Preliminary Analysis on the Status Quo and Problems of Land Use of Educational Space in Primary and Secondary Schools in the Downtown Area, Tianjin- Results of data analysis based on information entropy and equilibrium

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Abstract. In this article, in order to have a better understanding of the current situation and supply-demand challenges with regard to the land use of educational space in primary and secondary schools in the downtown area, Tianjin and address the related problems, the comparative analysis is conducted on the land-use layout of 30 ordinary primary and secondary schools. In addition, for these primary and secondary schools, based on the information entropy, balance and dominance of land-use structure, and in conjunction with the actual conditions, spatial location and time of construction, efforts are made to analyze the diversity and balance of educational space. Generally speaking, the land-use layout of the surveyed schools falls into three types: ring-shaped with a center, linear, and group-based. Besides, thus, the main factors which exert certain influence on the pattern of spatial layout and the land-use structure of educational space in primary and secondary schools in the downtown area, Tianjin are identified by data analysis. It provides reference for the intensive use of educational space in primary and secondary schools, and lays a solid foundation for formulating a series of land-use planning and management policies targeted at primary and secondary schools.

1. Introduction
In recent years, many cities suffer the ever-growing shortage of both educational resources of primary and secondary schools and educational land, which has become a bottleneck posing threat to the coordinated development of primary and secondary schools. In this article, 30 primary and secondary schools in the downtown area of Tianjin are selected to conduct a comparison of their spatial layout and land-use structure, in order to get a detailed picture of the overall educational land of these schools, the supply-demand contradictions, and those pressing problems to be addressed.

According to the statistics of the National Education Development Statistics Bulletin issued by the Ministry of Education, the statistics of the number of primary schools, junior high schools and high schools in Tianjin for the past five years, the number of students in school, the building area of school buildings and the floor area per student are calculated as follows:
In 2013-2015, the number of primary schools in Tianjin increased rapidly while in 2016-2017 it has not changed. As of 2017, the number of primary schools was 857. During this period, the number of students and the floor space of school buildings showed an upward trend. In 2017, the total number of students in school reached 648,800, and the construction area of school buildings reached 463 hectares. The final calculated primary school students’ per capita construction area showed a downward trend. In 2017, it was 7.15 m²/person.

In 2013-2015, the number of junior high schools in Tianjin increased slowly, and the growth in 2015-2017 accelerated. As of 2017, the number of junior high schools was 338. During this period, the number of students in junior high schools did not change significantly, and the overall number remained at 25-270,000 people, the building area of school buildings has been increasing year by year. The final calculated average construction area of junior high school students has shown an increasing trend, reaching 10.67 m²/person in 2017.
This paper takes the six districts in Tianjin as an example. According to the list of schools provided by the Tianjin Education Commission website, 5 districts are selected in each district of Hebei, Heping, Hexi, Nankai, Hongqiao and Hedong districts. The information collection of the primary and secondary schools with different school establishment time, school scale and campus environment are shown in Figure 4.

2. The Analysis on the Spatial Layout of Educational Land of Primary and Secondary Schools in the Downtown Area of Tianjin

The spatial layout, mainly focusing on the geographical location, relationship of combination and distribution characteristics of each functional space, is one of the key topics of human geography and urban planning. This study straightens out the spatial layout of 30 primary and secondary schools in Tianjin, and on the basis of this, the analysis is carried out on the overall combination relationship of primary and secondary schools. With the aid of the analysis on the plane composition of functional space, the combination of land forms, and so on, such insights are gained: the distribution characteristics and the combination law of functional elements in the geographical space. The model of spatial layout falls into three categories: center-ring type, line-type, and group-type, which are shown in Table 2.

Table 1. Schematic Map of Typical Land Use Layout Patterns for Primary and Secondary Schools in Tianjin

| Pattern   | Schematic illustrations of typical land use layout patterns |
|-----------|----------------------------------------------------------|
| line-type |                                                          |
| center-ring type |                                              |
| group-type |                                                          |

3. The Analysis on the Land-use Structure of Educational Land of Primary and Secondary Schools in the Downtown Area of Tianjin

3.1. The quantization method of land-use structure - information entropy
Towards SBE: from Policy to Practice

IOP Conf. Series: Earth and Environmental Science 329 (2019) 012013
IOP Publishing
doi:10.1088/1755-1315/329/1/012013

It is supposed that the total area of the region with a fixed administrative boundary is \( A \). The land type here falls into \( n \) categories. \( A \left( x_i \right) \) represents the area of each type, and the probability of the occurrence of a certain type is expressed as:

\[
p \left( x_i \right) = \frac{A \left( x_i \right)}{A}, \quad i = 1, 2, \cdots, n
\]

The normalization conditions are met. Based on the principles of information theory, for this region, the information entropy of the land-use structure can be defined as:

\[
H \left( \xi \right) = - \sum_{i=1}^{n} p \left( x_i \right) \ln p \left( x_i \right)
\]

In order to make the information-entropy values of the land-use structure more comparable, such concepts as the equilibrium and dominance of the land-use structure are introduced. The equilibrium \( E \) and the dominance \( D \) are respectively expressed as

\[
E = \frac{H}{H_{\max}} = \frac{1}{\ln(n)} \sum_{i=1}^{n} p \left( x_i \right) \ln p \left( x_i \right)
\]

\[
D = 1 - E
\]

The equilibrium \( E \) of the land-use structure is the ratio of the actual entropy value to the maximum entropy value; \( H \) is the information entropy of the land-use structure; \( H_{\max} \) is the information-entropy maximum; the dominance \( D \) is the land-use concentration, showing that the region is dominated by one advantageous land type or several advantageous land types.

According to the principles of information theory, if the region is home to different land types, the area of each type is much closer, with the larger information-entropy value. In a region where its potential is untapped, the information-entropy value is 0, that is to say, \( H_{\min}=0 \); conversely, when the land types in the region tend to be proportionate and stable as well as the conditions of maximizing the information entropy are met, namely, \( A \left( x_1 \right) = A \left( x_2 \right) = \cdots = A \left( x_n \right) = A/n \), the information-entropy value reaches the maximum, that is to say, \( H_{\max}=\ln(n) \). Since \( H \leq H_{\max} \), the change interval of \( E \) is \([0,1] \). When \( E=1 \), the region enjoys the optimal land-use equilibrium; on the contrary, when \( E=0 \), the region where the land is not developed is in the most unbalanced state.

3.2. The analysis on the land-use structure

According to the above formula, for the 30 universities and colleges in Tianjin, the information entropy and the equilibrium of the land-use structure are calculated. The results are shown in the table.

| District         | Number | Information entropy | Average | Variance | Equilibrium |
|------------------|--------|---------------------|---------|----------|-------------|
| Hongqiao District| 1      | 1.18                |         |          | 0.86        |
|                  | 2      | 1.20                |         |          | 0.87        |
|                  | 3      | 1.26                | 1.21    | 0.0939   | 0.91        |
|                  | 4      | 1.33                |         |          | 0.97        |
|                  | 5      | 1.05                |         |          | 0.76        |
|                  | 6      | 1.16                |         |          | 0.84        |
|                  | 7      | 1.21                |         |          | 0.88        |
| Nankai District  | 8      | 1.07                | 1.20    | 0.8612   | 0.78        |
|                  | 9      | 1.24                |         |          | 0.90        |
|                  | 10     | 1.33                |         |          | 0.96        |
|                  | 11     | 1.33                |         |          | 0.96        |
|                  | 12     | 1.25                |         |          | 0.90        |
| Heping District  | 13     | 1.18                | 1.22    | 0.0664   | 0.86        |
|                  | 14     | 1.17                |         |          | 0.85        |
|                  | 15     | 1.15                |         |          | 0.83        |
Hexi District

|   | Information Entropy | Equilibrium |   |
|---|---------------------|-------------|---|
| 16 | 1.06                | 0.77        |   |
| 17 | 1.21                | 0.88        |   |
| 18 | 1.31                | 0.0875      | 0.95|
| 19 | 1.28                | 0.93        |   |
| 20 | 1.20                | 0.87        |   |
| 21 | 1.26                | 0.92        |   |
| 22 | 1.24                | 0.90        |   |

Hebei District

|   | Information Entropy | Equilibrium |   |
|---|---------------------|-------------|---|
| 23 | 1.38                | 0.0981      | 1.00|
| 24 | 1.07                | 0.78        |   |
| 25 | 1.22                | 0.88        |   |
| 26 | 1.26                | 0.91        |   |
| 27 | 1.35                | 0.98        |   |

Hedong District

|   | Information Entropy | Equilibrium |   |
|---|---------------------|-------------|---|
| 28 | 1.01                | 0.1195      | 0.73|
| 29 | 1.19                | 0.86        |   |
| 30 | 1.10                | 0.80        |   |

It can be seen from the table that for the 30 primary and secondary schools in Tianjin, the average information entropy and the average equilibrium of the land-use structure are 1.21 and 0.88 respectively. The maximum is 1.38 and 1.00 respectively - Tianjin No. 35 Middle School; the minimum is 1.01 and 0.73 respectively - Tianjin No. 28 Middle School. Based on the mean, extreme and distribution of the information-entropy values of the selected primary and secondary schools, we can see that universities and colleges, with different geographical locations and at different stage of development have different information entropy of the land-use structure, and accordingly, the land-use diversity and equilibrium are also different.

According to the status of various functional space in primary and secondary schools (Table 1), the land-use structure is statistically measured. The results are shown in Figure 2.

Based on the results of Figure 2, we can see that the land-use structure of the selected 30 universities and colleges in Tianjin has the following characteristics:

Figure 4. The ratio of the area of each functional area to the total area of the school
(1) Construction land

Construction land, as the core type of the functional space of primary and secondary schools makes up a proportion of 28% on average in the land-use structure of the 30 primary and secondary schools. However, there are certain gaps in this respect. For instance, these key schools such as Tianjin Experimental Primary School and Tianjin Zhongying Middle School and Xinhua Middle School, affected by such factors as geographical location, land price, school fund and basic conditions, have a fairly high proportion of construction land in the land-use structure, which accounts for 50%, 46% and 46% respectively. Tianjin No. 30 Middle School has a relatively large area of land, where some space is idle. Thus, the construction land accounts for a fairly low proportion of merely 12%, while the other roads and squares occupy a large area, about 50%.

(2) Sports land

Sports land is the second largest functional land in primary and secondary schools in Tianjin. Different schools, due to such factors as the time of establishment as well as the land area and scale, have remarkable difference in the proportion of sports land in the land-use structure. The sports land accounts for 49% in Tianjin No. 3 Middle School, which is the highest; the lowest is 12% Tianjin Yuxian Middle School. There is a negative correlation between the proportion of construction land and sports land. These key schools such as Tianjin No. 3 Middle School and Nankai Middle School with a time-honored history, sufficient sources of fund, and wide social attention have been updated in order to meet the requirements of modern education, with the sports land accounting for 49% and 48% respectively. By contrast, the sports land in such schools as Tianjin Yuxian Middle School, Tianjin Zhongying Middle School and Tianjin Experimental Primary School accounts for merely 12%, 14% and 14% respectively, due to their unreasonable campus planning and spatial layout.

Figure 5. Information entropy of the land-use structure of primary and middle schools based on the differences in spatial location

It can be seen from Table 2 and Figure 3 that the difference in the average information entropy of the land-use structure of the primary and middle schools in the six districts is not obvious. The largest is 1.23 - Hebei District, the smallest is 1.18 - Hedong District; the values of Hongqiao District, Nankai District, Heping District and Hexi District are between 1.20 and 1.22. Thus, the gap in the land-use structure of the selected schools is not large, which is mainly attributed to the undiversified functional space and simple allocation of school land. No obvious data deviates from the standard. Thereby, a preliminary conclusion can be reached that the planning of primary and secondary schools in the six districts is under way in an orderly manner.

As is shown in the table of the land-use structure, the information-entropy variance, and the information-entropy distribution of the selected schools in the six districts of Tianjin, the minimum
information-entropy variance is found in Heping District - 0.0664, and the values are more proportionate, one following another. Since in Heping District the education projects have a solid ground and the district is home to quality students, teachers and schools, the campus there is more sophisticated. In Hedong District, the maximum information-entropy variance is 0.11946, and the values are far from proportionate. Thus, the campus planning there is still in its infancy, and a set of campus system which is well-defined and reasonable has not been formed.

It can be seen from the distribution of the information-entropy values that the line-type spatial layout has a small information-entropy value, and value of the group type is fairly large. These values are attributed to the following facts: for one thing, since the line-type spatial layout is limited by the land conditions, it is not easy to integrate the functional space; for another, the corners and transferring space are used in an improper manner. On the contrary, the group-type space, more flexible as it is, has its moderate area and reasonable planning, and as a result, the information-entropy value is larger and the land-use structure is more balanced.

4. The main problems to be addressed in terms of the education land of primary and secondary schools in Tianjin

(1) There is an insufficient source of land, especially the outdoor space. Much effort should be made for outdoor landscape.

Firstly, the land in primary and secondary schools is generally tense. In the campus, the teaching and administrative buildings play a dominant role, which complicates the problem of insufficient outdoor space. Besides, in the outdoor area, some space must be reserved for the playground, and as a result, the land for landscape construction and extracurricular activities for students is limited. Secondly, the campus suffers its undiversified landscape design. In many schools, landscape design is merely defined as a sign of boundary or activity space, without any creative and commemorative landscape elements. In addition, some landscape design is manifested by merely several seats or flower beds, in the absence of any landscape axis, which fails to bring the initiative of students into full play.

(2) There is no specific design for on-campus functional space, and the land-use structure needs to be optimized.

The campuses in different regions suffer their unbalanced planning and development, and there is no guiding strategy. The campuses of multi-campus schools are simplistic in function, without any connection with each other; most of single-campus schools have their relatively compact land-use structure, which compresses the area of other functional space. For instance, the entrance space is small, thus causing inconvenience in the personnel coordination when the traffic flow is high; due to the lack of outdoor space, the time for extracurricular activities of students is cut; the lack of courtyard space poses threat to the sustainable development of “green campus”. Besides, some campus-renovation plans cannot adapt to the requirements of modern education, and a series of campus-construction projects are launched in a passive manner, thus resulting in such problems as the disorder of both functional space and activity space for teachers and students.

(3) The campus is homogenized, and the on-campus spatial layout suffers the lack of personality.

Compared with universities and colleges featuring the diversified spatial function, primary and secondary schools have their simple and pure land-use structure. Therefore, the spatial layout and the land-use patterns are more or less similar. In terms of the on-campus interior space, some schools are merely home to necessary teaching and administrative buildings, without such public buildings as libraries and school-history museums; in most schools, stadiums, swimming pools, and so on cannot be found. With regard to the on-campus outdoor space, most schools are home to such space as the entrance square, the playground and the fragmented negative space surrounding the buildings, and there is no comfortable outdoor space for daily activities, which provides convenience and enjoyable experience for students. In some middle schools, the on-campus outdoor landscape lacks the people-oriented design, in order to meet the needs of students.
5. Conclusions
Based on the comparison and analysis of the spatial layout and land-use structure of 30 primary and middle schools in the downtown area of Tianjin, this article, proceeding from the four land-use functions of construction land, green land, sports land and other land for roads and squares concludes that the spatial layout of primary and secondary schools in Tianjin falls into three types: line-type, central-ring type, and group-type. On the basis of measuring the information entropy, equilibrium and dominance of the educational land in these schools, the comparative analysis is conducted on the diversity and equilibrium of the spatial layout and the land-use structure, in conjunction with the historical development and location characteristics of the six districts in Tianjin. The results show that universities and colleges, with different geographical locations and at different stage of development, have different information entropy values of the land-use structure, as well as the land-use diversity and equilibrium.
(1) The gap in the land-use structure of primary and secondary schools in the six districts of Tianjin is not obvious, and the campus planning is under way in an orderly manner. (2) Since in Heping District the education projects have a solid ground and the district is home to quality students, teachers and schools, the campus there is more sophisticated, and the information-entropy values are more proportionate, one following another. In Hedong District, with these values far from proportionate, the campus planning is still in its infancy, and a set of well-defined and reasonable campus system has not been formed. (3) The line-type spatial layout is limited by the land conditions, and therefore the information-entropy value of the land use is small; on the contrary, the group-type space, more flexible as it is, has its moderate area and reasonable planning, and as a result, the information-entropy value is larger and the land-use structure is more balanced. Therefore, such factors as the type, construction period and geographical locations exert certain influence upon the spatial layout and the land-use structure of the educational land of primary and secondary schools.

This study, identifying the problems in the spatial layout and the land-use structure of primary and secondary schools in Tianjin, aims to provide reference for campus planning and to render decision-making basis for the intensive land utilization of these schools.

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