Hong Kong New Town Sustainability Analysis from the Perspective of Low-Carbon Eco-City —Taking Tseung Kwan O New Town as an Example

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Abstract. Recent years, people have paid more attentions to environmental issues involving air pollution, urban heat island effect and accessibility of green space. Hong Kong is a representative high-density city. The mission of Hong Kong New Town Development is to scatter the densely urban centre population and to improve living quality. Based on the ArcGIS and CFD scientific simulation, this paper focus on the sustainability analysis of Hong Kong new town from the view of Low-Carbon Eco-City, taking Tseung Kwan O new town as the research object.

1. Introduction
Hong Kong New Town Development Programme started in 1973, which has built 9 new towns so far including Sha Tin, Tuen Mun, Taipo, Fanling, Sheung Shui, Yuen Long, Tin Shui Wai, Tseung Kwan O and Tung Chung. The current population of these nine new towns is approximately 3.4 million and is expected to rise to 3.6 million in 2019.

Figure 1. The present boundary and location of Tseung Kwan O new town

Source: Planning Department of Hong Kong
Tseung Kwan O new town is selected as the research area, which belongs to the third generation of Hong Kong new town in 1980s and 1990s. The total development area is about 1738 ha for a planned population of 450,000. The current population of Tseung Kwan O new town is about 386,000.

2. Issue Raised
The mission of Hong Kong New Town Development is to scatter the densely urban centre population and to improve living quality. Recent years, people have paid more attentions to environmental issues involving air pollution, urban heat island effect and accessibility of green space.

At the same time, the concept and practice of eco-city has been realized these years, such as Sino-Singapore Tianjin eco-city and Beijing Changxindian low-carbon community. With excellent considerations of environment, these low-carbon eco-cities have been performed well in aspects of passive building design, green and health environment, energy conservation and even green construction techniques.

Based on the data released on Hong Kong Planning Department official website, some eco factors such as breezeways, open space, green belt, landfills and renewable energy have been considered within the planning scheme, which are deemed as important measures to improve living environment. Combined with the low-carbon eco-city assessment criteria, the vision of becoming eco-city for next generation of Hong Kong new town will be analysed through the comparative research of present completion.

3. Methodology
According to previous researches, low-carbon eco-city assessment criteria mainly cover resource conservation, environmental friendly, sustainable economy and harmonious society [3]. Specifically, the importance of each item has been listed through network questionnaire and expert seminar.

| Classification | Item | Significance | Index in 2015 | Index in 2020 |
|----------------|------|--------------|---------------|---------------|
| Resource Conservation | Reclaimed water reuse | Core | Water shortage area (general) ≥15% | Water shortage area (general) ≥20% |
| Resource Conservation | Green building percentage | Core | New building = 100% | New building = 100% |
| Environmental Friendly | The number of days of good air quality | Core | ≥310 | ≥320 |
| Environmental Friendly | Green coverage rate (catchment = 500m) | Core | ≥80% | ≥90% |
| Sustainable Economy | Unemployment rate | Core | 4.20% | 3.20% |
| Harmonious Society | Green Transportation percentage | Core | ≥65% |

Generally, regulatory planning and urban design are the most significant levels in low-carbon eco-city planning, which directly impact basic alignment and future development of the project [2]. By giving specific indexes and controls, low-carbon performance and eco balance can be achieved. In addition, low-carbon eco-city uses positive space design and planning to decrease energy consumption effectively especially in summer, which can mitigate urban heat island effect in large degree. Combined with low-carbon eco-city practice and relative contribution of different planning factors toward the reduction of urban heat island effect, 3 elements are selected to conduct this comparative research [2].
Table 2. Three Selected Elements.

| Element                  | Contribution toward the reduction of urban heat island | Suggestive Index       |
|--------------------------|------------------------------------------------------|------------------------|
| Green Coverage Rate      | 53.9%                                                | ≥50%                   |
| Breezeway                | 14.6%                                                | Built and optimized    |
| Green Roof Coverage      | 6.4%                                                 | ≥30%                   |
|                          |                                                      | Public building ≥42%   |

4. Data Collection & Analysis

4.1. Green Coverage Rate
As mentioned above, green coverage is one of the most important indexes to measure low-carbon eco-city, whose pattern normally includes public green space, street greenbelt, green courtyard and etc. As an important index to measure urban environment and living quality, it is generally considered that green coverage rate should be larger than 50% for a good environmental quality. Green land can greatly reduce surface temperature by water transpiration comparing urban impervious surface. Besides, public green space can offer opportunities for people to communicate and to relax. The accessibility to public green space is also considered as a basis of planning.

According to the general land uses of Tseung Kwan O new town, apparently it adopts a layout of high density built-up area with widespread green land area, which increases the green coverage rate to some degree. (Fig.2)

Figure 2. The general land uses of Tseung Kwan O new town

Figure 3. Land uses classification of Tseung Kwan O new town by ArcGIS

Source: Planning Department of Hong Kong

In order to obtain present green coverage rate, the green land data have been extracted by ArcGIS classification. Basically, it is made up of 2 components, built-up area and green land. (FIG.3) Through ArcGIS statistic summary, the green coverage rate in Tseung Kwan O new town can reach almost 57.75%. Obviously, this kind of completion is quite excellent compared with the suggestive index (50%).
4.2. Green Roof Coverage

Green roof means that the roof of building is covered with vegetation and soil. Using vegetated roof will help rainwater management, because vegetation will absorb rainwater and reduce runoff. In addition, it also can provide views of rooftop gardens for building users. At last, it can combat heat island effect.

For Tseung Kwan O new town, green roof has already occupied a certain proportion. It has become an important place offering people opportunities to communicate and release pressure visually. In order to assess this eco design element, green roof coverage has been calculated based on google map and on-site confirmation. The calculated vegetation forms on green roof include bush with strong wind resistance, small arbor and flowers.

At the same time, building in Tseung Kwan O new town is divided into 5 classifications based on function analysis for easy data collection, which includes official building, public infrastructure, school, shopping mall and community. By making counted grid, google map is divided into small cell specifically (FIG.4). These small cells act as pixel professionally, which can be measured individually.

![Figure 4. Grid and measurement used](image)

In this research, the size of each cell is 4m*4m. Basically, it is fit for the real scale of general roof greening. More importantly, it is quite feasible. As a result, the statistic result is shown as below.

| Total Roof Area (m²) | Total Green Roof Area (m²) | Green Roof Percentage (%) |
|----------------------|-----------------------------|---------------------------|
| 748,288              | 104,336                     | 13.94                     |

Similarly, compared with the suggestive index, no matter for residential building or for public building, this result seems not good to some degree. However, considered that this kind of green technology is in the process of developing and the complicated context, this statistic result (13.94%) is acceptable.

4.3. Breezeway

As an important measure of passive design, the plan of breezeway can improve the air circulation within the site and between the surrounding area and the site. Generally, it is suggested to design the breezeway along the main direction of the prevailing wind, which can introduce air flow into the site deeply and maximally. As elaborated above, one of the most important items that local residents care
about is the good air quality. It is believed that breezeway can improve the air quality by dispersing heat and dust, which can also reduce the incidence of infectious disease.

According to the feasibility study for establishment for air ventilation assessment (AVA) system, breezeway should be connected with large open area, such as major roads, open space connected amenity areas and non-building land.

The Figure 5 shows official planning of breezeway, whose red part stands for the planned breezeway in the core area of Tseung Kwan O new town. One thing is worth mentioning that the planned breezeway is accompanied with open space. Besides, the core area is surrounded by green belt. As elaborated above, this is a kind of layout of high density built-up area with widespread green belt. This is a very significant planning layout adopted by Hong Kong planning, which aims at improving environment and living quality in the context of high density population. Therefore, it has put forward higher requirement of passive ventilation design in the built-up area.

![Figure 5. Planned breezeway of Tseung Kwan O](Source: Planning Department of Hong Kong)

It manifests that air flow will be introduced into core area of the site deeply and effectively. On the one hand, this pattern of design can mitigate the urban heat island and realize energy saving in Tseung Kwan O. On the other hand, it can disperse dust and air pollution.

In order to test the performance of breezeway in Tseung Kwan O new town, Computational Fluid Dynamics (CFD) has been used in this research. In the progress of data selection, it can be found that the direction of prevailing wind in TKO is about 202.5° in summer, to be specific, in July and August. (FIG.6)

![Figure 6. Tseung Kwan O wind rose in July and August](Source: Planning Department of Hong Kong)
Based on the present situation of data collection and its feasibility, the wind data (ABL-BC) come from Kai Tak wind station, which is not far from Tseung Kwan O new town (FIG.7). Basically, the wind data (BC-3x3-0.33-202.5.prof) are reliable.

![Kai Tak wind station](source: Hong Kong Observatory and Google map)

The model is built in Sketch-up pro with 1:1 scale. Combined with the planned breezeway, the core area of Tseung Kwan O new town is defined and included with the model. (FIG.8) In addition, for the sake of reducing uncertain impacts of rolling terrain, the chosen core area is relatively flat. More importantly, the prevailing wind (202.5°) has not been influenced too much by surrounding terrain. (FIG.9)

![3D model and core area of Tseung Kwan O new town](source: Hong Kong Observatory and Google map)
The simulation result is shown as below. Generally, the brighter color stands for a more powerful air flow, whose range is from 0 m/s to 6m/s. The simulated surface is 1.5 meters above the ground, which is regarded as the pedestrian level. According to Hong Kong BEAM (Building Environmental Assessment Method), wind velocity of pedestrian at 1.5 meters above should be less than 5m/s. Besides, in urban built-up area, in order to keep a good air circulation, the least wind velocity is 2m/s [1].

From Figure 10, it is obvious that the basic breezeway has been established in the core area of Tseung Kwan O new town by comparison of the planned breezeway. Under the condition of prevailing wind (202.5°) in July and August, the average wind velocity is between 2m/s to 5m/s, which is able to introduce air flow effectively in such a high density built-up area.

In addition, ample open space connected to the breezeway has not only increased air quality inside the core area but also improved local living environment of the whole Tseung Kwan O new town. It is
known that landfill issue and wastage disposal is pretty severe in Tseung Kwan O. The closest landfill is just 800 meters away from local residential region. Since the alteration and extension of existing landfill is in progress and discussing, the breezeway is not only a passive design measure to mitigate urban heat island but also a primary method to relieve air pollution especially brought by wastage disposal.

5. Conclusion
Based on these selected 3 elements (Green Coverage Rate, Green Roof Coverage and Breezeway) of low-carbon eco-city assessment criteria, comparative analysis have been made by relevant techniques. The completion of each element is in different degree and phase. It is sure that the previous planning of Tseung Kwan O new town is effective and does consider about low-carbon eco-city factors. For the vision of next generation of Hong Kong new town, it should be more ecological, environmental friendly and energy saving.

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