COMPARATIVE SPACE SYNTAX ANALYSIS OF DESIGN STRATEGIES FOR ISTANBUL UNDERGROUND RAILWAY SYSTEM

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Abstract

This research is intended to enlighten currently emerging design problems of the underground railway stations of Istanbul Metropolitan Municipality. Within the last decade, rapidly growing Istanbul metropolitan underground railway system has been expanding through two different construction strategies. Among these, the first and the most common one is the Binocular Tube Tunnel (BTT); while the other is “cut and cover” (CC). As the BTT system does not affect to the surface traffic flow, it presents relative convenience for construction process. Thus, instead of CC, BTT type design is commonly preferred for the station projects that were carried out. BTT system, however, has a limited potential of visual perception and capacity of visual perception during evacuation process, whereas CC system has considerable advantages regarding visual perception. The paper examines and compares the two systems in an exemplary metro station design context. As both systems present similar results with NFPA 130 on the evacuation route, space syntax model is executed to emphasize the difference of spatial quality between these two systems. Thus, the difference of spatial quality can be proven numerically through syntactic level. In order to determine and compare the spatial qualities of the evacuation routes between the platform and the concourse floors of the two systems, a comparative research of ITU–Ayazaga metro station covering BTT and CC design strategies is conducted. Starting from the platform floor, the evacuation route forms special “evacuation nodes”, which are analyzed for the comparison of the two systems. The comparison of the BBT and CC design strategies exposes that CC systems are much more advantageous regarding the escape routes. The number of shallow nodes formed by the convex spaces spreading through a large span within the CC strategy brings out the factors that increase the spatial quality and aesthetics. The potential and capacity of the visual perception on the evacuation nodes presented by the CC planning strategy is proven through space syntax model.

Anecdote

Client: … we insist on selecting “binocular tube type station” because of high speed in construction and low price…

Architect: … I have verifications, “cut and cover” type of design is cheaper than” binocular tube tunnel”…

Client: …what about the traffic flow over the metro station? If we construct "cut and cover", we will close one lane and we will detour the traffic, we will do it on the densest traffic of Istanbul… Did you evaluate this situation?

Architect: I am an architect… (Long silence)… I care about the spaces, the width of the space, and the length of the space…Moreover, we are designing a metro station, and we should care about the traveller's perception… The spaces that I design should not be claustrophobic. The spaces should be larger, so I should provide wide visibility for way finding, perception and evacuation…

Client: On one hand, our remarks on low price, traffic, and high speed in construction technology, on the other hand your remarks on aesthetics…

Architect: (angry, red face) it is not simple as you considered…My point is more valuable than your design criterion. How will I force the public to occupy metro spaces 30 meters below 0?

Client: We have proofs about the comparison of two strategies… Can you prove your comments; do you have evidence about your remarks? Do you prove that "cut and cover" is beneficial than "tube tunnel"… (Long silence)

Architect: Hmmm…No… My consideration…

(… The conversation occurred for the ITU-Ayazaga metro station between the municipality and the architect…Such discussions have continued for five months. The client decided that the design of the station would be "tube tunnel" and the architect made the design promptly due to the client's desire…)

Introduction

There are many meetings such as above in architectural practice and many times the architect is a humble person who is not able to express the truth and experience adequately. Architecture is a profession concentrated on norms and regulations, and the experience of architect is always regarded as part of design and normative considerations (Lang, 1987). However, the experience of architect is fulfilled due to norms of architectural praxis; they mostly do not have concrete issues and they might easily be manipulated by opposite options, and their arguments on aesthetics are always vague. The experience of the architect overcomes many problems in design, but "experience" is an ambiguous term especially in design feasibility concerns. Contrary to this fact, "space syntax theory" opens a new discussion in architectural feasibility concerns.

The relationship between the cells and the building configuration brings out a new discussion regarding not only the connectivity of cells, but perception and cognition of spaces. According to Peponis (2001), the syntactic analysis is derived from geometric and topological properties. He defends that interaction between the geometric shape and the analysis of topological relationships is at the core of space syntax theory, and that the notions such as structure of experience, perception and occupation of space are mapped and visualized with building plans (Peponis, 2001). We may accept that a person in space has always a span of visibility accorded with the configuration of cells around the person (Unlu, et. al., 2001). So, space syntax theory, beyond its main concern on morphological essence, may be regarded as an important tool for topological qualities including perceptive potentials in the space. This paper aims to discuss the perceptive qualities based on different design and construction strategies in metro stations; therefore, geometric and perceptive qualities are comparatively discussed between two options in construction such as “cut and cover” versus “tube tunnel”.

The Node and the Route

The node on the circulation system is a critical point that specifies a decision-making area in way finding. O’Neil (1991) constructs his theoretical approach with nodes intersecting axial channels, and the building configuration analysis is based on these decision-making points. The building configuration depicts a path linking all nodes thus; presenting a critical issue in cognitive formation and architectural legibility (Passini, 1984; O’Neil, 1991). The building configuration is a path constructed with many nodes reflecting geometric and topological qualities of interior environment. The number of nodes is a critical issue in concept of complexity. O’Neil (1991) defends that an increase in “Inter Connection Density” model is correlated with delay in evacuation time, stress and problems in architectural legibility. If the connection density occurs between the nodes, we assume that the building has an aspect of complexity (O’Neil, 1991).

Contrary to the anecdote of this paper, if we evaluate the circulation path and the location of nodes over the circulation, the building design is not an abstract concept; on the contrary, it may be measurable. We may suggest concrete remarks about topological characteristics about the nodes such as distance, density, real integration values, and isovists (Unlu, et. al., 2005). As a prominent of way finding issues in architectural legibility, increasing complexity may lower the values in way finding performance (Weisman, 1981). The theory is also shared by Peponis et al. (1990); they defend that if there are more integrated and shallow spaces in the building design, we should assume lower real asymmetry (RRA) values as a syntactic outcome, while this case corresponds to high complexity problems in architectural legibility. The legibility concern here is considered as a contradiction to deeper and axial building configurations.

Many researchers (O’Neil, 1991; Peponis et. al., 1990; Weisman, 1981) accept that lesser connection on the determined route is accorded with high architectural legibility level. By this way, we may assume that more connections and high permeability between the cells on the route cause more complexity in interior environment. This opinion may be true for hospitals or shopping malls; however, the design of a metro station is a specific and paradoxical issue. Although, the “tube tunnel” (TT) strategy creates sharp axial lines for orientation and clarity in way finding, this strategy is derived from the decrease in connection density. This design strategy also presents low perceptive quality especially in way finding, less connectivity, less option in evacuation, and standardized circular tubes and repetitiveness. If we compare these syntactic and perceptive qualities with “cut and cover” (CC) strategy, we find out higher connection values and more options for evacuation in CC, in other words, spatial richness.

The node and route strategy in way finding implies a limited knowledge and a static simulation excluding topological relationships. The static nodes do not reflect the spatial qualities in way finding. However, as Weisman (1981) proposed that the node and its vicinity should have more topological aspects in way finding. He argues existence of perceived landmarks, architectural difference, signs and symbols, and the pattern of layout in way finding may be considered as essential parameters of architectural legibility. These qualities, rather than syntactic ones, can be regarded as semantics of space.

Spatial Connectivity

The theory of legibility in space cannot solely be linked to the node and the route relationship. The way finding approach should be based on perceptive qualities of the node. As Gibson (1950) proposed, each node has a visibility potential and richness that may be the primary sensory input in the mutual relationship between the object and subject. The terms such as Gibson's (1950) "visual field" and "visual world" help us to understand visual affordability of the environment and the impact of visual stimulation, while we move through the spaces. This definition forces us to consider that the viewer uses all spatial options during the evacuation. However, spatial manifestations of the metro station can blockade way finding, whereas some internal partitions like Tolman's maze motivate the viewer towards the exit (Tolman, 1973). The critical issue in this discussion involves the building configuration and its reflections on the mental representations of the traveller.

The space syntax theory brings out an important discussion that high real integration values in shallow spaces propose high visibility values and high values in permeability, as sum they propose more options in the evacuation route. This assumption confirms that we assume higher visibility potentials in shallow spaces corresponding high social interaction in more integrated spaces. Contrary to this fact, we may accept lower social interaction occurrence in deeper cells emphasizing sociofugal aspects (Unlu, et. al. 2001). Spatialist presents the isovists of building configuration and proposes s-partitions that as more lines intersect on surfaces, more visibility options emerge on the shallow spaces. Thus, we may judge that lower values may be found in less intersected surface lines, mostly in deeper spaces.

This theoretical argument motivates us to concentrate on "cut and cover" strategies that present larger and wider total spaces at platform levels, which are not blocked by cells. The spatial configuration of "cut and cover" reflects the minimization in depth levels, indicates lower values in real asymmetry. Therefore, we assume that this building configuration proposes high occurrence of intersection of surface lines at platform and concourse levels.

Visibility

Higher visibility span of isovists as an outcome of s-partition analysis verifies high visibility potential in shallow spaces. Hence, "cut and cover" (CC) strategy has many advantages and more options especially in evacuation. However, it is difficult to grasp this notion in "tube tunnel" (TT) strategy. This assumption can be easily verified in space syntax theory. If we return to discussion above, each nodal point on the evacuation route also brings out the span of visibility based on the area of isovists not only in plans, but also in sections.

This paper proposes an additional analysis for the node so that we may assume the vertical visibility potential of nodes through the section of the building. Thus, this assumption verifies that "cut and cover" (CC) strategy presents high visibility span at building, because of wider and higher sectional surfaces around the traveller. The visibility notion has different angles of visibility based on surfaces located on the determined route. Each nodal point confirms that wider and higher physical qualities of CC type solution are more convenient for the traveller, compared to TT type solution. We may assume that high visibility ratio in each nodal point specifically CC strategy brings out spatial richness and more convenience in way finding. The comparison between CC and TT strategies indicate, the determinants that we initially accept as part of our argument. In other words, these indicators are accepted as our core of methodology.

- Integration Values: Each node presents a syntactic value as an outcome of surface partition lines. In comparison, more connection possibilities of shallow spaces as an outcome, we accept high integration values at each node corresponding to CC strategy.

- The Area of Planar Isovist: The more intersected surface lines get, the more they reflect high visibility values at each node. We assume that CC typology presents high visibility values on nodal points. So, the area of "isovists" at plan level can be regarded as another outcome of the comparison.
- The Area of Sectional Isovist: The planar isovist can also be implemented as sectional. An agent at the eye level brings out all possible visibility potential with reference the profile of the building at the node. Presumably, CC has vast potential at the section level, a traveller can easily sees and monitors options for evacuation, so the area of isovist will be larger than tube tunnel.

Method

The metro station involves two options in planning that are discussed in here as CC (cut and cover) and TT (tube tunnel) strategies. The option of TT is the preferred design type for ITU-Ayazaga metro station by the client. The basic criterion for designing TT is to connect the platform, concourse and landings by standardized circular tube tunnels. This design type provides limited perception in way finding, so travelling through tube tunnels is a critical issue (Figure 1).

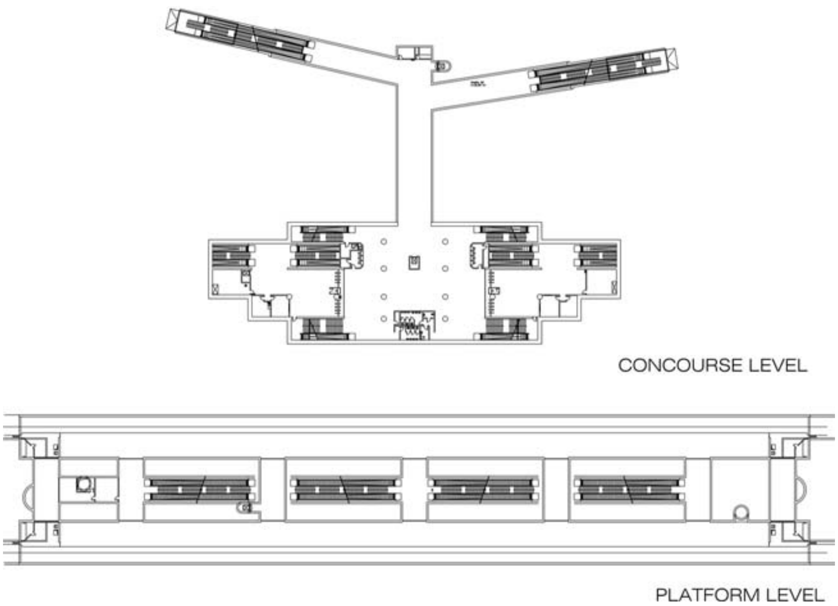


Figure 1:

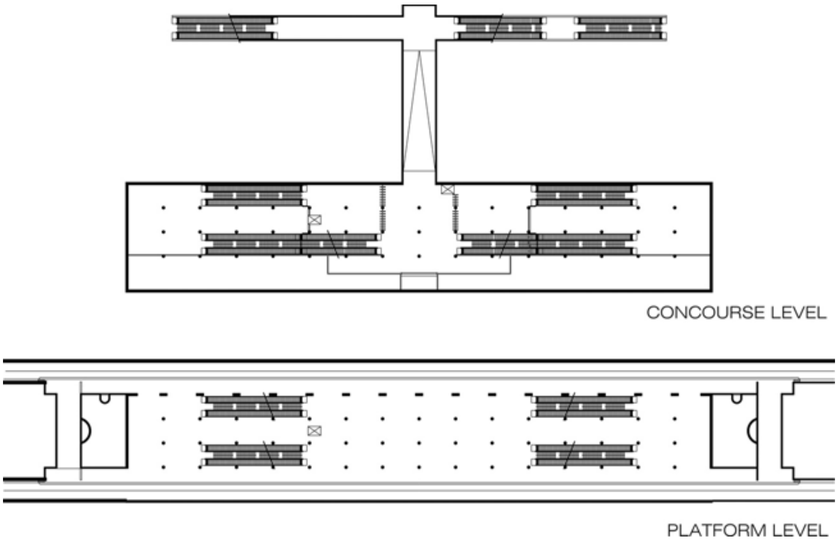
ITU - Ayazaga Metro Station, Tube Tunnel Strategy (Client's preference)

Contrary to this type, CC strategy presents a spatial void at platform and concourse levels. The vertical circulation systems are clear, and the total space presents many options for evacuation. The layout of this type is presented as below (Figure 2).

The design of evacuation route is always a critical issue in metro stations. Based on the metro stations in Istanbul, we may suggest that many platform levels are designed at 30 meters below ground level. Therefore, the design of evacuation route in metro stations should strictly be accorded with USA NFPA-130 regulations. The designer always checks the evacuation route out due to 4 minutes duration for reaching the safe halls and areas, where the fire risks are minimized by the help of fire protection and alarm devices. As an extent of this regulation, the designer also evaluates the evacuation route in 6 minutes for reaching the ground level.

Figure 2:

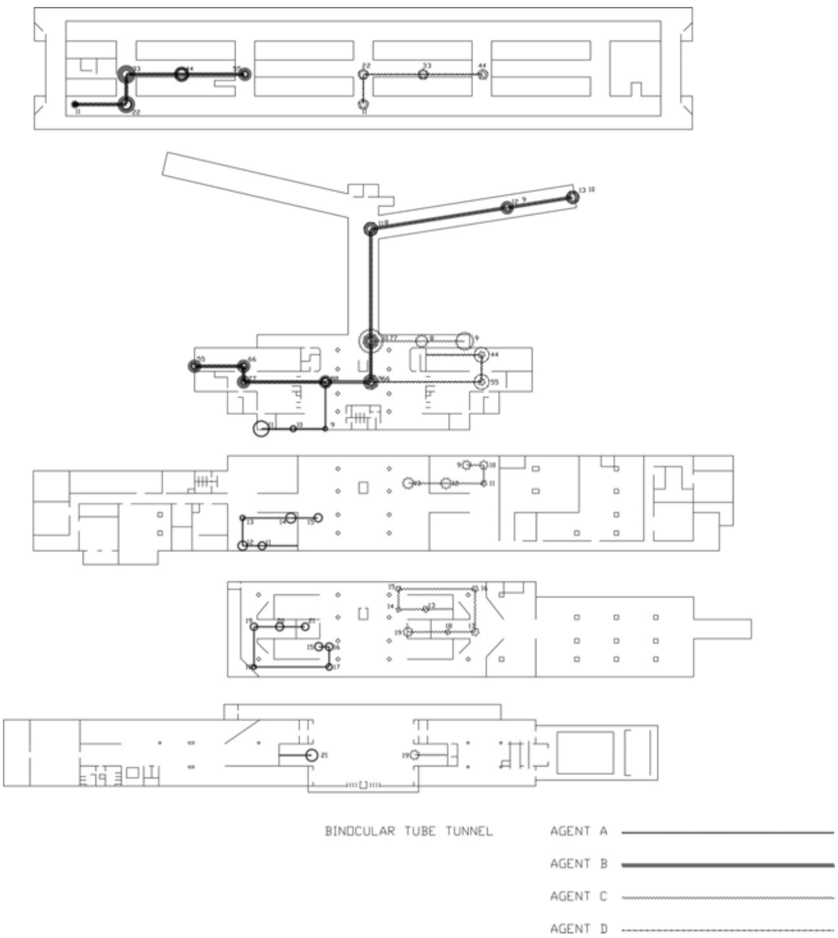
ITU - Ayazaga Metro Stations, Cut and Cover Strategy (Architect's preference)



In this research, 4 evacuation routes for each design strategy were determined. Agents A and B of both systems starts from the end of platform, while agents C and D starts from the centre of the platform. Agents B and D of each systems leaves the station at concourse level through an auxiliary hallway, while agents A and C travel vertically through to the ground level. All of these evacuation routes present different number of nodes varying from 10 to 21, related with the design restrictions, and each route is formed according to clockwise movement of right hand side preference (Figure 2 and Figure 3).

Figure 3:

Evacuation Routes Determined for Tube Tunnel Strategy



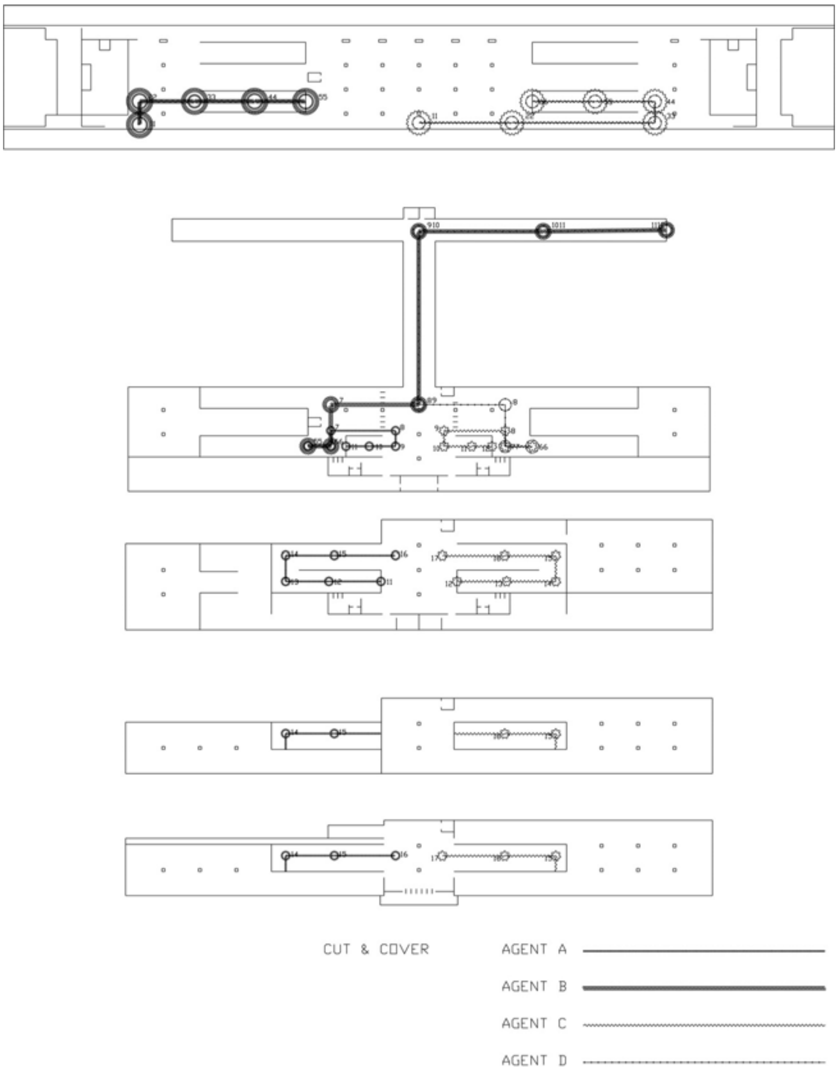


Figure 4:

Evacuation Routes Determined for Cut and Cover Strategy

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For each level of both design strategies, s-partition analysis performed using Spatialist presenting the most integrated and deepest spaces of the systems. The nodes of the determined routes are placed on specific convex spaces performed by s-partition analyses. The real integration values of these shapes are recorded; the visibility performance of the nodes is calculated both as planar isovist and sectional isovists from the recorded specific convex shape. Samples of such node visibility calculations are shown in Figure 5 and Figure 6.

As a comparison strategy, this paper evaluates the evacuation routes between CC and TT typologies due to 4 minutes of evacuation time. The duration of travelling in the metro station due to 4 minutes of evacuation time in Istanbul railway system generally occur between platform and concourse levels as result of the depth of railway lines. So, we assume that the 4-minute route has many nodes as an intersection of axial lines in way finding scenarios. The nodes are assigned integration and isovist values as an outcome of s-partition analysis. The comparison between CC and TT type is based on real integration values and area of isovists for each node. The paper presents the comparative tabulations with reference to integration and area of isovists in 4 minutes evacuation route along with the time span to surface level. The comparative tabulations extract outcomes based on determined selected nodes. The mean score obtained from real integration values and area of isovists clarifies the comparisons and verifies the difference between CC and TT types.

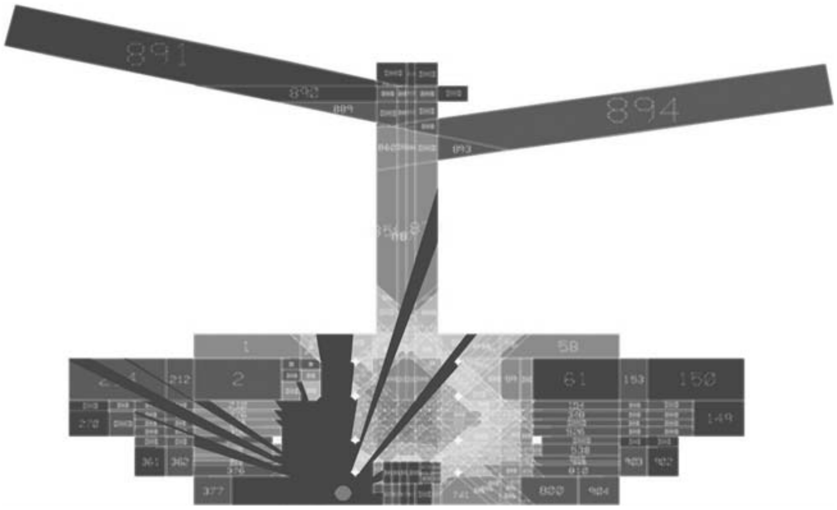

Figure 5:

Planar isovist area sample calculated for Route A of TT Strategy (top)

Figure 6:

Sectional isovist area sample calculated for Route A of TT Strategy (bottom)

Analysis of Real Integration Values

The figures indicated in Table 1 and Table 2, present outcomes corresponding to the nodes. The real integration values explain the shallowness of the node as an integration of surface partition lines. The high permeability between spaces forces us to assume that "cut and cover" strategy will create void and shallow spaces at platform and concourse levels. The tabulation demonstrates lower value of real integration in "tube tunnel" strategy comparatively (Table 3).

Table 1:

Evacuation Route Data for Tube Tunnel Strategy

Tube Tunnel Strategy							
Route A				Route C			
#	RI	IA_P	IA_S	#	RI	IA_P	IA_S
1	0,531	36,651	7,922	1	0,738	41,494	8,690
2	0,631	41,543	8,690	2	0,643	16,958	5,577
3	0,578	11,958	14,000	3	0,543	11,609	9,229
4	0,493	6,756	8,487	4	0,287	26,690	2,808
5	0,285	24,998	4,566	5	0,298	50,975	16,379
6	0,295	46,219	2,920	6	0,469	101,540	11,989
7	0,307	50,359	15,820	7	0,432	90,305	11,927
8	0,434	76,896	17,846	8	0,325	22,816	14,512
9	0,317	39,178	4,621	9	0,355	8,967	5,222
10	0,297	21,020	6,712	10	0,355	14,229	10,113
11	0,312	12,147	7,452	11	0,355	21,151	7,371
12	0,312	14,956	10,113	12	0,355	8,093	8,649
13	0,312	19,772	7,371	13	0,402	36,145	14,207
14	0,312	8,271	8,649	14	0,467	50,193	4,947
15	0,319	34,880	14,207	15	0,430	42,930	17,500
16	0,345	48,037	4,947	16	0,399	35,804	4,807
17	0,349	51,328	17,500	17	0,390	54,131	6,546
18	0,271	30,610	4,807	18	0,367	40,467	7,248
19	0,276	16,147	4,284	19	0,387	33,214	9,766
20	0,262	6,620	5,761				
21	0,460	33,431	9,510				
	ΣRI/#	ΣIA_P/#	ΣIA_S/#		ΣRI/#	ΣIA_P/#	ΣIA_S/#
	0,367	30,085	8,866		0,421	37,248	9,341

Cut & Cover Strategy							
Route A				Route C			
#	RI	IA_P	IA_S	#	RI	IA_P	IA_S
1	0,325	38,372	13,814	1	0,492	53,502	165,848
2	0,344	28,660	57,640	2	0,408	48,070	165,583
3	0,407	20,807	53,499	3	0,392	37,399	16,733
4	0,407	11,064	54,156	4	0,407	21,671	54,150
5	0,401	30,563	53,783	5	0,407	10,176	54,221
6	0,469	26,078	8,780	6	0,404	33,300	53,919
7	0,541	49,053	92,832	7	0,436	27,640	8,780
8	0,667	75,117	11,484	8	0,499	45,797	92,832
9	0,583	57,745	31,163	9	0,637	70,126	11,484
10	0,583	34,659	27,658	10	0,560	55,365	31,163
11	0,447	11,348	26,724	11	0,560	33,716	27,658
12	0,447	11,870	23,448	12	0,498	11,347	26,724
13	0,447	16,288	3,556	13	0,498	11,875	23,448
14	0,514	42,845	3,163	14	0,498	16,141	3,556
15	0,514	45,964	5,487	15	0,568	41,392	3,163
16	0,574	55,460	6,174	16	0,568	45,472	5,487
				17	0,642	53,052	6,174
	ΣRI/#	ΣIA_P/#	ΣIA_S/#		ΣRI/#	ΣIA_P/#	ΣIA_S/#
	0,479	34,743	29,585		0,498	36,238	44,172

Table 2:

Evacuation Route Data for Cut & Cover Strategy

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Analysis of Planar Isovist Area

As an extent of real integration analysis, the lower value of real asymmetry value will imply a total and shallow space in CC. The tabulation presents higher planar isovist area values in CC, so that, we may assume high perimeter ratio in planar isovists of CC (Table 2). As result of high asymmetry value in TT, tabulations (Table1) prove that lower ratio in isovist area of TT.

Analysis of Sectional Isovist Area

The examination of isovist areas in metro stations is an additional analysis for spaciousness of the route. The tabulation (Table 1 and Table 2) presents big difference between CC and TT strategies. This analysis emphasizes the higher ratio of spaciousness in CC strategy.

Synthesis and Conclusion

All these measurements indicate that there is always a concrete aspect of way finding. The preference of CC strategy presented by the architect is the result of professional experience or maybe it is “common sense”. In reality, all nodes in the selected route of CC exhibit higher values in integration and isovist area levels. Therefore, we may conclude that TT type is a critical design strategy not only in exhibiting deeper areas or branch-like axial configuration, but also in decreasing values in spaciousness (Table 3).

	Tube Tunnel Strategy		Cut & Cover Strategy	
	Route A	Route C	Route A	Route C
RI	0,367	0,421	0,479	0,498
IA_P	30,085	37,248	34,743	36,238
IA_S	8,866	9,341	29,585	44,172

Table 3:

Comparison of Syntactic Data for both Strategies

If we return to the anecdote, architect cannot verify his speech without grasping empirical evidences. Architect’s opinion is very vague, but space syntax theory can help one to understand the latent aspect of the environment and it is always considered as a tool to transform ambiguous subjects to concrete issues. Sometimes, architects confront in making comparisons in obvious subjects such as design strategies in metro station. It is obvious that CC has many advantages such as low levels of stress in spacious and void interiors. But, the problem is how to verify one's feelings and "common sense" in computable determinants or how to concretize one's approaches in design. Regarding the design possibilities in other public facilities, we designers may also confront with many possibilities that cannot easily be soluble such as the metro stations above. In sum, we may be confronting sharp distinctions between the options in which, we are stuck and indecisive; space syntax is a real tool for analyzing our vicinity, and reaching the decision for such conditions.

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