A Study on the Pedestrian Space applying Space Syntax and the Segment Unit

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Abstract
We studied an urban area surrounding railway stations in Kashii, a sub-center located in Fukuoka City, Japan. Applying the concepts of Space Syntax Theory we clarified the macro-spatial characteristics of the urban space. Convex and axial maps were constructed and analyzed to forecast the general functioning of land use and pedestrian volume.

The analysis of the attributes of the pedestrian space was conducted using the segment unit, a tool that we defined as each one of the fragments located between the nodes in which the pedestrian network is divided. We also clarified the relationship between three-dimensional building use and pedestrian volumes. Conducting a cluster analysis on pedestrian space with the segment unit, we found six different segment types. From the evaluation of all these factors, we deduced that it is necessary to control building use to improve the quality of pedestrian space and the activities in its area.

Keywords: The pedestrian space; Railway stations; Space Syntax; Segment unit; Pedestrian volume

Introduction
Japanese cities have grown up around roads and railways radiating from transport facilities where the major business activities are concentrated. Fukuoka is one of the major cities located in the Western part of Japan. In this city, railway stations, except for those with established areas as in Hakata Station or Tenjin Bus Center, have developed along roads, often on a narrow network of streets, saturating with their activities the surrounding areas. A common case of this kind of built environment is located in the neighborhood of Kashii in Higashi Ward; a district positioned as a newly developed city center. Here, two railway stations located less than 250 meters apart serve the area: An interchange, Kashii JR Station and Nishitetsu Kashii Station. Feeder buses deliver and collect passengers from five stops within walking distance from both stations. Also, bicycles are commonly used as transportation from home to stations or for shopping; therefore, some sidewalks are congested with bikes.

Kashii is a compact mixed-use center with shops, offices, markets, leisure facilities and residential developments. In a sector in constant movement, it is not only the people who pass through the area who change throughout the day, the elements that support activities also are arranged differently according to local components, producing specific mobility patterns and space requirements. In Kashii, while walking from the available transport facilities to the different destinations or vice versa, it is easy to observe how along the blocks, the existing building activities consume public space. Thus, producing complex spatial configurations when overlapping with other functions like walking, standing or riding a bicycle. The problem in Kashii lies in the shortage of road space and other open public areas and how it can be improved to the best advantage of users.

In some areas the streetscape has varied positively due to the development of structures providing front setbacks, e.g., buildings for activities with high demand of space for bicycle parking where the front setback supplies this requirement, or the case of buildings where the open space is the result of mandatory regulations. However, these semi-public areas had been thought of as extensions of private space and therefore used only for private benefit. For these city sectors it is necessary to gain additional open areas according to their specific demands. To conduct the study we selected the functional center of Kashii; a dense area limited by the

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JR Station railway to the east, National Road Route 3 to the west, the River Hamao to the north and River Kashii to the south (see Fig. 1).

Objectives
The general objective of this research is to clarify the spatial patterns affecting the physical environment of the pedestrian space in the area surrounding Kashii stations and the relationship between these conditions and pedestrian flows. We evaluated the relationship between pedestrian movements and the elements located on the network of pavements. At this stage, the subject of investigation is focused on the clarification of macrospatial characteristics. Further research will focus on defining the principles for a planning guideline for the pedestrian space based on the building use and a scale control technique.

Generally speaking, the area of study has an urban structure with a network of railways and routes for traffic going from south to north and other streets, paths, passages and alleys interconnecting the system from east to west. This shows the urban structure consisting of an irregular pattern. The main street connects JR Kashii Station with the National Route located on the west, while local streets connect Nishitetsu Kashii Station with the system.

In Kashii, streets without sidewalks prevail. The main street connecting JR Kashii Station and the National Road have sidewalks separated from the thoroughfare by small tree wells and some planters, whereas on the rest of the area the sidewalks are almost nonexistent. Most of the buildings have a minimum of two stories and a maximum of five, but there are few buildings with different story heights. In Kashii Center there are sufficient shops and markets to supply the ordinary needs of households. Composition of the dwellers varies considerably as well as the building types where they live. In Kashii, students and workers, housewives and children can be observed frequently. Even though the area has many of the conditions required to provide a range of ordinary human needs, there is a shortage of open spaces such as plazas, squares or green areas for leisure, especially around the areas of greatest activity.

Method of the study
To conduct the research, we interacted the technical tools for spatial modeling with investigation of the physical
characteristics. For the construction of a computer model of Kashii Center, we used the Spaces Syntax Theory; a method designed "to describe and analyze patterns of architectural space-both at the building and urban level!". Through this system we evaluated the open space composition, space form and movement patterns. Convex and axial maps of Kashii Center were constructed initially as follows:

The convex map was used to describe the spatial characteristics of the urban area in a structured and quantitative way. Following the procedure, a total of 202 convex spaces were defined and 493 entrances to buildings were marked on the map (see Fig. 2).

To evaluate the way in which space influenced movement, an axial map of Kashii Center was constructed, indexing a total of 99 axial lines starting with the longest until all axial lines were linked. The convex spaces crossed and the numerical values assigned to each line are shown (see Fig. 3). Global integration was evaluated on the respective map to clarify the relationship of each space with respect to others and to the whole system.

In addition, using the values of the global integration analysis; a correlation evaluation was carried out comparing its characteristics with the pedestrian volumes at different times of the day.

For the physical evaluation, a survey on the area was carried out in May 2001. Through fieldwork, three-dimensional building use data was collected on 29 blocks comprising the zone. To clarify activity fluctuation within the area, pedestrian counts on diverse street segments were conducted simultaneously with the counts of the elements located on the network of pavements and sidewalks during a period of 12 hours (7:00 a.m. to 7:00 p.m.) on one weekday.

To facilitate the analysis, we categorized the three-dimensional building use and the volumes of the elements located on the network of pavements and sidewalks. A new tool was also introduced for the analysis: the segment unit, that we defined as each of the fragments located between the nodes in which the pedestrian network is divided. Each segment unit has distinct technical implications that were clarified by first, the quantification and evaluation of the three-dimensional building use data then, cluster patterns of the elements located on the pavements and sidewalks and pedestrian volumes of each segment unit (see Tables 1, 2).

**Syntactic analysis of Kashii Center**

Some of the syntactic properties of the structure can be described initially in an empirical way with the information provided on the visual representation. The thicker lines on the map represent the most integrated spaces. In this case, few movements are required to go from one space to another. Conversely, the thinner lines link the spaces segregated from the center (see Fig. 4). To deepen the analysis, some numerical concepts of the syntactic analysis were applied. The measure of integration or relative asymmetry can be calculated to...
evaluate the space which tends to integrate the system and vise versa. The legend on the integration map shows a ranking from 0.55 to 1.57 where the lines indicating the most integrated values go from 1.37 to 1.44. The location of these values coincided with the area comprising Kashii Center and the streets connecting the core to the outer areas.

From the global integration map, some patterns were deduced. The pattern of the space: which shows how Kashii Center has an integrated core forming a tree-like pattern linking the main street to the outside but at the same time, leaves two zones with poor accessibility on either sides of the core. In addition, the adjacent roads connect evenly to the main street but, interconnect with difficulty within the surrounding area impeding smooth circulation. As shown until now, Space Syntax analysis had been carried out constructing and analysing maps. With these tools, research had also been conducted in other areas of the world. In the same way, this technique can be implemented in Asian cities using mainly cartographic information. It can be said, that this is a very useful analytical tool to be used for research in Asian countries.

The pattern of land use: which shows how the most integrated spaces correspond to those places where the major commercial activity is located. The structure of both patterns, the one of space and that of the land use, present the same organization. The quiet residential areas are located far away from the center forming clusters in the most segregated areas and also have problem regarding accessibility.

The correlation efficient table shows the pedestrian volumes during 12 hours correlated against the values of the global integration map (see Table. 3). The result indicated a fluctuation between 0.37 and 0.74, with the lowest correlation at 7:00 a.m. and the highest at 6:00 p.m.

This result can also be explained based on the activity of the area. In the morning, pedestrians are generally students and employees accessing the shortest road they can find to the different transport facilities. The situation is different after 10 a.m. when inhabitants and visitors come from other areas and stay longer while carrying out a variety of activities. Based on this data, it can be said that the results of the correlation and the integration maps are strongly related.
The map of the axial integration plus large convex*3 shows all the large convex spaces with over 400 meters² (see Fig. 4). The ranking of the legend goes from 0.55 to 1.57. The lowest values correspond to the axial lines crossing the major areas located far from the core and with few activities. Conversely, the high values correspond to axial lines crossing convex spaces with a narrow linear form, and these are also the areas with high urban activity.

Convex control from entrance ranked from 0 to 27 on the map. This concept refers to the degree to which the convex system of Kashii Center is controlled from the buildings*4 (see Fig. 8). There are at least two marked tendencies depending on the street. The convex spaces with strong control have the major number of entrances and activity is positively related. Another pattern found in Kashii corresponds to the aggregation of the convex spaces with few entrances that constitutes a negative factor in terms of control. In both cases, the spatial patterns are inverted negatively since active areas require a generous convex space to promote leisure. At the same time, a convex space with few entrances requires smaller areas to facilitate control.

Analysis of segment types in terms of the elements located on pedestrian space.
To carry out the analysis, we used the segment unit (three-dimensional building use data, cluster patterns of the elements located on the pavements and sidewalks and pedestrian volumes). In addition to this, we used the schedule with the major incidence on pedestrian space based on the correlation evaluation, which in this case was at 6:00 p.m.. We then divided the elements into six categories: I. Transportation; II. Display; III. Utility; IV. Obstacle; V. Private equipment; and VI. Public equipment.

Initially, we compared the volume of elements data collected in the physical investigation. At 7:00 a.m. we found a total of 1,851 and at 6:00 p.m. 2,828 elements in total (see Table 4). Categories I, II and VI, showed the highest volumes at 6:00 p.m. Categories I and VI; these two groups with a very negative effect on the pedestrian space displayed the highest volume of elements at 6:00 p.m.

We also divided the segment unit into six types based on a cluster analysis to quantify the element’s average per building at 6:00 p.m. (see Table 5). The characteristics of the segments are as follows:
Type A: Conformed by the segments with the least elements. This group had a total of 51 segments and their location corresponded to the places far away from the core including residential use.
Type B: A segment with a favorable pattern included an important number of displays.
Type: C and D, the transportation and obstacle segment types constituted a negative pattern.

According to the segment types distribution map, all segments of the main street (Sepia Street) are B, C and D, whereas the distribution of both sides of the street showed a pattern with specific characteristics. Type B located on the south of the street covered almost the whole area of the pedestrian space. Segment types C and D, two patterns requiring control were located on the north (see Fig.10). We also observed type C pattern close to JR Kashii station and some residential areas where the streets are narrow and control is very low.

Type E and type F, comprised of unique characteristics.

Table 6. Three-dimensional building use according to segment type

| Segment Type | Number of Segments | three-dimensional building use counts and rate | Buildings total |
|--------------|--------------------|---------------------------------------------|-----------------|
| A            | 51                 | Counts Rate 300 11 56 44 68 67 94 16 78 65 | Total 799 334   |
| B            | 12                 | Counts Rate 50 1 21 30 34 19 44 12 29 13 | Total 253 47    |
| C            | 15                 | Counts Rate 63 2 21 12 36 21 50 6 29 19 | Total 259 74    |
| D            | 11                 | Counts Rate 39 4 2 7 0 0 13 22 25 40 | Total 177 49    |
| E            | 11                 | Counts Rate 51 0 0 0 0 0 3 0 21 2 | Total 1 100     |
| F            | 15                 | Counts Rate 0 0 0 0 0 0 0 2 0 2 | Total 1 100     |
| Total        | 91                 | Counts Rate 463 18 105 86 154 129 215 42 179 121 | Total 1,512 509 |

Fig. 11. Pedestrian volumes in four segment types

Type E pattern corresponded to the area in front of JR Kashii Station, an area where many bicycles were found. Type F: the public equipment pattern with only one segment and a high average of elements. This segment corresponded to a semi-public circulation with many trees.

Three-dimensional building use and segment unit analysis

The three-dimensional building use differed depending on the segment type (see Table 6).
Type A: Housing, Type B: stores, services and bars, Type C: stores and services, Type D: offices, daily shops and others.

From this evaluation we deduced that building land use and segment types are strongly correlated. From this information, it can be said that if building use is controlled the elements on the pedestrian space diminish and its negative influences can also be supervised.

Connection of segment types and pedestrian volume

We related segment types and pedestrian volumes and found that pedestrian volumes from 60 to 150 and segment type B ranked as a favorable condition on the pedestrian space, both being strongly related.

Places containing these two factors are favorable for walking. Conversely, type C was negatively related, these areas require special treatment (see Fig.11).

In this sector of the city, it is necessary to control
building use and to regulate the elements on the pedestrian space. With these measures it can be possible to facilitate the creation of a high quality pedestrian space and to improve the activities in the area.

Conclusion

We studied an urban area surrounding railway stations in the Kashii sub-center, located in Fukuoka City, Japan. Applying the concepts of the Space Syntax Theory, it was possible to clarify the macro-spatial characteristics of the urban space. In addition, an analysis of the attributes of the pedestrian space was conducted for this purpose using the segment unit; a tool defined as each one of the fragments located between the nodes in which the pedestrian network is divided. Clarification of the relationship between three-dimensional building use and the pedestrian volumes in order to define the way in which the problem of the pedestrian space could be approached positively.

With the application of the concepts of the Space Syntax Theory on the structure of Kashii Center, we were able to define the macro-spatial characteristics using only cartographic information. After evaluating the convex and axial maps, it was possible to forecast the general functioning of land use and pedestrian volumes.

Conducting a cluster analysis on pedestrian space according to the segment unit, we clarified six different segment types.

We also found that there is a tendency to connect segment types. This situation is caused not only by the location of the segment but also by the influence that the segments exert on each other. From all of these factors, it can be said that it is necessary to control building use in order to improve the quality of the pedestrian space and the activities of its areas. Overall, we can conclude that it is necessary to integrate pedestrian flows and building use.

Notes

*1 Hillier (1993), p.49

*2 Reference Hillier (1984), p.108, The measure of integration, “To calculate relative asymmetry from any point, work out the mean depth on the system from the space by assigning a depth value to each space according to how many spaces it is away from the original space, summing these values and dividing by the number of spaces in the system less one (the original space). Then calculate relative asymmetry as follows: Relative asymmetry- 2(MD-1)/k-2 where MD is the mean depth and k the number of spaces in the system. This will give a value between 0 and 1,…”

*3 Reference Hillier (1984), pp.120-121, “… if we extract from the map all the interior spaces with marked convex extension and experimentally overlay these on various maps, we find that by far the best fit is with the high integration (RA-) high control (E+)”

“(b) the strongest difference between the high integration and high control maps lies in the number of vertical lines that have high integration (RA--) but low control (E--).”

*4 Reference Hillier (1984), p.115, The system seen from X, “A high RRA from X- and certainly a value over 1-will index the degree to which buildings are to be found in groups segregated from each other…”

References

1) Hillier, B. and Hanson, J. (1984) The Social Logic of Space. Cambridge University Press.
2) Hillier, B. (1998) The Common Language of Space. http://www.spacesyntax.com/publications/commonlang.html
3) Klarqvist, B. (1993) A Space Syntax Glossary http://www.arch.chalmers.se/tema/stadshygnad/glossary.pdf
4) Hillier, B. et al. (1993) Space Syntax. A Different Urban Perspective. Architectural Journal, 30, 47-63.
5) Kita, A. et al. (1997) Influence of Railway Station and Shopping Center Entrance Locations on Generation of Community Facilities Around Shopping Center. Journal of Architecture, Planning and Environmental Engineering, AIJ, No.495, 101-107.
6) Lee, M. et al. (1995) On Predicting Generation of Community Facilities Around Railway Station. Journal of Architecture, Planning and Environmental Engineering, AIJ, No.477, 71-79.