VISUAL GEOMETRICAL ANALYSIS OF OUTDOOR SPACE STRUCTURE AROUND RAILWAY STATION BUILDINGS*

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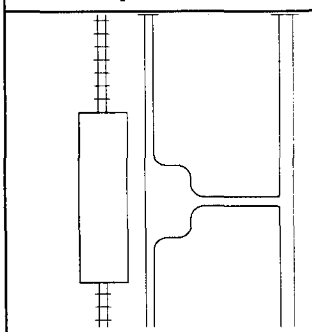
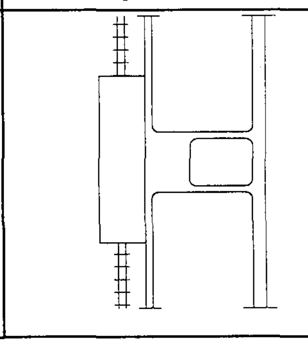
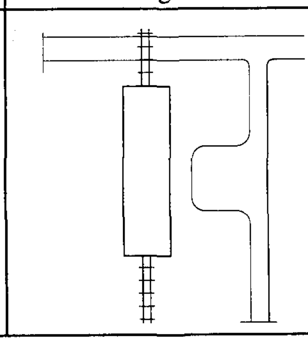
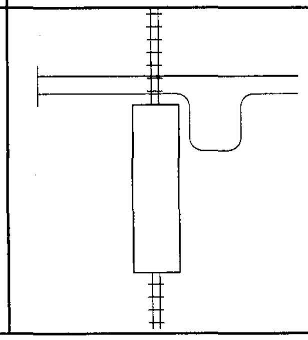
1. Introduction

After WWII in Japan, many railway stations in large cities have been rebuilt and extended several times. Because of the rapid growth of demand due to urbanization, clarity of form was scarified and little attention was paid to the main needs of passengers (accessibility and orientation). This resulted in visually complicated outdoor spaces that evoke feelings of confusion and disorientation in the passengers.

The main purpose of this study is to clarify the visual structure of open space patterns around railway station buildings. The visual structure has been analyzed by investigating the effect of different types of spatial relationships between the station and its surroundings on the degree of visual access of the station. Accordingly, a typology of space structure patterns around stations of the Tokyo metropolitan area could be constructed. Since many elements of open spaces were found to affect the visual accessibility, the study focused on clarifying the shape effect of the station plaza and the type of link to main street. A geometrical analytical methodology was proposed for measuring the degree of visual access for the different open space patterns. In order to clarify merits and demerits of the different patterns as well as current spatial problems characterizing the open spaces, the analysis was applied to both theoretical cases and a sample of real cases of study.

2. Typology of Space Structure Patterns

Table1: Space structure patterns having plaza in front of station

Pattern (1) Plaza orthogonaly linked to main parallel street	Pattern (2) Plaza Binary linked to Main parallel street	Pattern (3) Plaza binary linked to main orthogonal street	Pattern (4) Plaza directly opened to main street
			

Higuchi [1] has mentioned that designers, engineers, architects and urban planners who are charged with implanting physical installations as a setting, it is basic and essential to grasp the nature of that setting as a visible spectacle and to understand its spatial structure. Accordingly, analyzing the different types of relationships between the station and its surroundings is of a great importance in understanding the visual structure of open spaces around stations.

The study covered a sample of stations around the Tokyo metropolitan area where millions of passengers daily commute to and might find difficulties in reaching their destinations. Various types of open spaces were observed around the study area. The cases were classified according to the following criteria: availability of plaza, location of station plaza and type of link to main street. The grouped patterns were mainly classified into two categories: patterns with plaza in front of the station building and patterns with no plaza. According to the importance of station plaza as a transportation node and a creative space that is expected to generate its own culture and community in the future[2], the study focused on cases providing plaza in front of the station building. The main patterns used in the analysis are shown in table 1. The analysis of the other patterns encountered by the typology[3] is beyond the scope of this paper. The typology of space structure patterns clarified the nature of the different spatial relationships. A good understanding of the space structure patterns could be revealed.

*Keywords: railway stations, space structure patterns, visual access, visual structure
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3. Framework of Analysis:

(1) Concept of analysis

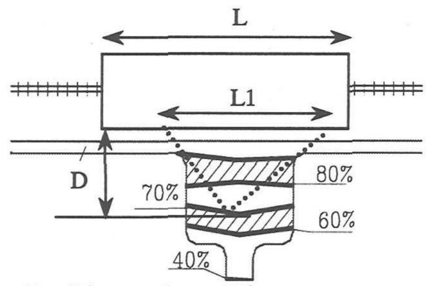
Studies often call for improving access to open space but rarely have a measure for access. An analysis is both descriptive and evaluative. It should depend upon a good description but goes beyond it to identify patterns and potentials. For instance, a description of open space might merely locate open space and describes its type but an evaluation might assess its accessibility, maintenance or visual interest.

Visual accessibility is an important factor in facilitating one's spatial orientation and way finding. Lynch[4] has noted that visual accessibility and its impact should be the design criteria for a highly "legible" or imageable environment. Therefore, clarifying the impact of open space patterns on the degree of visual access can provide a basic idea about the visual structure of open space. In order to provide an intuitive comparison between the effect of different space structure patterns, a geometrical analysis of open space structure patterns was conducted.

(2) Hypothesis

Visual accessibility is considered as a measure of the portion of vision provided from the station building with the respect to the distance from the station. The issue is to clarify how the passenger passing through different types of space patterns can visually access the station building.

The horizontal and the vertical angles of views express the extremities of the field of vision. In the present study the percentage of visible length from the station building is considered to express the extremities of the horizontal angle of view. However, the effect of vertical angles of views is to be covered in future studies concerning vertical elements of space. Consequently, the percentage of visible length and the distance from the station building are considered as criteria or indexes for determining the degree of visual access as shown in Figure 1. The percentage of visible length is defined as the ratio between the visible length of the station from any viewpoint (L1) and the length from the station building (L)*100. The distance (D) is measured from the station façade up to the viewpoint.



D: Distance from station
L: length of station
L1: Visible length from any viewpoint

Figure 1: Indexes of analysis

(3) Design of theoretical cases

The analysis of cases of study can clarify current problems and effect of composite elements. While the study aim is to analyze the effect of space structure patterns, a design of theoretical cases representing the different patterns was proposed. Design guidelines of ideal railway station buildings and basic theories of urban space design were implemented.

A flow chart of the theoretical cases design process is shown in Figure 2. Table 2 shows the classification of the different elements. The cases were first classified according to traffic size (i.e. number of passengers per day)[5] into six size classes as shown in table2. Many factors are to affect the station building length such as the building size, land use, and architectural design... Accordingly, the platform length was considered as the station length (L). The estimation of the platform length was based on several elements[6,7] such as building size, number of trains, capacity of vehicles, headway, average length of vehicles and others. Which have been considered in the calculation process. The estimation of the plaza area size was based on the model introduced in the 1981 handbook of traffic demand prediction[8]. The area was calculated for each building size as shown in table2. The main street width is mainly related to traffic volume. The estimation of the main streets width was based on the Japanese design standards of streets in urban areas[9] and streetscape design guidelines.

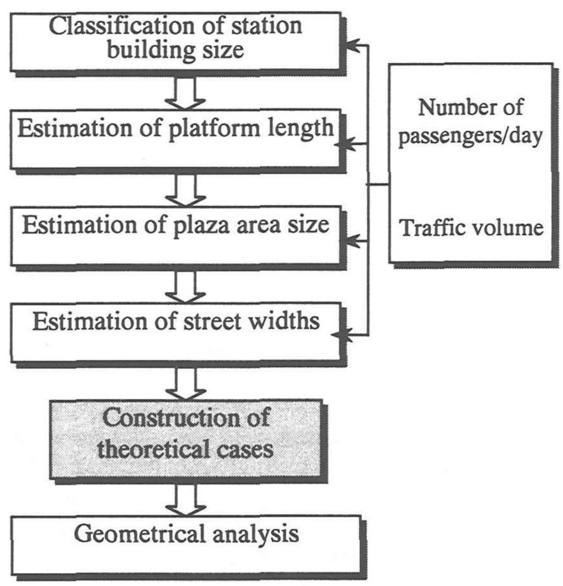


Figure 2: A Flow of the design of theoretical cases

Table 2: Space structure patterns having plaza in front of station

No. of passengers (P/Day)	Station size	Platform length	Plaza area size	Street width
. Less than 2,000	. Very small	125 m	559 m^2	20 m
. Between 2,000-6,000	. Small	160 m	1194 m^2	25 m
. Between 6,000-15,000	. Medium	190 m	1838 m^2	30-40 m
. Between 15,000-100,000	. Large	240-300 m		
15,000			2174 m^2	
15,000-25,000,			3078 m^2	
25,000-50,000,			5338 m^2	
50,000-100,000			9858 m^2	

(4) Outlines of methodology

The method of Visibility Contour Lines Distribution has been proposed for measuring the degree of visual access of the space structure patterns. The main concept is to illustrate contour circles rising from the station center and distributed around the station. Viewpoints can be located on these circles. As mentioned previously, the percentage of visible length and the distance from station building are the indexes for determining visual accessibility. Therefore, the percentage of visible length can be measured from these points. The viewpoints having equal percentage of visible length are joined by one contour line. Finally, the distribution of visibility contour lines for each type of space pattern can be drawn. The distribution of contour lines identifies locations of high and low degree of visibility. That is very important in early stages of station design as well as improvement projects. Thus, better allocation of space elements and traffic functions can be estimated. In such a case good degree of visual access can be achieved. Figure 3 illustrates the method, which proceeds in four steps:

Step 1: The first contour circle is constructed (diameter = station length). Every point on this circle has a view angle of 90° and can see 100% of the station building facade.

Step 2: Successive contour circles are drawn having view angles ranging from 0° up to 180°.

Step 3: In order to avoid random distribution of viewpoints, a set of radial lines with 20 degree interval was drawn from the station center. Intersection of the contour circles and the radial lines defines locations of the viewpoints around the station building.

Step 4: The percentage of visible length is measured from these points. The viewpoints with similar percentage are joined by one contour line. Finally, the distribution of contour lines can be drawn for each pattern.

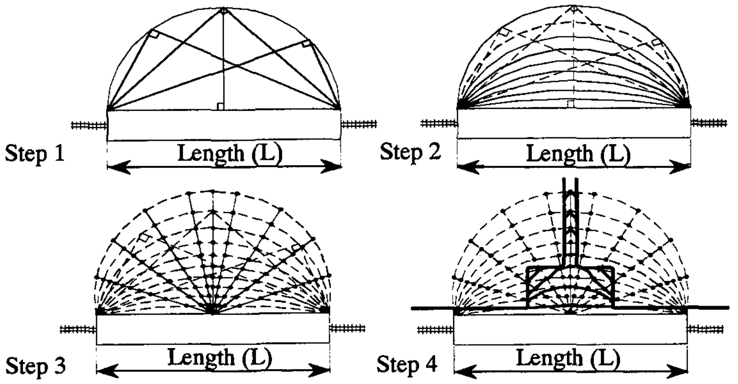


Figure 3: Visibility contour lines methodology

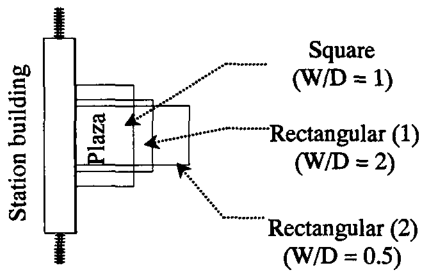


Figure 4: Assumptions of plaza shape

(5) Study parameters

Many elements of open spaces are to affect the visual access such as building height, shape of plaza, traffic functions distribution, type of relationship to main street and others. This study focuses on the shape of plaza and type of link to main street, however the effect of other factors is the matter of discussion of further studies.

a) Shape of plaza:

Anastasi[10) found that the perception of the area of geometric figures having the same area varies according to their shape. Also, Sandalla and Oxley[11) found that the area of a room was perceived as larger as the length/width ratio increased. In the present study three types of shape were proposed by changing the width/depth ratio as shown in Fig.4.

b) Type of link to main street:

It was observed from analyzing the different space patterns that type of relationship or link to main street determines the main physical relationship between the station building and the surrounding street network. The types of links to main streets can be observed from the space patterns previously shown in Table 1.

3. Results of Theoretical Analysis

(1) Distribution of visibility contour lines

The method of Visibility Contour Lines was applied on both the theoretical cases of study as well as a sample of cases from the study area.

Figure 5 illustrates the process of the analysis results. First the percentage of visible length was measured from the primary illustrated contour circles as explained previously. Then the distribution of effective visibility contour lines could be drawn for the different patterns. The final results are shown by the relationship between the percentage of visible length and the distance from the station façade up to the main street level.

Figure 6 shows the difference between the shapes of contour lines thus expressing the effect of varying W/D ratio.

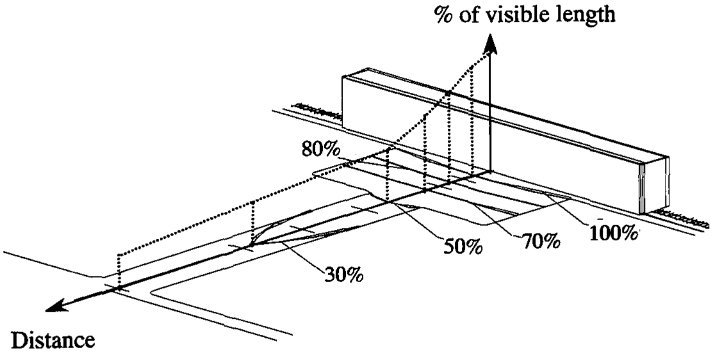


Figure 5: Process of analysis results

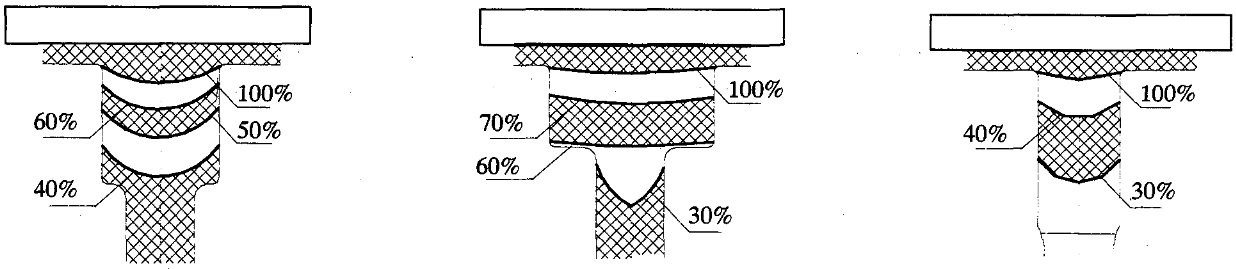
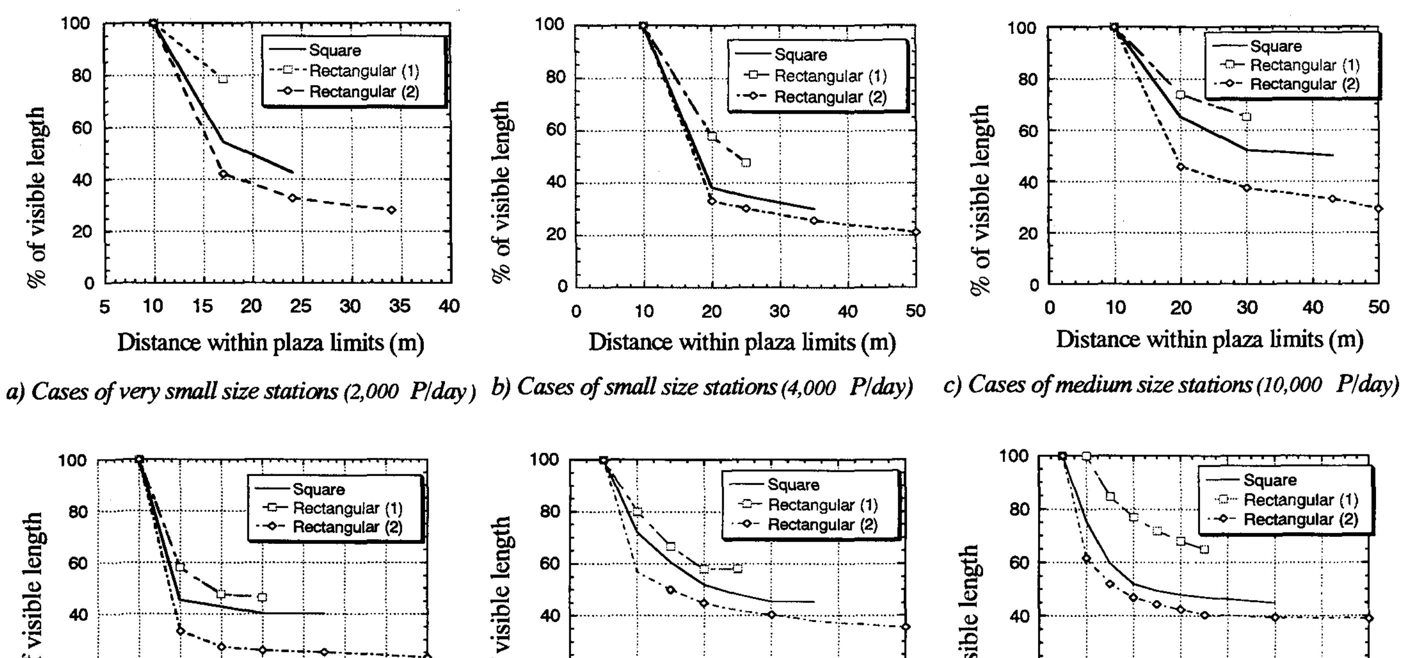


Figure 6: Contour lines distribution of different shapes for cases of large stations

(2) Effect of plaza shape

Figure 7 represents the relationship between the percentage of visible length and the distance from the station building for the different cases from small size stations to large size ones by varying W/D ratio. Large depth Plazas (W/D=0.5) were observed to provide low degree of visibility. As can be seen from the graphs, the percentage of visibility ranges from 20% for case of small stations up to 40% for large stations. While cases having square shape plaza provided better results for the different station sizes. Large width plazas (W/D=2) provided the best degree of visibility. By increasing the width of plaza, larger amount from the station frontage can be seen. Thus, increasing the degree of visibility of the station. Additionally, it provides good arrangement of traffic functions and different elements of plaza as well as creating gathering spaces and pedestrian accommodations. That is very important especially for large size stations characterized by complexity where several functions are grouped in one place. These implies the importance of providing appropriate dimensions for the station plaza that increases the degree of accessibility and enhance the quality of the visual environment around the station building.



a) Cases of very small size stations (2,000 P/day) *b) Cases of small size stations (4,000 P/day)* *c) Cases of medium size stations (10,000 P/day)*

d) Cases of large size stations (25,000 P/day) *e) Cases of large size stations (50,000 P/day)* *f) Cases of large size stations (100,000 P/day)*

Figure 7: Relationships between distance and percentage of visible length for different shape of plaza

(3) Effect of type of link to main street

Out of plaza limits, the type of link to main street mainly affects the visual accessibility to the station. Accordingly the effect of each type will be discussed separately. The distance up to main street level was considered as a walkable distance of 300 m in radius.

a) Pattern 1: Orthogonal link to main parallel street relationship

This type represents the classical European pattern for planning important buildings that have a strong position in the city such as cathedrals and stations where the building becomes "Vista".

Good degree of visual access to the station is provided as shown in Figure 8. The plaza ideally centered to the station entrance permits larger amount of the façade to be seen along the main street.

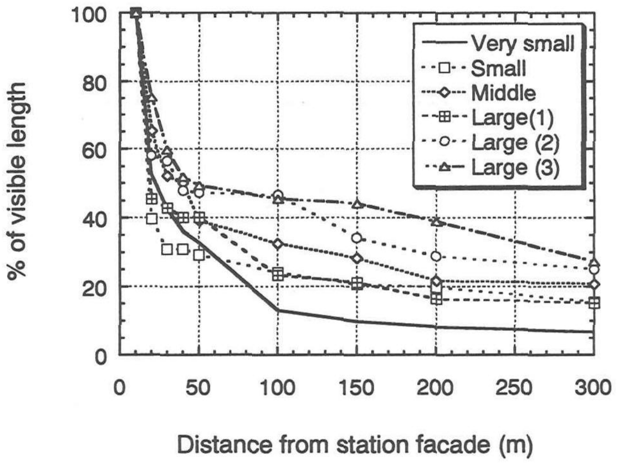


Figure 8: Distance versus percentage of visible length for different station sizes of pattern1

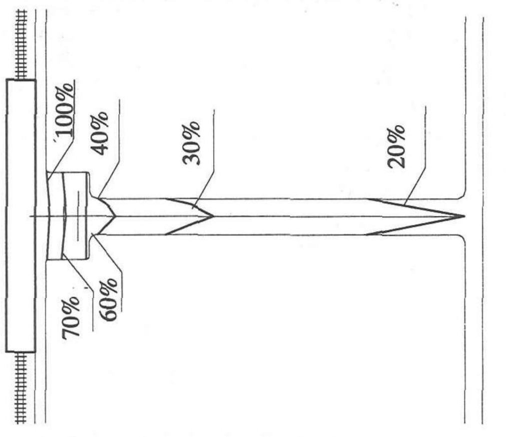


Figure 9: Distribution of contour lines for middle size stations of pattern1

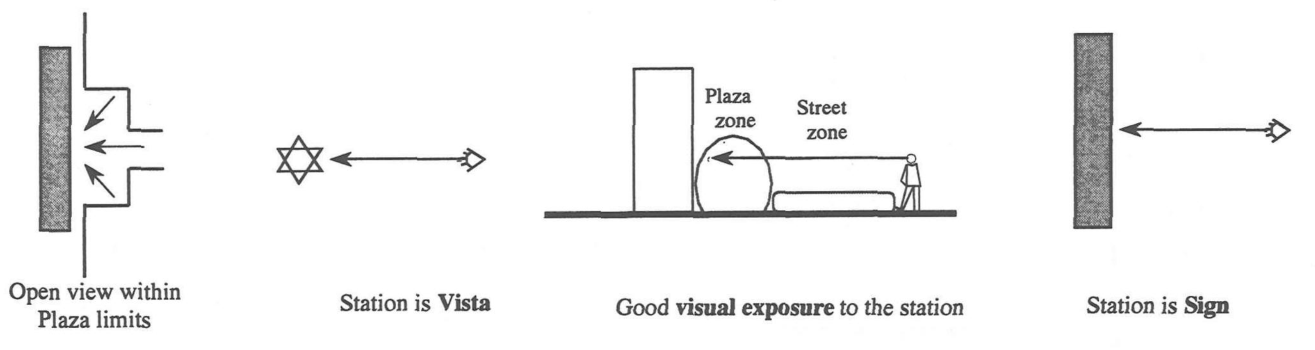


Figure 10: Spatial characteristics of pattern 1

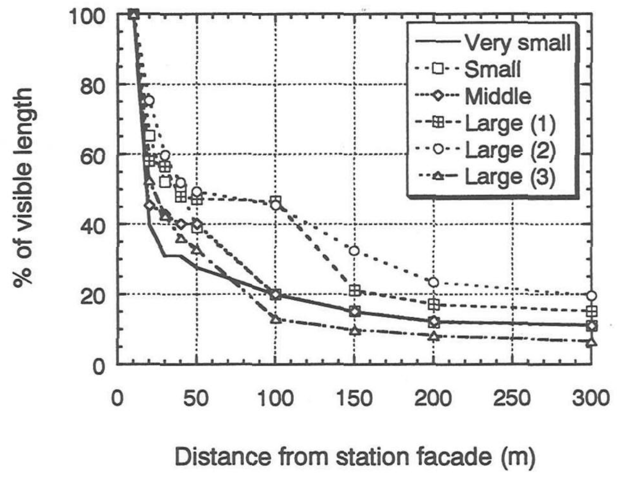


Figure 11: Distance versus percentage of visible length for different station sizes of pattern 2

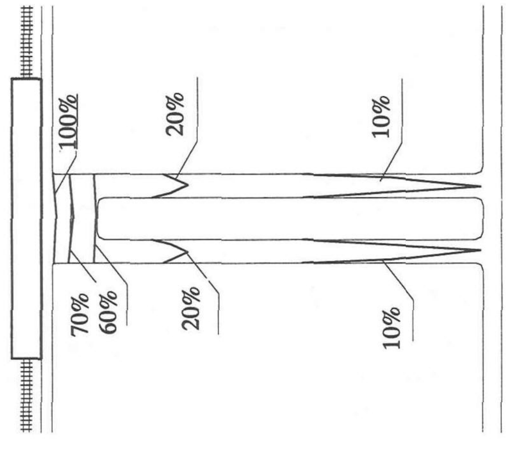


Figure 12: Distribution of contour lines for middle size stations of pattern 2

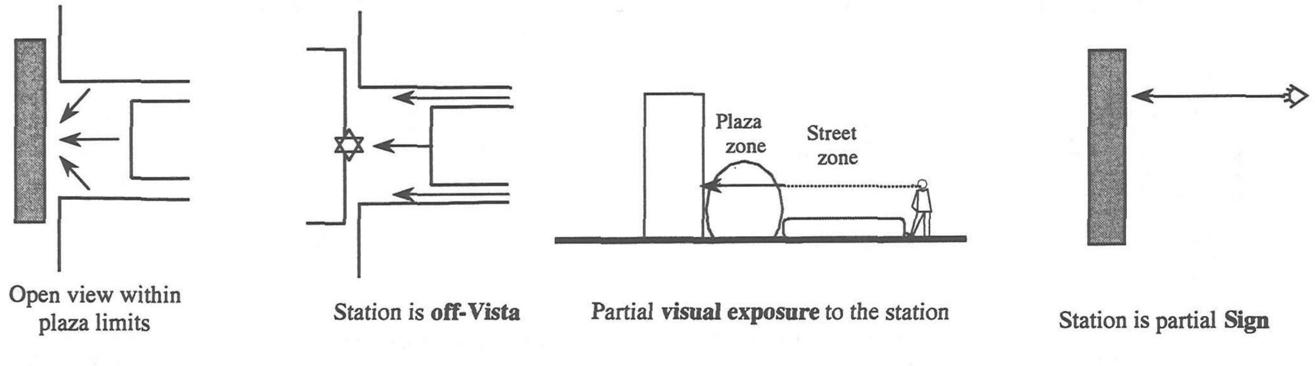


Figure 13: Spatial characteristics of pattern 2

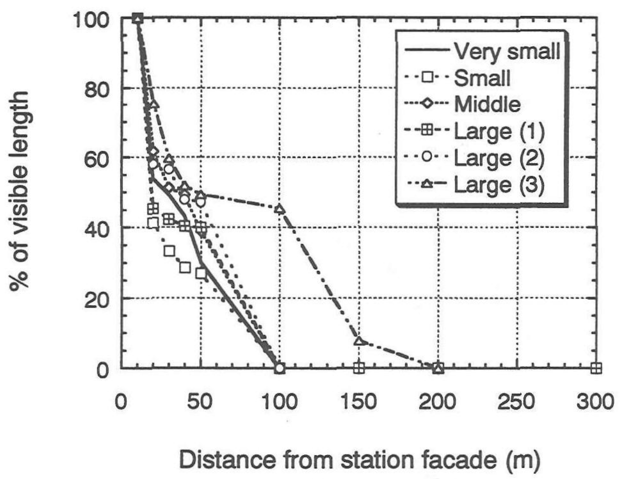


Figure 14: Distance versus percentage of visible length for different station sizes pattern 3

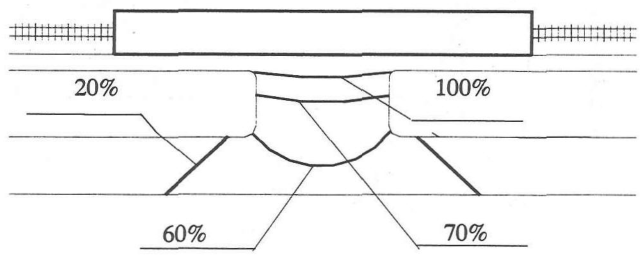
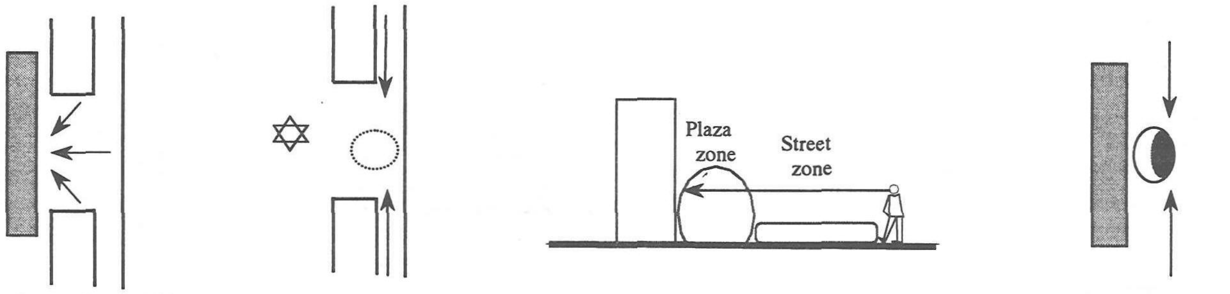


Figure 15: Distribution of contour lines for middle size stations of pattern 3



Open view within plaza limits

Station is **not-Vista**

Partial **visual exposure** to the plaza

Plaza is partial **Sign**

Figure 16: Spatial characteristics of pattern 3

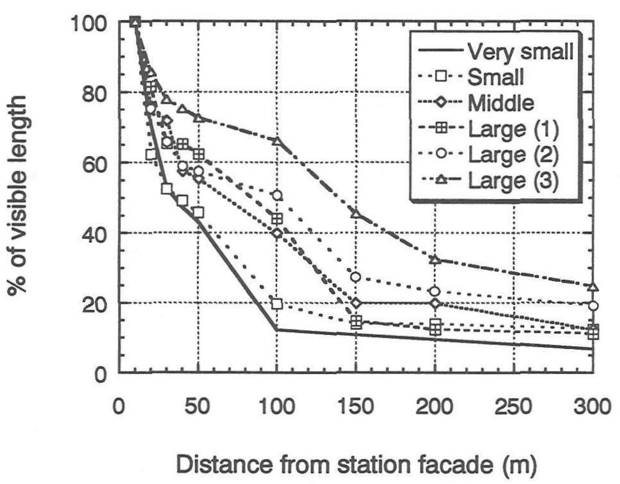


Figure 17: Distance versus percentage of visible lengt different station sizes of pattern 2

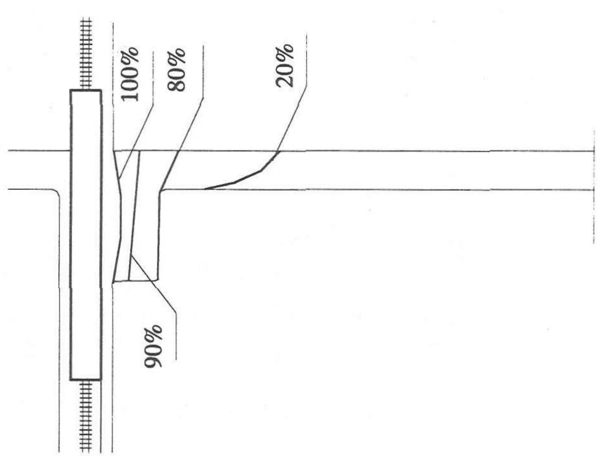
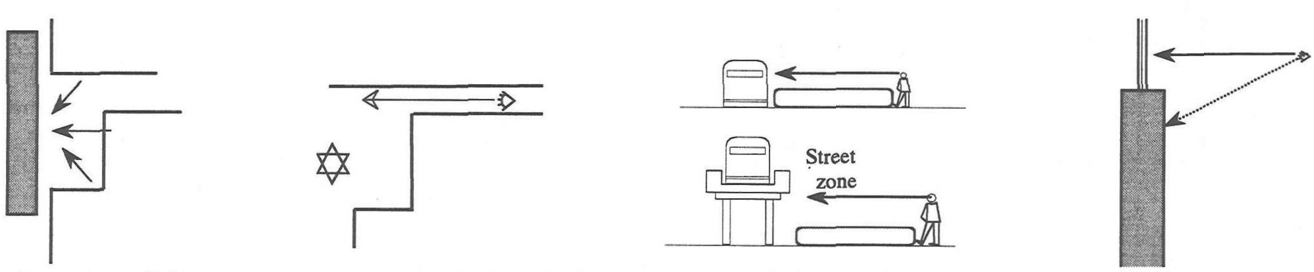


Figure 18: Distribution of contour lines for middle size stations of pattern 4



Open view within plaza limits

Station is **not- Vista**

Good **visual exposure** to rail line

Rail is **Sign**
Station is partial **Sign**

Figure 19: Spatial characteristics of pattern 4

There is a gradual decrease in the percentage of visibility as observed from the shape of contour lines for cases of middle size stations shown in Figure 9. As observed, good percentage from the station façade can be perceived up to main street level. A strong visual axe to the station building maintains good degree of visual exposure for the passengers. Accordingly; feelings of stability and ease of access are provided.

In these types of space structure, the station identifies its presence and it is "sign" for the passengers. It can be seen from Figure 11 that not only good percentage of visible length could be seen, furthermore the spatial characteristics of this type improve its degree of visual access.

b) Pattern 2: Binary link to main parallel street relationship

As shown in Figure 11-12, there is a slight decrease in the percentage of visible length out of the plaza limits. A small amount from the station frontage is perceived. Accordingly, providing appropriate width for the binary streets is very important for cases of pattern 2. As shown for cases of middle size stations, only 20% from the station can be seen at 100m far. The station is partially exposed to the passenger and becomes partial sign (Figure 13). This implies the importance of identifying the station as well as choosing appropriate location for the space elements especially the station entrance for improving the degree of visual access.

c) Pattern 3: Binary link to main orthogonal streets relationship

Less degree of visual access is generally observed for types of binary links to orthogonal street. As shown from the results (Figure 14-15), the percentage of visible length slightly decreases out of the limits of plaza. The station is almost unseen at 100-200m according to the station size. It is revealed from the distribution of contour lines out of plaza limits that it is very difficult to perceive the station or to identify its presence when approaching from the main street.

The station is not vista any more. The plaza is partially exposed to the passenger and it becomes the only sign for the station as shown in Figure 16. It can be observed that the design of plaza is very important to clarify the presence of the station. Additionally, providing landmark elements can guide the passenger and improve the degree of visual access to the station.

d) Pattern 4: Direct relationship to main street

This direct relationship to main street increases the degree of visibility within the limits of the plaza as observed in Figure 17-18. Visual exposure is maintained along the main street. This pattern is commonly observed in Tokyo central area. Usually the rail line is elevated. For the passengers coming from the main street, rail line is signaling the presence of the station location (Figure 19). This implies the importance of the station canopy design.

5. Analysis of Real Cases of Study

In the previous chapter, the analysis was applied on theoretical cases ideally designed. Due to site restrictions and different spatial characteristics, different results are expected from the analysis of real cases of study.

In order to clarify the effect of these elements the analysis was applied on a sample of cases of study. In order to provide intuitive comparison, the same process of the theoretical analysis was applied on the cases of study. First, the cases of study were categorized according to the station size following the same classification shown in table2. Secondly, in order to study the effect of the parameters, the cases were classified according to the shape of plaza and type of link to main street as have been done in the theoretical analysis.

It was observed that the location of the station has an effect on the distribution of space structure types. The distribution of space patterns location is shown in figure20. It can be seen that pattern (1) having the previously explained advantages was observed to be concentrated in the suburban areas. While cases of pattern (4) are commonly found in the central areas, which will have, an effect on the analysis results as will be explained.

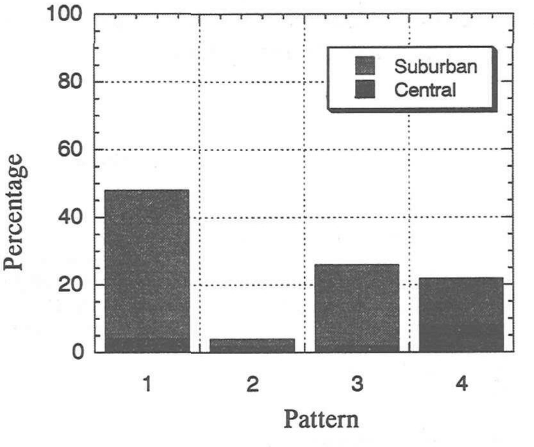


Figure 20: Distribution of space structure patterns location

(1) Pattern 1: Type of orthogonal link to main parallel street relationship

It was observed that most of the cases belong to type of large stations (25,000-50,000 P/day). As shown in Figure 20, pattern 1 was commonly observed in the suburban areas. While central area characterized with complexity and congestion lakes the advantages of simplicity and ease of access provided by this pattern.

Rectangular shape plaza (W/D>1) is the common within the cases of study as shown in Figure 21, implying the advantages of this type of shape as explained previously.

Figure 22 represents the results for cases of large stations (25,000-50,000 P/day) together with the results of theoretical cases of the same category. The obtained results were found to have low degree of visual access compared with the theoretical cases. It was observed that around 300 m far, the percentage of visible length is around 10% for all the cases. Considering the effect of space elements (landscape, poles, advertisement poles....), the station will be unseen. This is clearly observed in case of "yutenji" station having small area size of plaza compared with the design standards introduced in the theoretical analysis. It could be observed that the location of plaza has an effect on the degree of visual access as shown in the case of "Yutenji" and "Sakado", where the plaza is located at the corner of the station reduces its visibility. Another reason of the reduction in the degree of visual access can be attributed to narrow streets commonly observed in all the cases of type (1).

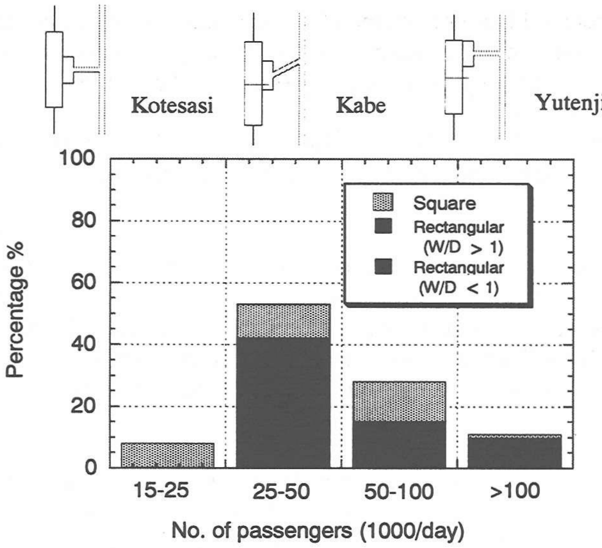


Figure 21: Relationship between No. of Passengers/day and percentage for cases of pattern 1

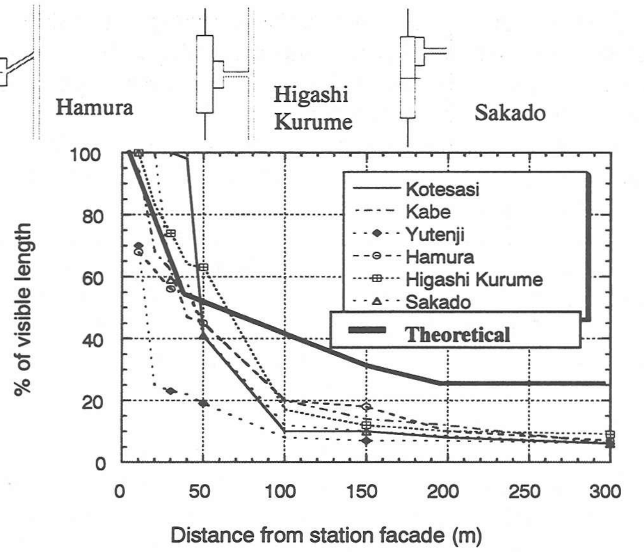


Figure 22: Distance versus percentage of visible length For large stations (25,000-50,000P/day)

(2) Pattern 2:Type of binary link to main parallel street relationship

Generally few cases were found to belong to this pattern as shown in Figure 20. The results are shown for examples from cases of large stations (over 100,000P/day) commonly found in the central area. As mentioned before in the theoretical analysis, cases of pattern (2) have a slid decrease in the degree of visibility out of the plaza limits. Also the cases of study showed lower degree of visibility than the theoretical analysis as shown in fig.24.

All the cases are having rectangular shape plaza (W/D>1) providing wide frontage from the station façade and appropriate arrangement of traffic facilities. Accordingly, good degree of visual access can be acquired within the limits of plaza; while from the street level, the visibility is completely restricted. This can be attributed to the nature of binary links and narrow streets that mainly restrict the visibility as observed in cases of type (1). Thinking about the effect of vertical elements such as surrounding buildings and street furniture especially advertisement poles characterizing Japanese streets, the station will be almost unseen from the binary links.

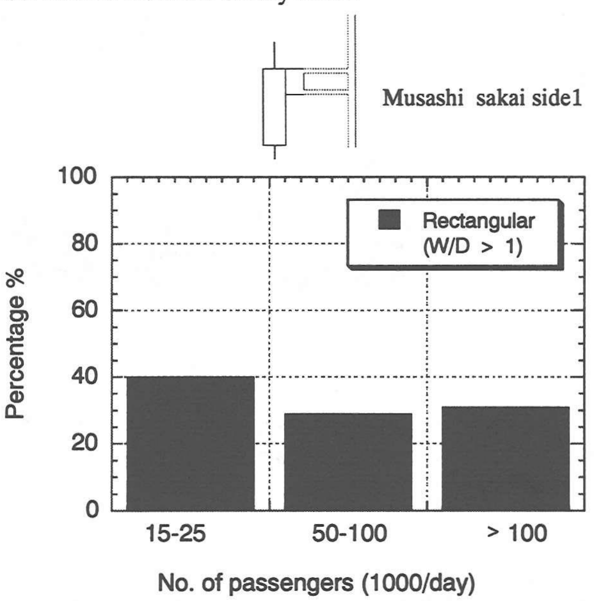


Figure 23: Relationship between No. of Passengers/day and percentage for cases of pattern 2

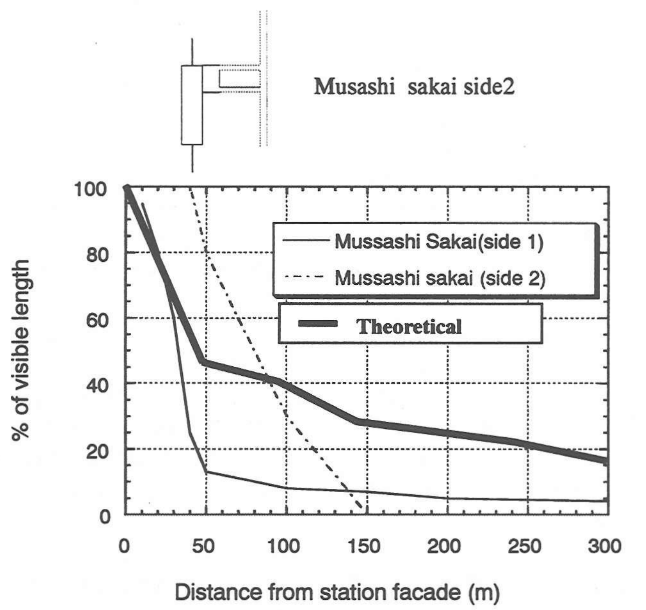


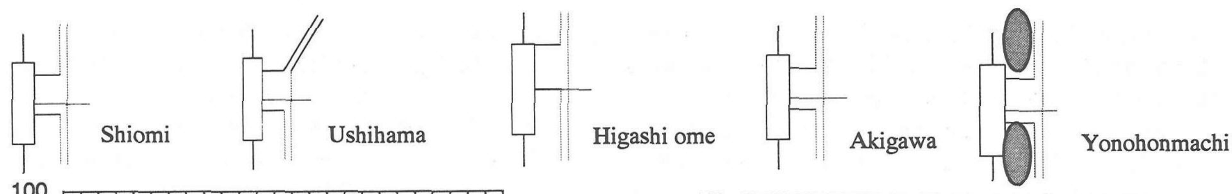
Figure 24: Distance versus percentage of visible length for large stations (>100,000P/day)

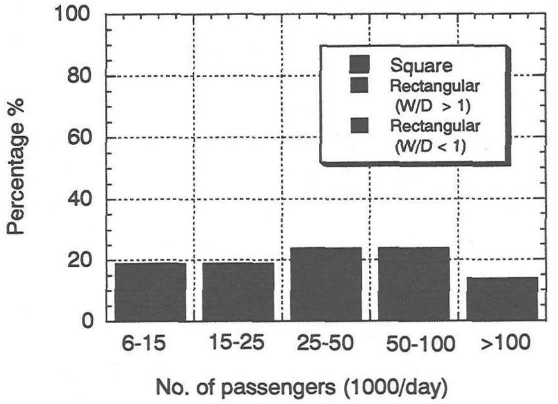
(3) Pattern 3:Type of binary link to main orthogonal streets relationship

As shown in Figure 20, cases of pattern (3) are commonly observed in the suburban areas. Site restrictions greatly affect the percentage of visible length from the station where usually the station is separated by high buildings parallel to the station. Narrow streets linking the plaza to main street decrease the degree of visual access as observed in case of "Shiomi" station.

It was revealed that the direction of link has an effect on the degree of visual access to the station. Skew links were observed to permit better degree of visual exposure as shown for case of "Ushihama" station.

Providing landscape areas parallel to the station can greatly overcome the shortcomings of pattern (3) as can be seen in case of "Yonohomachi" station. Where the passenger reaching the station can identify its presence and can locate himself directed by the landscape areas up to the station entrance. However this extremely difficult in the usual cases of limited land to build on but should be considered in case of future design or development.





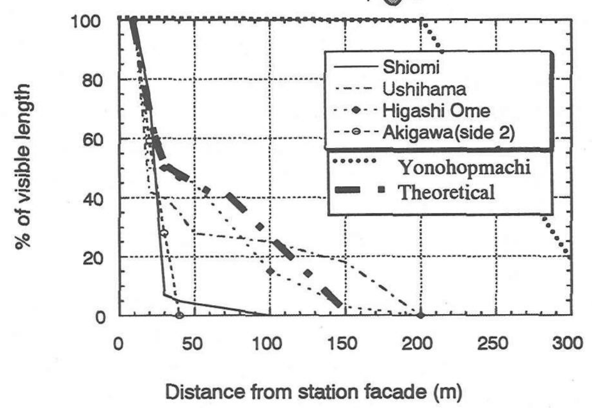


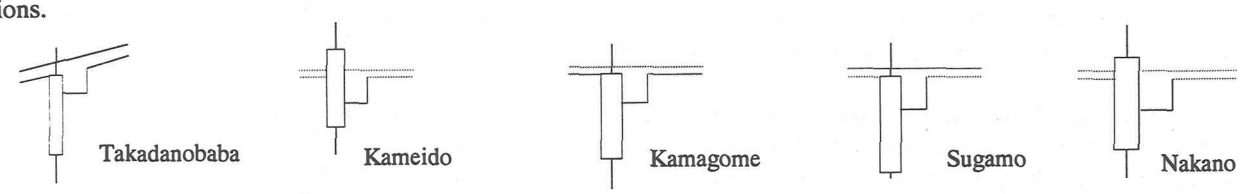
Figure 25: Relationship between No. of Passengers/day and percentage for cases of pattern 3

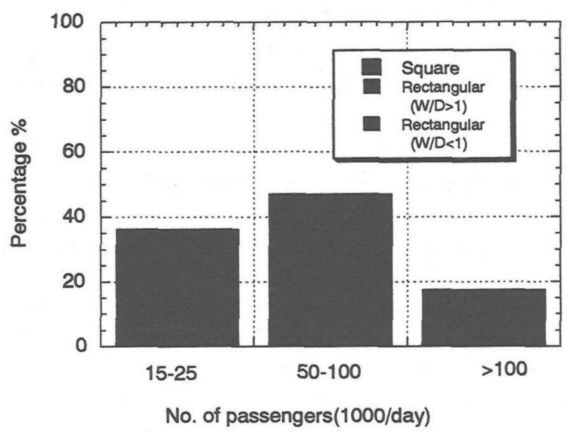
Figure 26: Distance versus percentage of visible length for small stations (6,000-15,000P/day)

(4) Pattern 4:Type of direct relationship to main street

All cases were found to belong to types of large stations and frequently found in the central areas. Figure 28 represents the results of cases of large stations (100,00 p/day). Square shape plaza is the common one (Figure 27).

In spite of the fact that almost all the cases are located at the busy central areas, low degree of visibility was found compared with the theoretical cases. It can be observed that usually the plaza is located at the station corner. As most of the types are elevated railways, rail line is clearly identified by the passenger coming from main street. Therefore giving good attention to the station canopy design can increase the degree of access to the station as well as the effect imposed from the site restrictions.





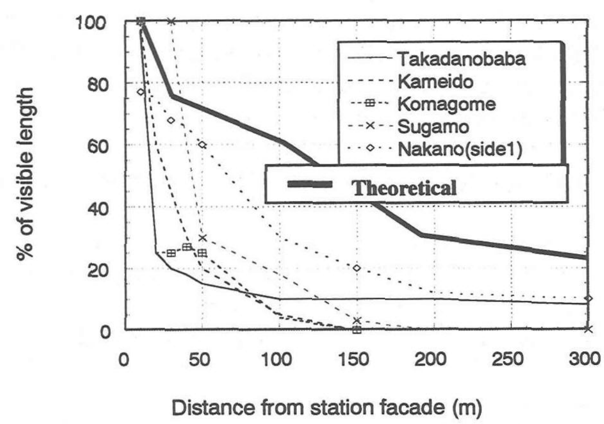


Figure 27: Relationship between No. of Passengers/day and percentage for cases of pattern 3

Figure 28: Distance versus percentage of visible length for small stations (6,000-15,000P/day)

6. Conclusions

This study focused on analyzing the visual structure of open space around railway station buildings by studying the impact of space structure patterns on the degree of visual access of the station. A typology of the space structure patterns was constructed. A geometrical analysis was applied on both theoretical cases and a sample of cases of study. Shape of plaza and type of link to main street were considered as the main parameters in the analysis.

It was revealed that the degree of visibility varies according to the shape of plaza. By increasing width/depth ratio of the plaza, larger amount from the station façade could be perceived thus increasing the visual access. Additionally, it provides good arrangement of traffic functions and different elements of plaza.

Merits and demerits of the different space structure patterns could be revealed from the analysis of the theoretical cases. It was observed that the classical patterns having plaza centered to the station building and orthogonally linked to main street provide good degree of visual access. Station is vista for passengers and a strong visual axe is maintained up to the main street level. On the contrary, patterns with binary links were found to decrease the degree of visual access out of the limits of plaza. This implies the importance of providing appropriate width for the streets as well as identifying the station presence.

The effect of site restrictions and current problems characterizing outdoor spaces could be clarified from the analysis of cases of study. All the cases were found to provide low degree of visual access compared with the results of theoretical analysis. It was observed that the gape between the theoretical analysis results and those of the cases of study could be attributed to several factors. The central areas lack the advantages of simple patterns, which were commonly found in the suburban areas facing small size stations. Streets linking the station to its surroundings found to be very narrow compared with the design standards. Generally, no harmony between the station size and the plaza area size was observed in several cases. Thus reducing the degree of visual access. Additionally, It was revealed that the location of plaza affects the degree of visibility where plazas located at the station corner decreases the portion of vision provided from the station especially in cases of pattern 1. Direction of link to main street was found to affect the percentage of visible length from the station. Where skew link was observed to maintain better degree of visual exposure especially for cases of pattern 3 (plaza is binary linked to the orthogonal street).

The effect of other space elements rather than the shape of plaza and type of link should be discussed in further study in order to clarify the dominant factors. Additionally, the expression of visual access was limited to the percentage of visible length from the station concerning the extremities of horizontal angle of view. Further studies are required to estimate the effect of space elements individually as well as vertical elements. Then, the combined effect of all parameters on the degree of visual access to the station could be discussed.

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Visual Geometrical Analysis of Outdoor Space Structure around Railway Station Buildings*

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The purpose of this study is to clarify the effect of space structure patterns around railway station buildings on the degree of visual access of the stations. A typology of open space structure patterns could be constructed based on analyzing different cases of study around the Tokyo metropolitan area. A geometrical analysis was applied on both theoretical analysis and a sample of real cases. The study focused on studying the effect of shape of plaza and type of link to main street. Merits and demerits of the different space structure patterns and the effect of size restrictions were clarified.

The results indicated that increasing the W/D ratio of the plaza increase the degree of visual access to the station. Stations with plaza orthogonally linked to main street were found to provide good degree of visual access. On the contrary, stations with plaza binary linked to main street were found to restrict the degree of visual accessibility. Additionally, the effect of factors such as location of plaza and direction of link were shown to affect the degree of visual accessibility.

Abstract (in Japanese) 鉄道駅周辺の空間構成に関する視覚的解析*

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本研究の目的は鉄道駅舎周辺における空間構造パターンが駅への視覚的アクセスに及ぼす影響を明らかにすることである。まず東京の鉄道駅を対象としたケーススタディをもとに広場のタイプ分析が行われた。視覚的構造の解析は、調査対象となった実際の駅周辺空間と、交通需要予測に基づいて仮定された広場について実施された。解析においては広場のスケールや形態、街路との接合形態の要因を重視した。結果として広場の W/D が増加すると視覚的アクセシビリティも増加すること、街路が正面から広場にアクセスする形態は視覚的アクセシビリティが高く、２本並行してアクセスするタイプは逆に低いことなどが判明した。