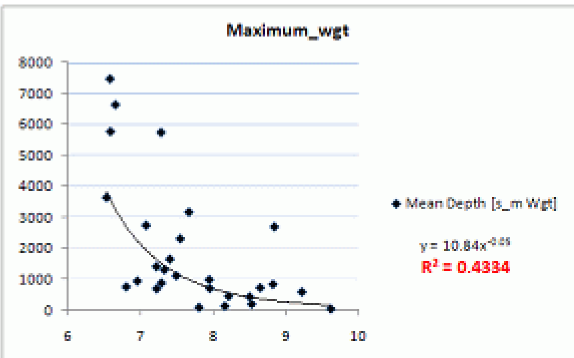



***Figure 7***

*Correlation analysis of pedestrian traffic volume and MD, considering the maximum weighted value for each factor*

The maximum weighted value for each factor is applied to the present model, and the result yields higher correlation values. Such outcome implies the analytical result of the surface and underground walking correlation study to have a notable influence on the subject area analysis. Although the maximum weighted value for each factor is selected, the outcome may not yield the highest correlation value due to interaction among factors. Therefore, new ways to measure and assign weighted values to factors need to be explored.

| Weight applied | | | | |
|---|---|---|---|---|
| w0 | w1 | w2 | w3 | w4 |
| 0.6 | 0.1 (Excluding 0) | 0.1 (Excluding 0) | 20 | 0.1 (Excluding 0) |

***Table 7***
*Assigned maximum weighted value for each type*

#### 4.1.3 Sequential Application of Weighted Value Based On Types of Visually Perceived Information

Classification of visually perceived information types has been conducted during weighted value classification. In essence, visually perceived information differs based on weighted value factors. Type 1 has the highest correlation with the surface level, allowing it to have the surface and underground as a single unit space; such visual perception factor gradually decreases in value from type 1 to type 4. Conversely, from the underground perspective, underground[4] and underground space can be defined as a single unit space. Depending on the relative distance between the surface level and underground, changes occur as either the depth of space or weighted value is incorporated in the analysis.

Furthermore, maximum weighted values relevant to pedestrian traffic volume and to MD may altered due to the relative distance. Reflecting such concerns, weighted values were assigned in the increasing order of the amount of visually perceived information, both from the underground and the surface level perspective. The result of the correlation analysis is as follows:

- The order of change in the amount of visually perceived information (underground perspective)
- The underground space having the maximum value of 0.6, type 4, 3, 2, and 1 were sequentially added one at a time.
- The order of change in the amount of information visually perceived (surface perspective)

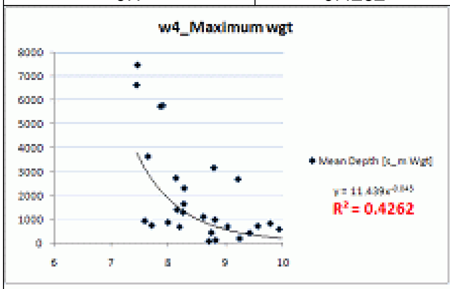
Type 1 having the maximum value of 0.1, type 2, 3, 4, and the underground space were sequentially added one at a time.

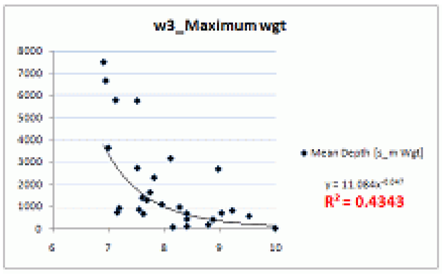
The model, which assigned weighted value in the order of descending amount of visually perceived information, is seemed highly correlated with the pedestrian traffic volume. The underground space, type1, 2, and 4 have high correlation with the traffic volume within the maximum weighted value range for each type, regardless of the origin point. Type 3 with the highest weighted value, however, seems to experience changes in weighted value as the origin point altered. When the variance in the maximum weighted value of type 3 is reviewed, the weighted value from the underground perspective has a lower value. This may be interpreted that, although type 3 is located in the tangential space to both the surface level and underground, its depth in relation to underground goes farther down.

The movement from the surface to underground, and that from underground to the surface have asymmetrical depth correlation as different sequential weighted value is obtained from the point, which the weighted value is selected, in each space. Numerical values imply that the perception of depth associated with the escalating movement, from underground to the surface, is less than that associated with the deescalating movement, from the surface to underground.

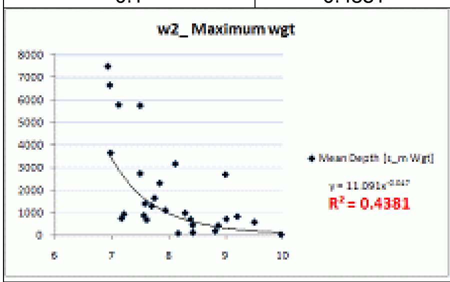
| Underground_maximum (w0=0.6) + W1, 2, 3, 4 | | | | | | | |
|---|---|---|---|---|---|---|---|
| w0 + w4 | | w0 + w4 + w3 | | w0 + w4 + w3 + w2 | | w0+w4+w3+w2+w1 | |
| wgt | $R^2$ | wgt | $R^2$ | wgt | $R^2$ | wgt | $R^2$ |
| 0.1 | 0.4262 | 0 | 0.4224 | 0 | 0.4385 | 0 | 0.4383 |
| 0.2 | 0.4238 | 20 | 0.4309 | 10 | 0.3892 | 3.5 | 0.434 |
| 0 | 0.4285 | 21 | 0.4306 | 5 | 0.4155 | 0.6 | 0.4383 |
| | | 19 | 0.4313 | 2 | 0.4299 | 1 | 0.4381 |
| | | 15 | 0.4327 | 1 | 0.4343 | 0.3 | 0.4383 |
| | | 10 | 0.434 | 0.5 | 0.4364 | 0.5 | 0.4383 |
| | | 5 | 0.433 | 0.1 | 0.4381 | 0.1 | 0.4383 |
| | | 8 | 0.4343 | | | | |
| | | 9 | 0.4343 | | | | |
| | | 8.5 | 0.4343 | | | | |

| Maximum_wgt graph (w0=0.6) | | | |
|---|---|---|---|
| w0 + w4 | | w0 + w4 +w3 | |
| w4_maximum wgt | $R^2$ | w3_maximum wgt | $R^2$ |
| 0.1 | 0.4262 | 8.5 | 0.4343 |




| w0 + w4 + w3 + w2 | | w0+w4+w3+w2+w1 | |
|---|---|---|---|
| w2_maximum wgt | $R^2$ | w1_maximum wgt | $R^2$ |
| 0.1 | 0.4381 | 0.1 | 0.4383 |



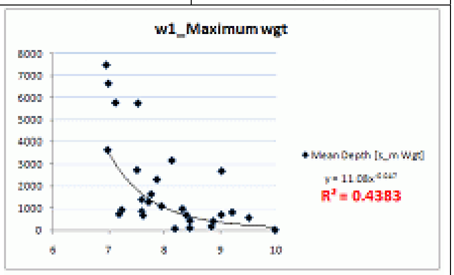
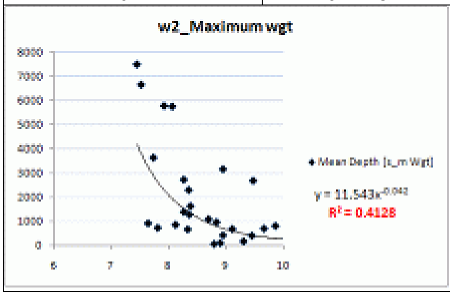



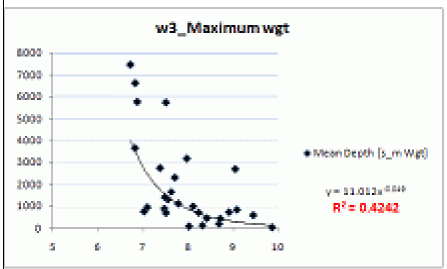

***Table 8***

*Selection of the maximum weighted value for each type*

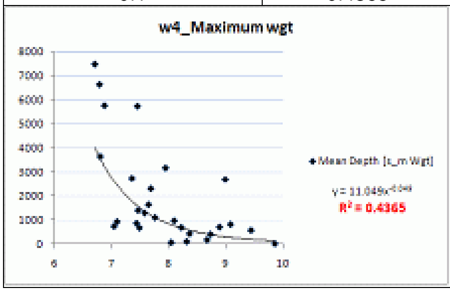
| Fully open_maximum(w1) + w2, 3, 4, 0 | | | | | | | |
|---|---|---|---|---|---|---|---|
| w1 + w2 | | w1 + w2+w3 | | w1 + w2+w3+w4 | | w1+ w2+w3+w3+w0 | |
| wgt | $R^2$ | wgt | $R^2$ | wgt | $R^2$ | wgt | $R^2$ |
| 0 | 0.4135 | 0 | 0.4092 | 0 | 0.4378 | 0 | 0.425 |
| 1 | 0.4062 | 20 | 0.4239 | 1 | 0.4242 | 0.6 | 0.4347 |
| 0.5 | 0.4099 | 10 | 0.4237 | 2 | 0.4105 | 0.3 | 0.4307 |
| 0.2 | 0.4121 | 15 | 0.4242 | 0.5 | 0.431 | 0.5 | 0.4333 |
| 0.1 | 0.4128 | 14 | 0.4242 | 0.2 | 0.4351 | 1 | 0.4365 |
| | | 16 | 0.4242 | 0.1 | 0.4365 | 0.4 | 0.4326 |

| Maximum_wgt graph (w0=0.6) | | | |
|---|---|---|---|
| W1 + w2 | | W1 + w2 +w3 | |
| W2_maximum wgt | $R^2$ | w3_maximum wgt | $R^2$ |
| 0.1 | 0.4128 | 15 | 0.4242 |




| W1 + w2 + w3 + w4 | | W1+w2+w3+w4+w0 | |
|---|---|---|---|
| W4_maximum wgt | $R^2$ | W0_maximum wgt | $R^2$ |
| 0.1 | 0.4365 | 0.6 | 0.4347 |



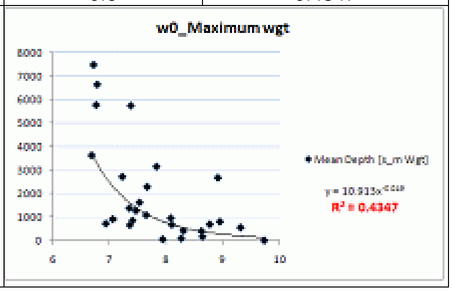




***Table 9***
*Selection of the maximum weighted value for each type*

### 4.2 Comparative Analysis with The Present Network

This study has analyzed types of intermediary space, stairs, and weighted value range, along with changes entailed from application of weighted values in compliance with visually perceived information for each factor. It is discovered that inclusion of weighted values yields outcomes highly correlated with the pedestrian traffic volume, proving the important role of intermediary space in the interconnection between the surface and underground. Such elucidation of intermediary space fortifies the notion of close relation in regard to the surface level and underground space utilization.

Validating the maximum weighted value of each factor, selecting the maximum value range is deemed highly correlated. It is also confirmed that each factori¯s weighted value reciprocally acts with one another, affecting the traffic volumei¯s influence in the correlation rather negatively. Sequentially added sum of weighted values of the surface and underground is examined in order to analyze the sequentially changing amount of information visually perceived. All analyses mentioned and conducted above lead to a speculation that the subject areai¯s surface level and underground are not in a symmetrical relationship.

Looking at the weighted value selection for underground, assignment of the maximum weighted value to underground, and sequentially adding the changing amount of visually perceived information result in the high correlation with the pedestrian traffic volume. In case of the subject area, as the traffic volume is increased due to a large population movement conducted by the subway system, it is assumed that there is more movement from underground to the surface level. As such, the level of correlation with MD and the traffic volume is higher when escalating movements occur, from underground to the surface. Also considering the lack of crosswalks on the surface, the subject area underground is as intensely, if not more, utilized as the surface is.

When reviewing the correlation between the traffic volume and the depth, higher values are yielded when the surface and underground have similar depth. Lastly, intermediary space directly linked with the surface and underground has small depth values, and the correlation value with the traffic volume increases as the depth of factors linked to both the surface and underground increases.

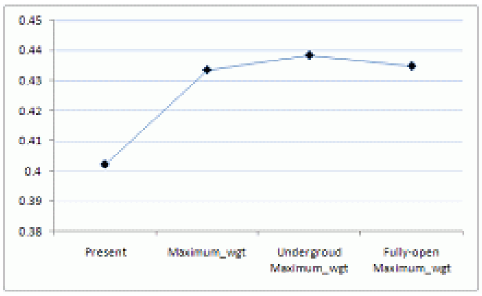



***Figure 8***

*Correlation analysis of pedestrian traffic volume and MD, considering weighted values*

## 5. Conclusion

This study analyzes the correlation between the surface and underground interconnection mode and pedestrian networks within the subject area, in which the pedestrian networks in those two spatial levels are deemed vital. There is no well-defined way of evaluating spatial changes between the two levels in the present space syntax model. In other words, it is difficult to grasp the combined network structure of the surface and underground space through factor analysis for vertical movements. Thus the purpose of this study is to analyze the space for vertical movements with visual cognition, the concept which the present model fails to incorporate.

Stairs mostly interconnect the surface and underground space in the subject area, and such intermediary spaces are categorized based on the extent of information recognized visually. Each categorized space is, then, ranked in terms of the amount of visual influence, and maximum weighted values are assigned. Correlation analysis between the current pedestrian traffic volume and weighted MD leads to the possible range of maximum weighted values. Ways in which pedestrians cognize the surface and underground pedestrian networks are estimated through the correlation.

It turns out that, when weighted value is applied to the current pedestrian network, the depth of space becomes better correlated with pedestrian movements. Also, underground space that is utilized as much as the surface space prevails to have the same weighted value as that of surface level. Such result implies that pedestrians in Dongdaemun Stadium neighborhood perceive the depth of the surface and underground spaces to be the same, being independent of each other.

From the calculations of sequential weighted values depending on the amount of visual information, it is found that the correlation with pedestrian traffic volume is increased and the weighted value is decreased when ascending from the underground to the surface. This suggests that the depth-perception associated with escalating movement, from the underground to the surface, is less than that associated with deescalating movement, from the surface to the underground.

After reviewing modes of interconnection between the surface and the underground, type 1, 2, and 4 are deem to have increased correlation as weighted value decrease, while type 1 and 2 has a high level of visually perceived interconnection with the surface, and the underground[4] has a high level of visually perceived interconnection with the underground. The high level of correlation of these types can be realized as weighted values decrease by increasing interconnection between the surface and the underground.

Type 3, on the other hand, presents a different result. Such phenomenon is largely due to the position of type 3, placed in the midst of visually perceived interconnection of the surface and the underground. Having a high level of visually perceived interconnection with the underground, in particular, weighted value will decrease as escalated from the underground to the surface. In essence, when determining interconnection factors for the surface and the underground, type 3, which greatly affects the change in depth, should be reduced, and the other types, which increase the level of interconnection, should be emphasized. This will allow a smooth transaction from one separate network to the other as the depth of space is minimized as much as possible.

This study focuses on the examination of correlation between the surface and the underground pedestrian networks, which is why a subject area with a high level of underground space utilization is chosen. Assignment of weighted value range and its application method is proposed as a possible solution to the question of how to analyze current vertical connection space that links two different levels of space. It is necessary to increase the logic and accuracy of the proposed method in order to get more organized results in the future. The main concern of this study lies on the effort to provide basic ideas as to selecting weighted value.

## Acknowledgement

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## Notes

1 Cho Jeong-Yeon, Kim Jong-in, "A Study on the Urban Pedestrian-space and Organization related to a mean of underground transportation", Architectural institute of Korea v.20 n.2 (2000):379-382

2 Park sun-mae, "Study on the improvement of the unit space in the Space Syntax",( Master diss, Ewha Womeni ̄s University, 2008) : 23-27

3 Yoon Chae-shin, "A Study on the Space Visualization of Architectural Plan", Architectural institute of Korea v.14 n.5(1998): 93-106.
- The trial paper visual influence space analysis theory that Professor Ewha Women's University "Yoon Chae-shin" devised the enclosing balance theory.

4 Yoon Chae-shin, "A Study on Natural Segmentation and Shape Representation of Space Primitives in Architectural Plan", Architectural institute of Korea v.15 n.2(1999):91-103

## References

Kim, Young-ook. 2003. A Study on the Relationship between Properties of Spatial Configuration and Patterns of Space Use using Space Syntax. Korea Planners Association v.38 n.4(Series Number 129):7-17.

Cho, Jeong-Yeon. Kim, Jong-in. 2000. A Study on the Urban Pedestrian-space and Organization related to a mean of underground transportation. Architectural institute of Korea v.20 n.2: 937-340.

Park, sun-mae. 2008. Stydy on the improvement of the unit space in the Space Syntax. Master diss., Ewha Women's University.

Yoon, Chae-shin. 1998. A Study on the Space Visualization of Architectural Plan. Architectural institute of Korea v.14 n.5: 93-106.
- The trial paper visual influence space analysis theory that Professor Ewha Women's University "Yoon Chae-shin" devised the enclosing balance theory.

Yoon, Chae-shin. 1999. A Study on Natural Segmentation and Shape Representation of Space Primitives in Architectural Plan. Architectural institute of Korea v.15 n.2 :91-103.

Kim, beam-seok. 2005. On study of analysis of vertical circulation for type of vertical circulation and spatial structure. Master diss., Sejong University.

Im, Hyun-sik. 2002. Analysis of the Pedestrian Space System Using Space Syntax : Pedestrian Environment vicinity of the City Hall, Seoul. Master diss., Sejong University