

Configurational exploration of pedestrian and cyclist movements: A case study of Hangzhou, China

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Abstract:

This research organized a systematic survey on both pedestrian and cyclist movements in Hangzhou, to test whether the strong correlation between spatial configuration and movement discovered in western countries is also valid in a Chinese city with different urban morphology and social/culture conditions. Both axial model and angular segment model are adopted. A statistical analysis then shows that angular segment model provides stronger explanation for the movements than axial model. Configurational variables are well correlated with cyclist movement, while R² value drops significantly with pedestrian volumes. To understand the movement flow which cannot be interpreted by spatial model, three reasons are deduced. First, the gated community management culture in China brings difficulty in constructing an accurate axial map. Second, due to the water channels across the site and abundant crossing points with level changes, there is a significant difference between accessibility graph and visibility graph. Finally, the hierarchy street system made the wide road not only a spatial connector but also a line with severance effect. Standard axial map cannot represent this feature and on the other hand how to deal with different resolutions of axial lines in one model has not been properly discussed. It is believed that these problems are common issues need further discussion.

Keywords: *Pedestrian, cyclist, movement, configuration, Hangzhou.*

1. Introduction

Space syntax has always argued that the geometrical and topological structure of street network is the most powerful shaper of urban movement patterns (Hillier et al. 1993). This “natural movement” concept serves as a solid foundation for the later concepts such as movement economy, and centrality process, etc. And it has been verified many times by case studies carried out in various cities all over the world after the first case studies conducted in London.

In China, space syntax theory has been applied to many urban planning

researches to explore the relationship between land use pattern and spatial configuration, and has facilitated many planning decision making process (Duan et al. 2007, Ye & van Nes. 2013) However, the number of empirical studies developed on the natural movement concept in China is much less than applied studies. In fact, both the morphological pattern and social/culture background in Chinese settlements are quite different from the west. It could be suspicious if apply the proposed “movement in the urban grid is, all other things being equal, generated by the configuration of grid itself” (Hillier 1997) theory directly without empirical case studies being developed locally.

A literature review shows that only four Chinese case studies which collected pedestrian movement data and conducted statistic analysis between configuration variables and movement have been published (Table 1). Among all, two studies took place in towns, one in village, and one in city. Compared to the result of case studies in London, where 60% of pedestrian movement flows are due to the pattern of the street network itself (Hillier and Iida 2005; Hillier 2005; Penn et al. 1998), the performance of Chinese syntactic spatial models is relatively weak. The Lijiang study and Tongli study has not shown the R-square value for aggregated movement, but has shown when the tourist’s volume separated from the locals’. The result from Nanjing’s study is positive. However the experiment only adopted small behavior sample size. Only two time periods, with two minutes per round were observed. These four case studies only test the configuration variables derived from an axial analysis, but not from an angular segment model.

Table 1. R-square values for correlations between pedestrian flows and configuration variables in four Chinese Case studies.

Case study	Spatial model	Settlement Size	Movement sample	Mean Movement per gate per hour	Highest R-square values	Author
1. Lijiang Town	Axial only	2438 axial lines	231 gates	391	Tourist: 0.59 (Integration) local : 0.18 (Integration)	WANG et al. 2012
2. Wangkou Village	Axial only	114 axial lines	45 gates	51	0.48 (Integration)/ 0.609 (choice)	Wang 2009
3. Tongli Town	Axial only	404 axial lines	55 gates	Not available	Tourist: 0.50 (Integration) local : 0.2 (Integration)	Chen et al. 2012
4. Part of Nanjing City	Axial only	Not available	Not available	Not available	0.68	Shao 2010

This research took the northern part of downtown area in Hangzhou as a case study, with an approximate size of 2 kilometer by 3 kilometer. This site presents distinctive morphology and social /culture conditions such as the densely distributed river channels and gated community management culture, which are different from cities in western countries. These factors might lead to new problems to our spatial modeling. This study was conducted in four steps. First, a behavior observation was organized by the “gate count” method. As many cyclists were also observed on the streets previously, cyclist numbers was also recorded. The movement data was collected for six periods in a weekend day during Mar, 2012 at 71 gates. Second, spatial models were constructed. Based on the aerial photos and field survey, both traditional axial map and angular segment map were drawn and analyzed. The configurational

variables calculated from these two models converted from the maps were then used in the following statistic analysis stage. During the operational process, it was found that the transformation of an axial map to an angular segment map was not a straight forward step. The difficulties and solution will be further described in section 3, where the author suggests a new practical method to draw axial map. Third, a statistical correlation analysis was conducted among different movement flows and various configuration variables developed from spatial analysis. Overall speaking, the measures from angular segment model performed better than the measures from axial model, and the cyclist movement was explained better than the pedestrian movement. These findings lead to the final part of this paper. How shall we understand the movement flow which spatial model is not able to interpret, where we refer it to the “unexplained” movement in the paper? The author proposed three reasons to this question and future studies are needed to support these hypotheses.

2. Movement data collection and analysis

A systematic movement data collection was conducted in a weekend of March, 2012. The sampling was taken for 10 minutes in every two hours from 7 am to 7 pm at 71 gates. With eight observation teams, each gate collected an hour movement flow in total. In the recording sheet, we designed several categories. By gate count method, we first recognized the travel type. If it was by bicycle, we only recorded the number of riders on each bicycle. If it was on foot, we then record the age, gender information of the person by filling in a specific column on the recording sheet. There were four categories in the age feature: child under 8 years old, teenage between 9 to 18 years old, adult between 19 to 60 years old and elderly more than 60 years old. Besides age, gender information was also recorded except the children below 8 years old. As the data was collected during a short period of visual inspection, the pedestrian data could only be presented in categories and the cyclists' age and gender information was not able to record due to their swift movement.

In the pre-survey, we recognized the presence of many wide roads within this site, where it is difficult to observe movements in both sides of pedestrian/cyclist lanes at the same time. For these locations, we assigned a pair of gates observer on each side of one wide road. Afterwards, the data collected from the twin gates was combined, by which the behavioral data could correspond

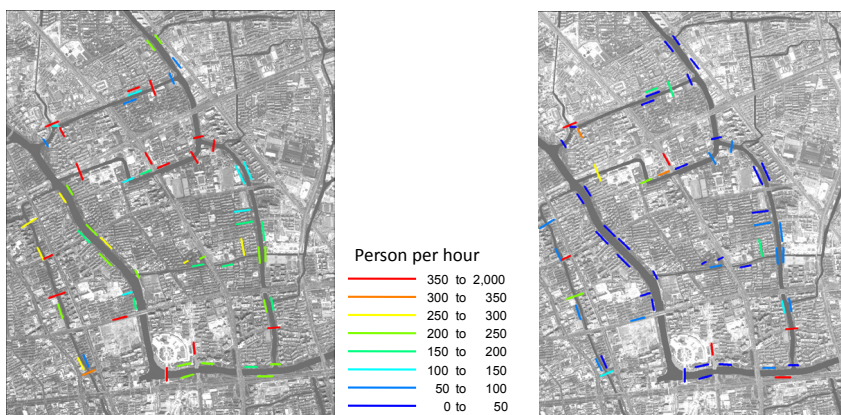


Figure 1. Pedestrian flow distribution (left)/ cyclist flow distribution (right).

with the low resolution axial/segment model. The final number of gate was adjusted from 71 to 63. After inserting all the movement recording data into excel, the originally results were reviewed by gates and it was found that three gates appeared error. These data were eliminated after an enquiry with the observers. Finally, the clean set of data

consisted of a total number of 18500 pedestrians and 8429 cyclists.

Using the same colour rage to illustrate, the spatial distribution of pedestrian movement and cyclist movement shows significant colour difference (Figure 1). A further statistic analysis also shows these two movements weakly correlate with each other (R-square value of 0.14).

To understand why the two movement flows show different distribution, the author examined each gates accordingly to figure out why popular pedestrian routes are unpopular to bicycle, and vice versa. Two possible reasons are proposed. First, the conditions of the routes for two types of movement are different. Although most of the streets are both available for pedestrian and cyclist, there are many routes along the river which have many steps or level changes which make the cyclist hesitate to use the path. The second reason is inspired by the perspective of space syntax theory. As pedestrians and cyclist have different trip distance, they may follow different spatial logic. More precisely speaking, they may follow different radius of configurational variables in the space syntax model. We will test the second hypothesis in section 4.

3. Syntactic models and a discussion of angular segment map

Since the paper of Hillier and lida in 2005(Hillier and lida 2005), angular segment model has gradually showed its stronger ability in describing the spatial structure of urban settlements. Therefore, both traditional axial model and angular segment model were constructed for this case study. The configuration measures from both models will be compared according to their capability to explain the movement flows.

To eliminate 'edge effect', the spatial model extends a buffer zone to about 2-3 kilometers (more than 30 minutes walk) outside of the area where observation was conducted. The boundary of the spatial model was decided cautiously. It was surrounded by an elevated highway in the north, a main road and railway in the east, a main road in the west, and a main road by hills and, lake in the south (see Figure 2).

In the process of drawing the axial map, many technological problems were encountered. The obstacles included how to decide the boundary of public domain while many semi-public

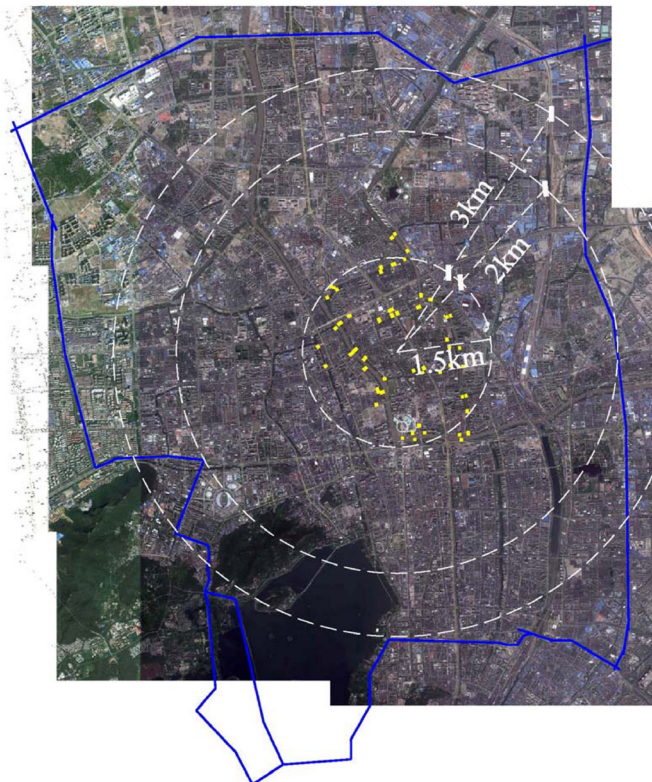


Figure 2. Boundary of the spatial model.

paths were used by the locals; how to represent the level changes between streets and riverside and how to represent the severance effect of major road. These obstacles will be addressed in section 5, where we discover that these technology problems may transform into theoretical problems.

The final axial map generated was composed of 2004 axial lines. A segment based spatial model was then being created based upon this axial map. However, there is little discussion on how the map being converted. Although it has been recorded in the depthmap software introduction manual (Pinelo and Turner 2010) that a command could convert axial map to segment map automatically and the user could simply choose what percentage of line length an axial stub would like to remove, it seems that to make a proper segment model is not such a simple process.

In Figure 3, we found that segment model converted directly from axial model contained “trivial triangles” which is meaningless. If these triangles did not get removed from the segment model, it would double count the total number of segments in the model. In addition, these triangular forms sometimes created strange red spots which reduced the model’s accuracy. To get rid of these trivial triangles, not only it would take a lot of effort to adjust the file, the line of axial model and segment model would be slightly mismatched and might cause problem for further comparison in GIS platform. This problem has not been properly discussed by space syntax community yet.

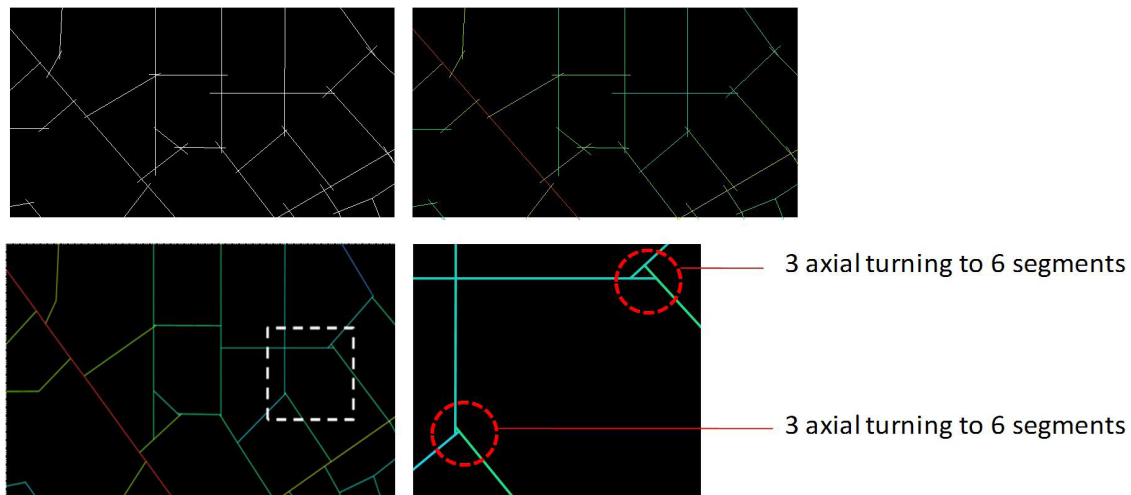


Figure 3. The trivial triangular problem.

The origin of the trivial triangular problem is due to the standard drawing method of axial map always slightly overlap the axial lines whenever they intersect. We have not found a formal description of this drawing method, but have found a sentence which uncovers the benefit of this drawing method. *“Back a ruler against the building line of the facades which define a long line of sight and access and move it about until the ruler strikes the facades on the opposite side of the street. Maximise the length of this line”*(Vaughan 1997). In fact, the advantage of extending the lines slightly from the intersection point is to adjust the line to the maximum length when draw an axial map manually. In addition, it guarantees the lines are properly intersected.

However, this benefit has turned into problem for the new segment map. In

this paper, **the authors would like to propose a new method to construct a segment map manually.** We still consider the axial map as the first step of drawing segment map, but with a small twist. After we finished the longest lines, the “snap” function in Autocad software would be activated when drawing the shorter ones. Whenever there were more than 2 lines intersecting which each other, we snapped the end points of them to get rid of the trivial triangular. The remaining steps were the same. Instead of correcting the trivial triangular in the end, we avoided them at the beginning in this method.

By this method, the author modified the axial map and processed it in depthmap 1014. A bug of the software was found as shown in Figure 4a. We found 4 lines in the colour blue, which indicated their connectivity is “1”, which was obviously wrong considered the real structure of the model. The depthmapX 0.26b gave the same result. The authors recalled a conversation with Dr. Haofeng Wang and re-tested the same axial map by “depthmap beta 1.0” developed by Shenzhen University’s team lead by Dr. Wang. The result is shown in figure 6b. It was found the previous 4 blue lines have turned into red or yellow color which indicated their real connectivity value was more than 2 connections. “Depthmap beta 1.0” had fixed the bug which “depthmap could not recognize adjacent line intersections”. Based on this result, the following paper will continue to use this software for calculations. A segment map was then constructed in the size of 4150 segments in total.

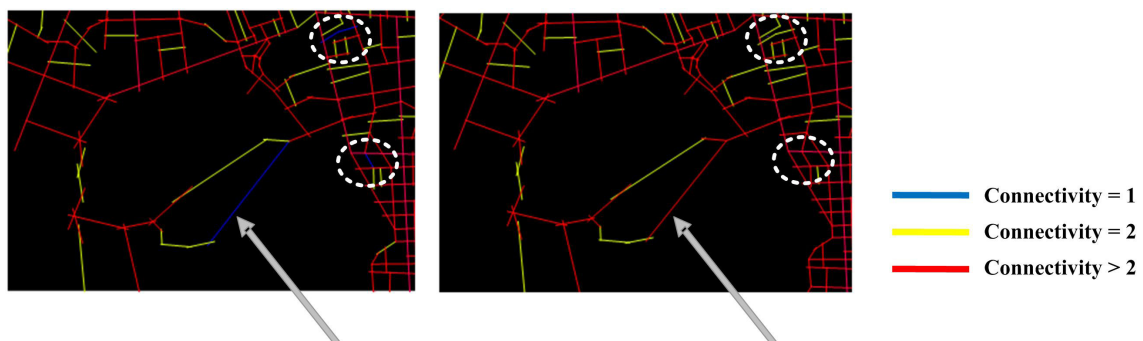


Figure 4a. The outcome of connectivity measure by depthmap 1014 (left).

Figure 4b. The outcome of connectivity measure by depthmap beta 1.0 (right).

4. Statistical Analysis

In the introduction section, we have reviewed four Chinese case studies which produce the correlation between pedestrian movement flow and configuration variables. These Chinese case studies were conducted in cities primarily with medium or small size of human settlement, except one case study which was done in Nanjing city. However, the sample size of the movement data collected in that case study was relatively small. This research collected a relatively big data set of both pedestrian and vehicle movement, which allows us to develop better understanding on three areas. First, whether the configuration measure could give a good explanation for movement flow in a settlement with distinctive urban morphology and social/culture background different from the west. Second, whether the configuration measures calculated by angular segment model is stronger than the ones produced by axial model in terms of explaining the movement. Third, this study has improved our understanding of the cyclist behavior pattern associated with spatial variables as there are only

a few space syntax case studies on the cyclist behavior currently available. The R-square values among spatial variables and movements were calculated in whole range of radiuses in these two models.

In the primary analysis, two gates (D4/D5) showed strange performance as they were located on the ramps connected to the elevated roadway with pedestrian path along the Great Canal on both sides. Whether to represent the ramps in a simplified way or to retain its real form is debatable. To make it more simplified the authors decided to remove the two gates from the data set. Afterwards, this research was conducted based on the new dataset with 61 gates, including the observed 18325 pedestrians and 6276 cyclists.

The results are shown below. In terms of pedestrian flow, axial model shows the highest R-square value of 0.28 (with R3) while angular segment model shows a higher correlation of **0.43** (with Choice Radius 1600m, $p < 0.0001$). In terms of cyclist flow, axial model shows the highest R-square value of **0.77** (with Choice N, $p < 0.0001$) but angular segment model only shows a

correlation of **0.67** (with Choice N, $p < 0.0001$) (Table 2). The normalized choice (Hillier, Yang et al. 2012) variables have also been tested, but the correlation is lower than the standard choice (highest R-square for Pedestrian is 0.37; highest R-square for Cyclist is 0.27).

Table 2. R-square values for correlations between movement flows and configuration variables.

		R-square for Pedestrian	R-square for Cyclist
Axial model	Rn	0.15	0.3
	R3	0.28	0.24
	Choice N	0.06	0.77
	Choice 3	0.12	0.37
Angular Segment model	Rn	0.11	0.3
	Integration R 6000m	0.09	0.3
	Integration R 3500m	0.13	0.22
	Integration R 700m	0.21	0.07
	Choice N	0.06	0.67
	Choice Radius 6000m	0.12	0.65
	Choice Radius 3500m	0.26	0.51
	Choice Radius 1600m	0.43	0.15
Choice Radius 700m	0.21	0.00	

This finding is encouraging as the spatial model could explain the cyclist flow up to 70% correlations. This is an equally good result as the previous space syntax research carried out in London, which found cyclist volume strongly correlated with the configurational variable mean angular depth conducted in both Stockwell and Elephant and Castle (0.76/0.68) (Raford, Chiaradia, and Gil 2005). It also validates the hypothesis raised in section 2, that the pedestrians and cyclist adopt different trip distance and different radius of configurational variables. The

former is better explained by local measures, and the latter is better explained by global measures. However, the correlation between observed pedestrian volumes and configurational variables is more modest and much lower than the values in the London's case studies. How to understand the "unexplained" pedestrian flows? We will discuss the possible reasons in the next section.

5. Double validation of the syntactic model

When the movement data does not match the configuration variables, the data set should be first checked if any error exists. Secondly, it should be field checked whether there is any presence of “dead dog effect”, a condition which deters pedestrian to pass by due to environmental nuisance such as bad smell. Thirdly, it should be verified whether the spatial model is properly constructed.

As described in section 1 and 4, the movement data set has already been examined to remove the gates showing abnormal results. The “dead dog effect” has also been checked carefully by field observation. Although each street has different dynamics, no gate was found with extreme nuisance in our study. The final task is the verification of the syntactic spatial model’s accuracy. In section 3, it was mentioned that many technological problems were encountered in the process of axial map construction and these difficulties could be summarized into three types.

5.1 Judgment puzzle - include semi-public space or not?

The first difficulty is to judge whether a semi-public street/path should be mapped or not. This dilemma is caused by the common Chinese “gated community” management culture. In our surveyed site, besides the housing estates, two universities campus are also gated. For residential sites built in different time period, the control

levels of the gates are different. Some are opened for residence and their visitors only and some are opened to the public but close for the others with less well-dressed (such as vendors). This makes the judgment of which street to include or exclude in the axial map difficult. From both observation and literature review, we know that local people use routes within a gated community as their frequent shortcuts in their daily life (Dai 2013). As a result, this paper has only included the street/path frequently used by the citizen onto the map. To test whether this would provide better explanation of the pedestrian movement or not, we have constructed another model without shortcuts for comparison (Figure 5). Statistical analysis shows that the “with shortcut” model produces higher R-square value than the “without shortcut” model. This supports the previous decision to include the semi-public paths. However, some shortcuts might be possibly omitted in our model due to



Figure 5. Green lines indicate shortcuts.

the subjectiveness of what a semi-public path is. Therefore, to confirm the accuracy of the model in this study area, researchers need to perform more scenario analysis in future case studies. Compared to other studies without the problem of ambiguous public space, this one requires additional effort.

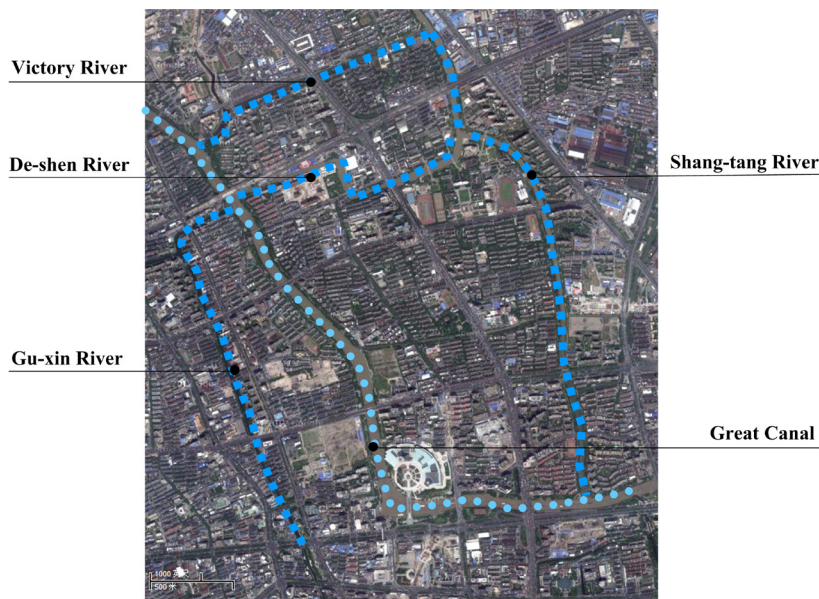


Figure 6. Water channels on the site.

5.2 How to represent level change?

The distinct geographical morphology of this site is featured by its densely distributed water channels (Figure 6). A water channel has either parallel or converging relationship with a street. When in parallel, they could be either adjacent or detached. When they converge, there are four types of connection (small street/small river/big street/big river), and create at least three kinds of level: riverside path level, street level, and bridge level. These

diversified types of roadways has complicated the situation which has resulted into 30 unlinks in this model in total.

To connect these levels, either stairs or ramps are needed. Therefore, the four types of “water channel intersects with street” have resulted into different patterns of vertical connections. The representation of these different stairs or ramps in a consistent manner becomes problematic. We could either represent the vertical connection in a conceptual way by one single line or retain its real form which might include excessive maneuvers. The former is interpreted as our perception and views; while the latter represents actual accessibility. This research has selected the former solution but the latter one should be tested in future research.

5.3 How to represent severance effect of wide roads?

Built according to the hierarchical transportation system in China, there are seven types of roads – elevated fast road, fast road, main road, secondary trunk road, branch road, residential street and pedestrian lane in our site. However, all these roads with different dimensions are represented as axial line with no width differentiations in our model. As the width of the elevated fast road, fast road and main road are substantially wide, they are natural dividers when they intersect with secondary roads. These physical dividers have directly affect the people’s route choice, which means people need to detour a certain distance to avoid the green island or other fence in the middle of the road.

As different dimensions of roads are represented in lines with no width differentiation and the human visual perception is not consistent with their movement trace, the visibility graph could be significantly different from the accessibility graph of a street network. This undermines the power of syntactic model to forecast movement. Gate f8 is a good example as shown in figure 7a. In the result, we found that the numbers are far off from the regression line– lower figure than the predicted volume. From Figure 7b, the detouring effect is shown more obvious. Gates f2, f9, f8 are located on a continuing

street, the figure shows the pedestrian movement volume drops dramatically from east to west when it is cut apart by Shang-tang Road, a major roadway.

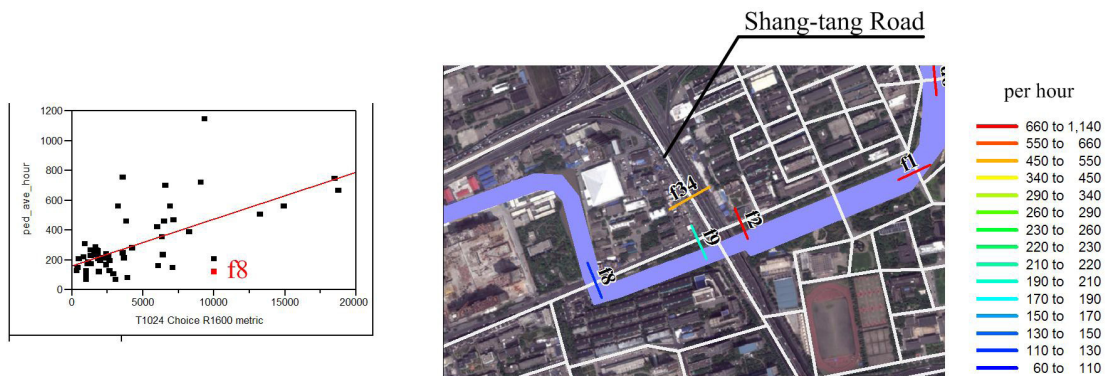


Figure 7a. Regression analysis (left).

Figure 7b. Pedestrian movement counts (right).

This mismatch of the axial model representation and real usage of the area separated by wide road was also emphasized by Runqing Shao, who has proposed a new type of syntactic model to resolve the problem (Shao 2010). Shao suggested an easy solution to this problem could be presenting the wide roads into two lines similar to what we usually do in high resolution map. However, this method has brought to a new problem, which means two different resolutions coexistent in one spatial model.

6. Conclusions and reflections

This research has collected systematic pedestrian and cyclist movement data to test the correlation among configuration variables and movement flows. It has revealed that angular segment model is a better model than axial model in terms of explaining movement. It also suggests that choice measure from both models can strongly predict cyclist movement, with an R-square value of 0.7 approximately. However, the R-square value for pedestrian movement is relatively low.

This research has proposed three reasons for the “unexplained” pedestrian flows - judgment puzzle of semi-public domain caused by the gated community management culture, the representation of different level changes caused by the presence of water channels across the site, and a method to map the severance effect of wide road caused by the hierarchy of street system. As these three features of the site are common conditions for Chinese cities in Yangtze River delta, these problems discussed in section 5 are not only technology problems but have more theoretical implication.

Chinese city has distinctive morphology and social /culture conditions which are very different from the west. This case study revealed that in order to construct a syntactic model in a consistency way under such conditions, we need further research to discuss the method of mapping the space in a syntactic model. Within these three puzzling conditions, there are two problems which belong to more generalized themes: how a space network with large difference between accessibility graph and visibility graph should be represented; how should a model with two different resolutions be treated

and its validation in explaining movement.

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