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INHABITANT-ORIENTED ENVIRONMENTAL PREFERENCES AND LAYOUT STUDY OF SLAB HOUSE CLUSTERS IN "YANGTZE RIVER DELTA" AREA OF CHINA WITH MAS

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Abstract: This paper has presented a design method of local inhabitant-oriented layout of slab house cluster including two main tasks: 1) analyzing inhabitants' preferences on environmental conditions in "Yangtze River Delta" Area in China through a household investigation; 2) simulating layout evaluated by the inhabitants' preferences. The investigation results showed: the local inhabitants have their own characteristics on environmental conditions, such as general preferences on layouts with dwelling units, roads, green land and individual preferences related with age, sex, occupation etc. The simulation results showed the local design criterions, such as the most suitable height of house, the green land size and the conjunction way between dwelling units and their relations with the types of houses.

Keywords: slab house cluster, parallel layout, inhabitant-oriented, Yangtze River Delta, Multi-Agent System (MAS)

INTRODUCTION OF RESEARCH

Background

Parallel layout of slab house cluster is the most popular site-planning pattern in "Yangtze River Delta" Area (includes Shanghai, the south part of Jiangsu province and north east part of Zhejiang province) in China since 21th century because of its excellent natural ventilation, wide views, sunshine space and lightening system with low construction costs. This area has 1% of the land, 5.8% of the population and 20% of the GDP of China in 2009. It is also the earliest area entering urbanization process and has the subtropical monsoon climate.

The traditional architect-oriented approach of layout design depends on the individual experience of architects. Even the most experienced architect will inevitably have subjectivity and cannot design efficiently and strictly for the inhabitants of certain area who have their own life styles and environmental preferences.

This paper tries to present an inhabitant-oriented design approach based on a self-programmed simulation. It is the first time to design the residential cluster layout from inhabitants' point of view instead of architects' personal experiences. The new design approach has a broad application prospect since it will decrease error occur ratio in the design phase and make the design process more precise, flexible, efficient and in detail. With the accomplishment of the database of local inhabitants' preferences, it will minimize the gaps of the design experiences between architects, accelerate the design process and fulfill the most inhabitants' living condition demands.

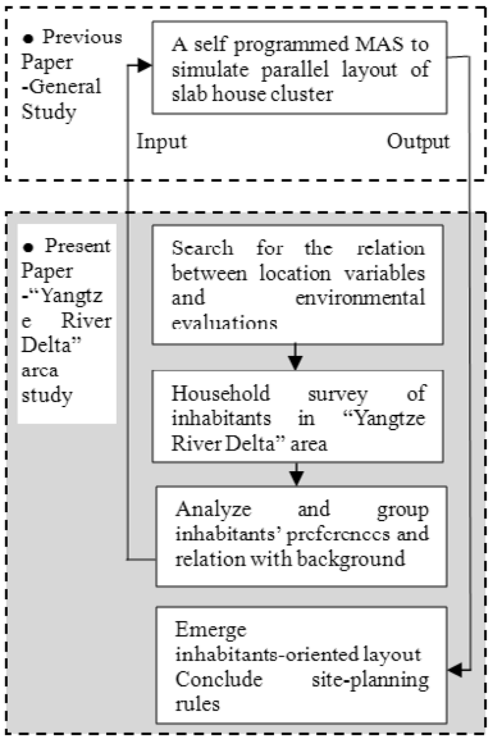

Fig. 1 Conceptual model of study process

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Note: Discussion on this paper is open until June 2014

The previous study (Ding 2010) has simulated the general parallel layout of Row House Cluster with a self-programmed Multi-Agent System (MAS), this paper (Figure1) will concentrate on 1) investigating the inhabitants' preferences by the household surveys of the residential environment subject evaluations of "Yangtze River Delta" area in China; 2) try to find some corresponding site-planning rules by simulating the inhabitant-oriented layouts of this area with Multi-Story Row House Cluster (MRHC) and High-Rise Row House Cluster (HRHC).

Purpose

The purpose of this paper is to present the specific parallel layouts based on the inhabitants' preferences of "Yangtze River Delta" in China. The inhabitants of this area have their own life style and environmental demands, for example: the inhabitants from southern China would like shorten the shine space and inhabitants from northern China would like enlarge the shine space; More than 80% (Ding 2010) of the inhabitants from Beijing area like the dwelling unit facing Greenland but only half of the inhabitants from "Yangtze River Delta" like it. Therefore, compared with the traditional architect-oriented layouts, layouts based on the inhabitants' preferences can fulfill the local individual's requires and have an overall consideration for the site-planning problems. The study questions include:

1) What is the relation between locations and environmental elements of Dwelling Units?

2) Which kind of residential environments do the inhabitants from "Yangtze River Delta" prefer based on the inhabitants' subject evaluations? Is the preference related with the background of each individual, such as age, sex, occupation?

3) Which kind of layouts will emerge based on the inhabitants' preferences from "Yangtze River Delta" with MAS? Which characteristics and site-planning rules can be drawn?

Past Study

Using MAS to solve the site-planning problems in architectural region is a new study filed and gets more and more attentions. M. HAN has optimized the layouts of MRHC by improving the sunshine hours of the dwelling units using Genetic Algorithm (GA) (Han 2010). Gao and Liu (2005) constrained and controlled the schematic layout design process by using GA. Kfir et al. (2002) studied the dwelling units on manmade island in Osaka Bay, processed the regression analysis based on the data from the subject evaluations and the views of the living space, got the general evaluation of the views. Takizawa et al. (2000) has modeled an urban system with MAS, the result showed that the emerged pattern is more like the land-use pattern of Osaka.

Difference of present paper from above is that it is the first time to study the inhabitants' preference of living conditions in "Yangtze River Delta" of China and simulate the related parallel layout of MRHC and HRHC with MAS. The similar previous study has only limited to improve the single living condition, such as sunshine hours, views, and the layout behaviors of the MRHC regardless of the inhabitants living background.

RELATION BETWEEN LOCATION AND ENVIRONMENTAL EVALUATION OF DWELLING UNIT

The certain location of every dwelling unit decides its own unique environmental conditions. The main task of this part is to search and classify the relations between locations and environmental elements.

Determinant and Classification of Location

The land of residential cluster is composed of three main parts: house land, green land, road land. So does the location of dwelling unit (Fig. 2).

1) House: Horizontal and vertical positions in a slab house decide the position of a dwelling unit. Because every dwelling unit is composed of floor 1, 2, 3,…, the vertical position can be neglected. There three types of horizontal positions (HP) in a house: in the middle (HM), at the west end (HW), at the east end (HE).

2) Green land: The distance and the direction between green land (GL) and dwelling unit determine their relations. There three types of relations of GL: dwelling unit direct faces GL in south or north direction (GD), indirect faces GL (GI), not faces GL (GN).

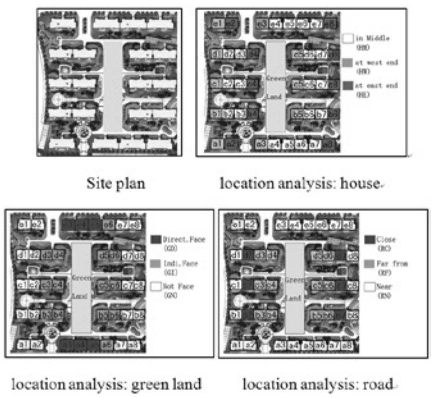


Fig. 2 Cluster of Olympic Garden in Shanghai

Table 1 Classification and presentations of the cluster of Olympic Garden

Type No.	Dwelling unit	Location		
		HP	GL	RO
1	a1,b1,c1,d1,e1	HW	GN	RN
2	a2,a8,b8,c8,d8,e2,e8	HE	GN	RN
3	a3,e3	HW	GD	RN
4	a4,a5,e4,e5	HM	GD	RN
5	a7,e7	HM	GN	RN
6	b2,b7,c2,c7,d2,d7	HM	GN	RC
7	b3,b6,c3,c6,d3,d6	HM	GI	RF
8	b4,c4,d4	HE	GI	RF
9	b5,c5,d5	HW	GI	RF
10	a6,e6	HM	GI	RN

3) Road: Noise is the main influence of roads on dwelling units. Data shows that the noise can be ignored when the distance (D) between house and roads is larger than 40 meters (Wu 1982). So there three types of relations with roads (RO) at west/east side: near roads (RN: D≤width of dwelling unit), close to roads (RC: width of dwelling unit＜D≤2×width of dwelling unit), far from roads (RF: D＞2×width of dwelling unit). There are only 2 types of RO at south/north side: RN, RF (According to the Shanghai Residential Areas Planning & Design Code, sunshine space≥1.2*house-height, depth of slab house normally in Shanghai is between 11meters and 15meters, so the relation between the first row of the houses and the road is "near"; the relation between the second row of the houses and the road is "far").

The complete presentation of the location is:

$$P_i = (HP_i, GL_i, RO_i) \qquad i = 0,1,2,...,n-1 \qquad (1)$$

HP ∈(HM, HW, HE)
GL ∈(GD, GI, GN)
RO ∈(RN, RC, RF)
i: Serial number
n: total number of dwelling units

Table 1 shows the classification and the location presentations of all dwelling units in the cluster of Olympic Garden in Shanghai.

Environmental Evaluation

The quality of environment determines the quality of the whole residential district which has close relation with layout design. The layout design of "Yangtze River Delta" includes 5 main environmental elements (E):

Sunlight (S): sunlight conditions depend on the shelter from the south direction of the house, besides; the shelter from southeast direction has more influences than it from southwest direction. In order to get more sunlight, most of the slab type residential houses are south and north direction houses (the most windows of dwelling units face south or north direction).

Direction (D): The south and north direction slab type houses have the same directional conditions which can be neglected.

Ventilation (T): The ventilation conditions are influenced by the heights of surrounding buildings, the direction of house, monsoons etc.

Noise (N): Most noise of residential cluster is caused by the surrounding traffic, thus keep enough distance between the roads and house is the key to solve such problem. Additionally, the chatting voice, activities of the residents gathering near the GL will also cause some noise.

View (V): The view quality is always decided by the surrounding environments including views of roads, houses, GL, trees etc.

The environmental elements can be presented as follows:

$$E_i = (S_i, T_i, N_i, V_i) \qquad i = 0,1,2,...,n-1 \qquad (2)$$

Thus the inhabitants' subject environmental evaluation of the dwelling units can be presented as:

$$\mathrm{GE} = \sum_{i=0}^{n-1} \mathrm{EE}_i \qquad i = 0,1,2,...,n-1 \qquad (3)$$

$$EE_i = ES_i + ED_i + ET_i + EN_i + EV_i \quad i = 0,1,2,...,n-1 \qquad (4)$$

GE: General Eva. EE: Environmental Eva.
ES: Eva. of Sunlight ET: Eva. of Ventilation
EN: Eva. of Noise EV: Eva. of View

Relation between Location and Environmental Evaluation

Location is the independent variable while environmental evaluation is the dependent variable. The environmental evaluation will be changed with the different location. At the same time, for a certain dwelling unit, the location is fixed, but the environmental evaluation is subject and will be changed by the individual of inhabitants (Fig. 3).

INVESTIGATION OF RESIDENT ENVIRONMENTAL EVALUATION

Each inhabitant has his/her own subject evaluation on the different dwelling unit which is affected by his/her background and life style. The main task of this part is to find the relations between the environmental evaluations and background and to classify the location preferences by using household investigation and two step cluster of SPSS methods.

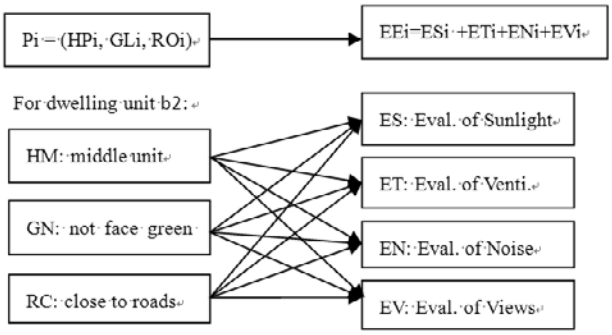


Fig. 3 Relation between location and Environmental Evaluations

Main Contents of Questionnaire

The questionnaire includes 4 parts: 1) background of inhabitant: age, sex, occupation etc.; 2) subject evaluations of different dwelling units which are classified by their location variables (HP,GL,RO) on environmental behaviors(EE, ES, Ed, ET, EN, EV) based on six models showed in Fig. 4; 3) most favorite layout; 4) most favorite dwelling unit.

Data Analysis

80 local inhabitants of "Yangtze River Delta" area who have already purchased apartments in slab houses with parallel layout were chosen as the respondents of household investigation, due to their familiarity with the evaluation models. Each respondent was asked to evaluate the environmental behaviors of 65 different locations from the above six models in Fig. 4. Using IBM SPSS Statistics 19.0 to count and analyze the data from 70 valid questionnaires, the surveyor got the results in Table 2.

The survey data shows the following characteristics on relations between the environmental evaluations and respondents' backgrounds:

The most favorite layout:

General preferences: 89.71% of all the respondents prefer the layouts with centered GL and not near any roads. Such kind of layouts has less disturbance from roads and can been utilized by the inhabitants most. Compared with rectangular form, square form of GL is more welcomed.

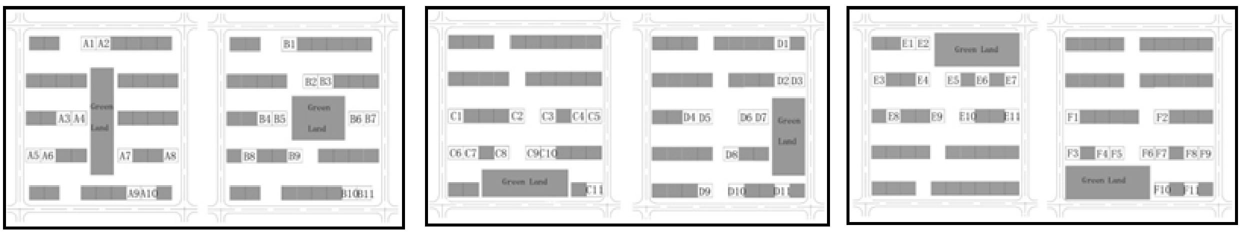
Table 2 General descriptions of the investigation data

Descriptives				
		Sex	Age	Occupation
N	Valid	4550	4550	4482
	Missing	0	0	68
Mean		1.47	34.49	
Standard Deviation		.499	11.458	
Skewness		.115	2.352	
S E Skew		.036	.036	
Kurtosis		-1.988	5.743	
S E Kurt		.073	.073	
Range		1	58	
Minimum		1	21	
Maximum		2	79	
Sum		6695	156910	

Preferences with backgrounds: 1) Respondents who are older than 40 or younger than 30, or female, or with architectural occupations have clearer and unified preferences of layouts. 2) Respondents who are older than 40 or with architectural occupations prefer layouts with great depth of GL to avoid the noise and the disturbance. 3) Respondents who are younger than 30 or without architectural occupations or male prefer layouts with small depth of GL to get better views.

The most favorite location:

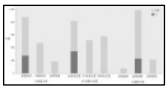
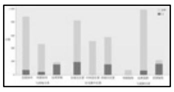
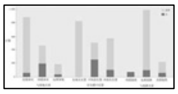
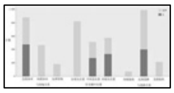
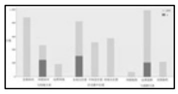
General preferences: 60.5% of all the respondents prefer the dwelling units far from roads, face the GL directly or indirectly. They don't care about the horizontal positions in houses.



GL in central part　　GL near one road　　GL near two roads

Fig. 4 Evaluation models of questionnaire

Table 3 Sample distribution and location variable determination

			Type				
			1	2	3	4	5
Sample distribution							
Location variable determination	HP	HE	1	1	0	1	0
		HM	0	0	1	0	1
		HW	0	1	0	0	1
	GL	GD	1	0	0	0	1
		GI	0	0	1	1	0
		GN	0	1	0	0	0
	RO	RC	0	0	1	0	0
		RF	1	0	1	1	1
		RN	0	1	0	0	0
Ratio			17.6%	17.1%	18.4%	15.7%	31.1%

Preferences with backgrounds: 1) Respondents who are older than 40 or with architectural occupations have clearer and unified preferences of locations. 2) Male and female respondents have the same preferences on locations. 3) Younger respondents prefer the dwelling units in the middle of houses and face the GL directly considering the price and the views (the apartments at the west or east end of house are usually bigger and more expensive than the apartments in the middle of house in residential districts of China). Older respondents prefer the dwelling units at the end of houses to get large spaces with better natural lighting and not face the GL to get quiet environments.

The relations between the locations and the environmental elements:

Sunlight: Dwelling units at the east end of houses have got the best sunlight evaluation which has few relations with GL and roads.

Ventilation: Respondents have no unified evaluation on this element.

Noise: Dwelling units which are far from roads have got the best noise evaluation. Some respondents also believe that the dwelling units far from GL can get good noise evaluation either. Positions in houses have no relations with noise evaluation.

Views: Dwelling units which face GL directly or indirectly have got the best views evaluation. Positions in houses and relations with roads have few relations with views evaluation.

Classification of Location Preferences

By using two-step cluster of IBM SPSS Statistics 19.0 with cluster criterion of Schwartz Bayesian Information Criterion and Distance measures of Log Likelihood, a cluster model of three discrete variables: HP, GL,RO can be established and 5 kinds of respondents' location preferences will be classified.

Fig. 5 shows the classification of 5 types of location preferences of inhabitants in "Yangtze River Delta". The sample distribution and the characteristics of each type can be described as in Table 3.

Fig. 6 shows: 1) Type 1 and type 5 have the best sunlight and Ventilation evaluations which means the inhabitants believe that the dwelling units in the middle position of house, face GL directly and far from roads have the best performance on sunlight and ventilation. 2) Type 4 and type 5 have the best noise and view evaluations which means the inhabitants believe that the dwelling units at the end position of house, face GL directly or indirectly and far from roads have the best performance on noise and view.

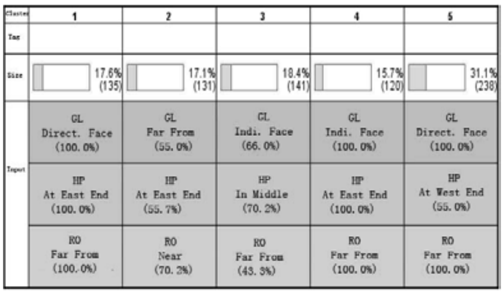
LAYOUT SIMULATIONS WITH MAS

Layout simulation (Ding 2010) of slab houses includes two aspects: 1) Layout problem: Several slab houses with different length have to be put into a certain area without overlapping satisfying the corresponding site-planning rules of fire protection, sunshine space etc. 2) Global optimization problem: Layout emerging bottom up process is from the optimization of one dwelling unit to all dwelling units based on their location preferences.

Test Environment Building

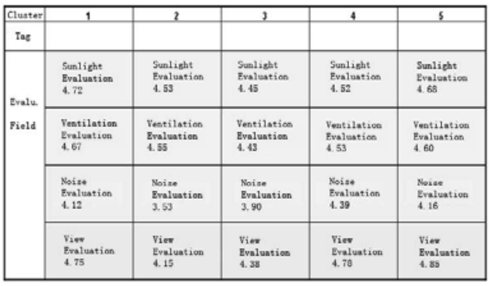
Software configuration of layout simulation: programming language C++, compiler platform Visual

Studio 2.8, operation system WindowsXP 5.1. The simulation will be processed in the same site and dwelling unit: site.depth=150m, site.width=200m; dwellingunit.depth=13m, dwellingunit.width=14. Table 4 shows the input data.



Cluster	1	2	3	4	5
Tag					
Size	17.6% (135)	17.1% (131)	18.4% (141)	15.7% (120)	31.1% (238)
Input	GL Direct. Face (100.0%)	GL Far From (55.0%)	GL Indi. Face (66.0%)	GL Indi. Face (100.0%)	GL Direct. Face (100.0%)
	HP At East End (100.0%)	HP At East End (55.7%)	HP In Middle (70.2%)	HP At East End (100.0%)	HP At West End (55.0%)
	RO Far From (100.0%)	RO Near (70.2%)	RO Far From (43.3%)	RO Far From (100.0%)	RO Far From (100.0%)

Fig. 5 Classification of location preferences



Cluster	1	2	3	4	5
Tag					
Evalu. Field	Sunlight Evaluation 4.72	Sunlight Evaluation 4.53	Sunlight Evaluation 4.45	Sunlight Evaluation 4.52	Sunlight Evaluation 4.68
	Ventilation Evaluation 4.67	Ventilation Evaluation 4.55	Ventilation Evaluation 4.43	Ventilation Evaluation 4.53	Ventilation Evaluation 4.60
	Noise Evaluation 4.12	Noise Evaluation 3.53	Noise Evaluation 3.90	Noise Evaluation 4.39	Noise Evaluation 4.16
	View Evaluation 4.75	View Evaluation 4.15	View Evaluation 4.38	View Evaluation 4.78	View Evaluation 4.85

Fig. 6 Environmental evaluations

Table 4 Input data of site−planning rules

slab house type		Multi −story	High -rise	High -rise
Story		6	11	18
Plot Ratio		1.2	2.0	2.5
Amount of dwelling units		33	37	23
No. of dwelling units	Type 1	6	7	4
	Type 2	6	6	4
	Type 3	6	7	4
	Type 4	5	6	4
	Type 5	10	11	7
Sunshine space (meter)		22	32	65
Distance between gable walls（meter）		6	13	13
Green land size（meter）	Width	23	23	23
	Depth	37	55	102

The judgment of layouts is base on the inhabitants' location preferences of "Yangtze River Delta" area. If the position of a dwelling unit can fulfill with its location preference, then it will get scores which can been described in the following:

For a single dwelling unit i:

$$S_i = HP.S_i + GL.S_i + RO.S_i, \text{ while } FS = 6 \quad (5)$$

For layout:

$$TS = S_0 + S_1 + ... + S_{n-1}, \text{ while } FS = 6 \times n \quad (6)$$

$$SR = TS \div n \quad (7)$$

S: Score
FS: Full Score
TS Total Score
SR: Score Ratio

Layout Analysis

The simulations of each kind of slab house will be processed 20 times to get 60 layouts totally. Fig. 7 is the comparison of score ratios among three kinds of layouts. The following conclusion can be drawn: the story of house has inverse proportion with the score ratio. The inhabitants from "Yangtze River Delta" prefer the low story house cluster than the high story house cluster with the better environmental living conditions and it is always been relatively easier to design an inhabitant-welcomed layout.

Table 5 shows the best and worst layouts emerged from the simulations. The following conclusion can be drawn: 1) For all kinds of house clusters, it is always better to put the houses far from roads. 2) For 6-story house cluster, because it is easy to satisfy the minimum size of GL, there will appear a lot of positions directly face GL in layout. Choosing a proper size of GLwill be a good design method. 3) For 11-story and 18-story house clusters, it should always maximize the size of GL. 4) For 18-story house cluster, instead of align conjunction, dislocation conjunction between the dwelling units will enlarge the distance from roads and improve the living conditions.

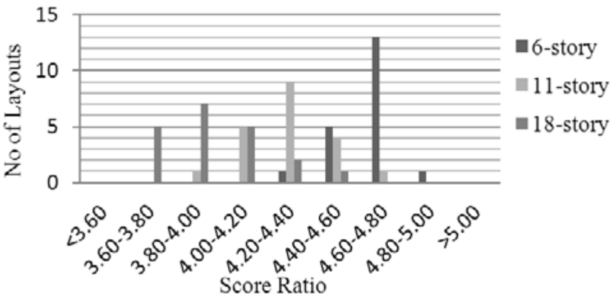
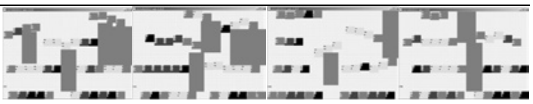
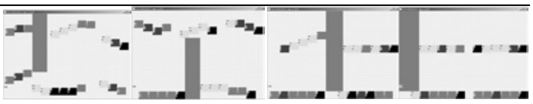


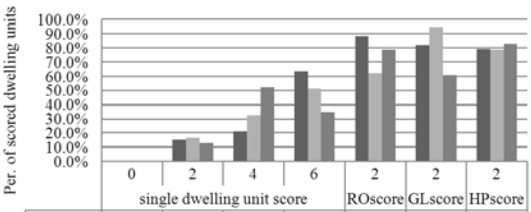
Fig. 7 SR comparison

Fig. 8 is the percentage comparison of scored dwelling units in best layout. For example: in the best layout of 6-story house cluster: 21.2% of all dwelling units got 4 point which means 2 location variables scored. The following conclusion can be drawn: 1) the 6-

story house cluster has a better overall layout performance than high rise house clusters, the main difference between them is the number of the full scored dwelling units. 2) Three kinds of cluster have the same performances of HPscore which means the position in a house will not cause any differences in the layout performances. 3) The GLscore depends on the height of house. It is relatively easier to fulfill the demands of GL for 11-story house cluster while it is more difficult for 18-story house cluster. 4) It is hard to satisfy the demands of RO for 11-story house cluster.

Table 5 Best & worst layouts emerged from simulations

Types	Best layouts		Worst layouts	
6-story				
	TS:164 SR:4.97	TS:158 SR:4.79	TS:146 SR:4.42	TS:142 SR:4.30
11-story				
	TS:174 SR:4.70	TS:168 SR:4.54	TS:146 SR:3.95	TS:148 SR:4.00
18-story				
	TS:102 SR:4.43	TS:100 SR:4.35	TS:84 SR:3.65	TS:86 SR:3.74



	0	2	4	6	2	2	2
	single dwelling unit score				ROscore	GLscore	HPscore
6-story	0.0%	15.2%	21.2%	63.6%	87.9%	81.8%	78.8%
11-story	0.0%	16.7%	32.4%	51.4%	62.2%	94.6%	78.4%
18-story	0.0%	13.0%	52.2%	34.8%	78.3%	60.9%	82.6%

Fig. 8 Scored dwelling units comparison in best layouts

CONCLUSION

This paper has 1) established a relation between the location variables (Position in house, Relation with GL, Relation with roads) and environmental evaluations (Sunlight, Direction, Ventilation, Noise, Views); 2) investigated the environmental preferences of inhabitants from "Yangtze River Delta" Area of China through a household survey and classified 5 kinds of preferences; 3) simulated the inhabitants-oriented parallel layouts of slab house cluster based on the inhabitants preferences of "Yangtze River Delta" Area with self-programmed MAS.

The following conclusions of design criterions of "Yangtze River Delta" Area in China can be drawn: 1) The multi-story house cluster has better environmental conditions than high rise house cluster and design the layout of lower story house cluster if possible; 2) For all kinds of clusters, houses should always far from roads. 3) For 6-story house cluster, the size of GL should be controlled; for 11-story and 18-story house clusters, it should always maximize the size of GL. 4) For 18-story house cluster, dislocation conjunction between dwelling units will improve the living conditions.

The above study has presented a new inhabitant-oriented layout design approach based on the household survey and the appropriate architectural digital simulation process. In future study, the range and depth of the investigation of "Yangtze River Delta" Area can be expanded, for example, the environmental preferences can also include the evaluation of different kinds of views, like landscape views, roads views, buildings views and so on. The layout simulation can be broadened to the point type cluster or the slab-point mixed type cluster etc.

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