Implication of Land Use Control on Urban Ventilation – A Case Study in Rail Station Areas of Kaohsiung City

Chun-Ming Hsieh*, Kang-Li Wu*, Wei-Cheng Li*, Ha-Wang Huang*
*Department of urban Planning, National Cheng-Kung University, Tainan, Taiwan.

Abstract

Promoting the concept of green-TOD that integrates the ideas of green urban design and Transit-Oriented Development (TOD) has become an important research issue. This study takes the Kaohsiung Railway Underground Project as an case study to study how to address the issue of climate-sensitive urban design in rail station area under the concept of green transit-oriented development. The relationship between wind environment and land-use control in urban design is discussed. The Computational Fluid Dynamics (CFD) simulation is used as the assessment method to examine the wind environment before and after the underground development of rail station in the main station area. According to the local meteorological data, the wind velocity and wind direction are analyzed separately in summer and winter according to different land-use control scenario. The simulation results reveal that the local wind environment was improved by the land-use control measure. The result could be used as a reference to re-examine current urban design policy.

Key words: Climate-sensitive urban design, Green Transit-Oriented Development (Green-TOD), wind environment, land use control, CFD (Computational fluid dynamics)

1. INTRODUCTION

Due to rapid development of urbanization, Urban Heat Island (UHI), worsening the urban microclimate, has become serious problems in urban environment. It is important for better urban air ventilation in a dense, hot–humid city to let more wind penetrate through the urban district (Edward, 2009). Wind path can be in the form of roads, open spaces and corridors through which air reaches inner parts of urbanized areas largely blocked by high-rise buildings. The wind pattern depends on the exact geometry of all buildings nearby, a standard performance approach of urban design taking wind environment into consideration should be applied (Capeluto, 2003). The air temperature and wind distribution was evaluated according to the building arrangement of construction plans and it was proved by simulation that proper geometry buildings can improve the thermal environment (Hsieh, 2007). This implies that performance standards related to the wind pattern should be established and evaluated in the planning and design stage.

Urban design brings together the ideas and plans to create livable urban places and sustainable land-use planning which reducing energy use and climate impact. Transit-Oriented Development (TOD) and ecological community are good tools to implement sustainable urban design. TOD aims at creating compact and compatible mixed land use within walking distance of rail stations (Cervero, 2008). Green-TOD concept attempts to combine traditional TOD model with ecological community concept in order to develop a planning model which integrates mass transit planning and sustainable community development (Wu, 2009). The key elements in TOD planning model include: maximizing subway system ridership; maximizing living-environment quality; and optimizing the social equity of land development (Lin, 2006).

This study uses the Kaohsiung Railway Underground Project as an example to study how to address the issue of climate-sensitive urban design in rail station area under the concept of green transit-oriented development. The underground project is an urban regeneration project that aims to rearrange land use and urban design of the existing railway corridor, stations and surrounding areas. Through the urban redevelopment and rezoning of the area, the project goal is to promote the vitality and livability of the local communities and to improve the land use efficiency in the corridor areas. This project will not only satisfy the local needs, but also improve the living environment through combining the consideration of climate sensitive design and transit-oriented development.

Among several key measures of green transit oriented development, this paper focus on the issues between wind environmental analysis and land use planning. To address the issue of climate sensitive-design in urban design control, the computational fluid dynamics (CFD) simulations is used as the assessment method to examine the wind environment before and after the underground development of rail station in the main station area. The alternative scenarios in wind environment aspect is analyzed and compared according to different land-control scenario by several land-use control measures, such as controls on density, FAR, and building masses. The result could be used as a reference to reexamine current urban design policy.

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*Address: No. 1 University Rd. Tainan, Taiwan

2. FOCUS AREA AND SIMULATION SETTINGS

Kaohsiung City is located in southern part of Taiwan and the urbanized area (urban planning area) is around 147 km^2. The number of inhabitants is about 1.25 million. In this urban climate investigation, the hourly meteorological data source is available based on Kaohsiung Weather Station, the wind velocity and wind direction are analyzed separately in two seasons, summer and winter from year 2003 to 2007. All these two seasons in Kaohsiung City belong to the type of tropical monsoon climate and tropical marine climate, which has the northern frontal edge coming from mainland China in winter and the rainy season in summer. The frequency of wind coming from southern occupies the largest percentage in summer, and the mean speed of southern wind is 2.96 m/s. On the other hand, more than 30% of the wind coming from northern in winter was recorded, and the mean speed is 2.26 m/s. According the distributions of wind direction in each season, it mostly concentrate at north in winter, that means the effect of northern frontal edge in winter is heavier than the effect of marine monsoon in summer, although it is a tropical city (Figures 1 and 2). The wind velocity as a function of height above ground was assumed to follow the power law. The exponent is set to be 0.27, which is the value in the city area.

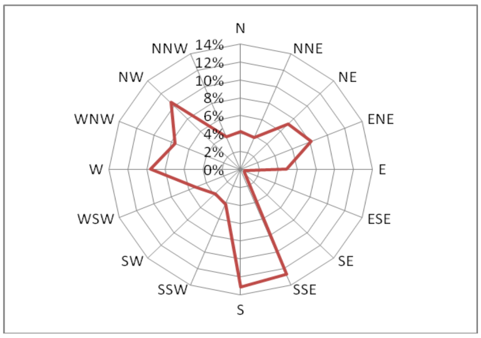

Figure 1 The frenqucy of wind direction in summer

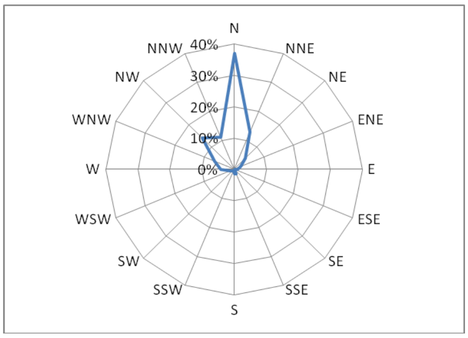

Figure 2 The frenqucy of wind direction in winter

As shown in Figure 3, the railway station of Kaohsiung is located in the center of the simulation boundary. The diameter of the simulation area is 800m and total mesh number of the simulation is about 2.2 million. The specific climatic condition within the urban canopy is determined by urban design policy of the local area. BCR (building coverage ratio), FAR (floor area ratio) and building masses are the main approaches when implementing the concept of TOD to rail station area of Kaohsiung. This study examines how the building regulations affect the wind environment of the local areas. Three focus areas, shown in Figure 4, are defined in this study. “Focus area 1”, “Focus area 2” and “Focus area 3” indicate the north-south road, east-west road and the walking area nearby the station respectively.

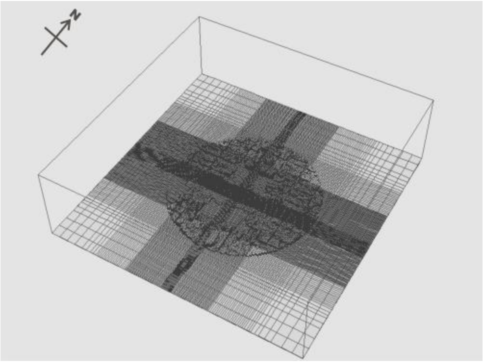

Figure 3 Geometry of CFD simulations

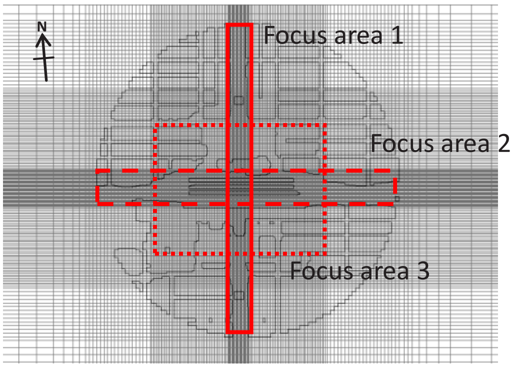

Figure 4 Focus areas

The influence of urban planning factors BCR and FAR on wind environment are discussed in this paper. BCR is defined by the ratio of the building area to the total land of the construction site. FAR is the ratio of the total floor area of buildings on a certain lot to the size of the land of that location. FAR can be used in zoning to limit the amount of construction in a certain area. In other words, the control policy of BCR belongs to a restriction of two dimensions (plane) and FAR belongs to a restriction of three dimensions (space). Table 1 shows all the cases in this study. Case 1 shows the present situation of the Kaohsiung railway station. Cases 2 and 3 examine how the incentive policy of BCR and FAR implemented around the station area affects the local wind environment. Finally, a indicates summer season, and b represents winter season.

Table 1 The simulation cases

	Case 1: The current situation	Case 2: TOD-1	Case 3: TOD-2
Summer	Case 1-a	Case 2-a	Case 3-a
Winter	Case 1-b	Case 2-b	Case 3-b

3. SIMULATION RESULTS

Figures 5 & 6 show the wind distribution of present situation at the height of 1.5m at the Kaohsiung railway station in summer and winter respectively. In the current situation, the railway and platform of Kaohsiung station stretching from west to east and there is a bridge above the station. The bridge crossing from north to south above the railway station blocks the street ventilation since the wind is mainly coming from south in summer and from north in winter. Compared to the wind environment at the elevation above the bridge, the lower wind speed was observed below the bridge. It was also found from the simulation results that wind speed above the railway and the west-east direction street was relatively slow. Poor wind environment was observed around the station in the current situation.

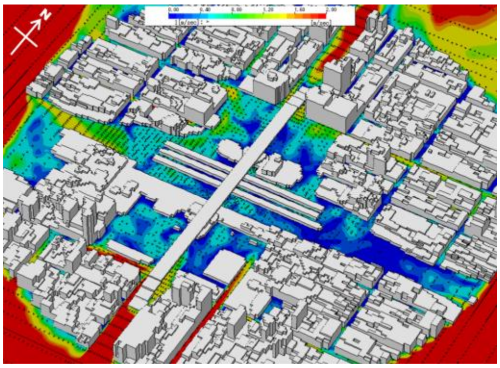
Figure 5 The wind distribution of Case 1-a

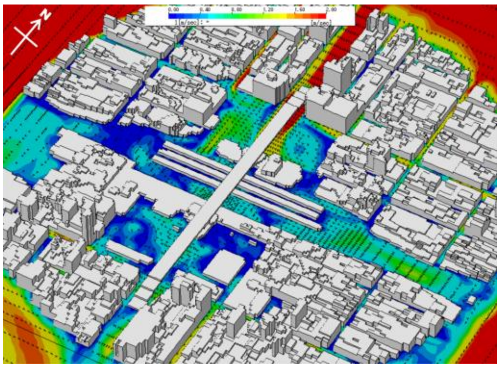
Figure 6 The wind distribution of Case 1-b

Figures 7 & 8 show the wind distribution of cases 2-a and 2-b at the height of 1.5m respectively. Management of FAR on two sides of the roads are implemented. Obvious difference between summer and winter is found. In case of summer, the buildings on northern side of the road induced better ventilation to the pedestrian-level height (Figure 7). Furthermore, better ventilation was also found around the station. On the other hand, the wind speed was found slow at the leeward side of the buildings in winter (Figure 8). The wind coming from north was obstructed by the buildings located at the northern part of station.

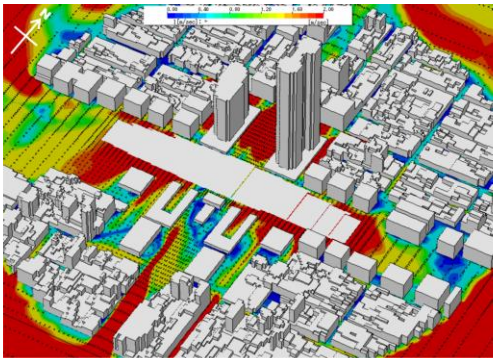
Figure 7 The wind distribution of case 2-a

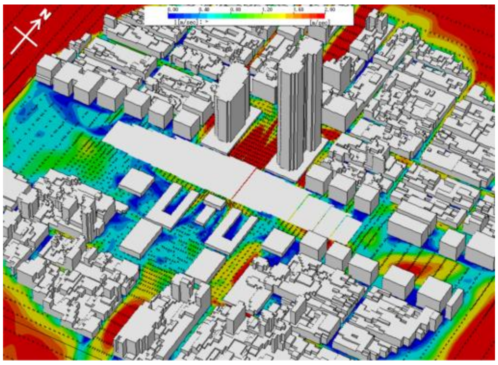
Figure 8 The wind distribution of case 2-b

High-rise buildings are constructed and in Cases 3-a and 3-b, in which the incentive policy of FAR is carried out within the walking distance of station. As shown in Figures 9 & 10, the larger wind speed was found around the high-rise buildings in both seasons. However, the wind speed in the southern part of the station is relatively slow compared to that in northern part of the station. This phenomenon was obvious in winter.

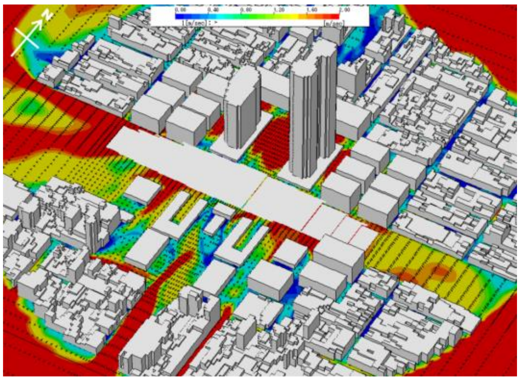

Figure 9 The wind distribution of case 3-a

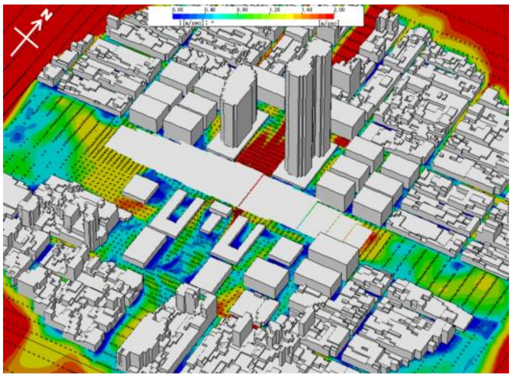

Figure 10 The wind distribution of case 3-b

Table 2 lists the average wind speed in Focus areas 1, 2 and 3, defined previously, for all cases. Poor ventilation in Cases 1-a & 1-b was observed from the simulations for both summer and winter seasons. Although the obvious difference between Cases 2 and 3 was not found, the simulation results revealed that the ventilation at the height of 1.5 m was improved for both seasons in Cases 2 and 3 compared to those in Case 1. High-rise buildings were constructed because of the incentive policy of FAR around station. It was found from the simulation that the ventilation in the Focus area 2, the east-west road, was better in summer than that in winter. The better ventilation was also observed in summer inside the Focus area 3.

Table 2 Simulation results of velocity (m/s) at the height of 1.5 meter in each case

	Case 1-a	Case 1-b	Case 2-a	Case 2-b	Case 3-a	Case 3-b
Focus area 1	0.72	0.85	1.40	1.40	1.34	1.36
Focus area 2	0.46	0.40	1.71	0.91	1.69	1.00
Focus area 3	0.60	0.48	1.07	0.76	0.95	0.73

4. CONSLUSIONS

Green-TOD enables the realization of ecological design and climate-sensitive land use planning and urban design. Kaohsiung city is an ideal exemplary metropolis to advocate the concept of TOD, for its urban spatial structure and activity system are undergoing adjustment. The wind environment of Kaohsiung rail station was evaluated by simulations using the CFD model. The local wind environment was affected by conducting reasonable organization of urban space, building layouts in blocks and building mass. The result showed that that the urban ventilation was improved by the incentive policy of FAR, land-use control measure. More detailed study will be conducted in the future to discuss the impact of different BCR/FAR and building set back criteria on the wind environment.

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