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Abstract

With the challenges of climate change, heatwaves, and air quality problems, design schemes for public spaces are increasingly seeking climate-sensitive design to optimize climate regulation services. Numerical modeling has become a key tool for improving the reliability of urban planning and design decisions. Upgrading and improving the ENVI-met microclimate model has become one of the most popular software for assessing microclimate environment and thermal comfort. The thermal index continues to develop into a more specific assessment tool for thermal environment and mitigation strategies for different climate zones. In Japan, the Transit-Oriented Development (TOD) of urban planning is used to construct and manage cities systematically. In principle, the design and planning of station square areas in urban centers concern residents' living environment and quality of life. How to optimize the design strategies of the station square area to realize more environmental benefits and reduce urban energy consumption has become a major concern for designers within the TOD principle. Therefore, this study proposed the New Synergistic Strategy (NSs) in landscape design and the Urban Space Regulation Strategy (USRs) in urban building morphology to actively guide the rational configuration in the station square for achieving mitigation of microclimate conditions, thermal comfort, and air quality to address the severe challenges posed by the climate environment.

This study simulated the optimal design strategies in three small-scale square spaces (block, courtyard, and canyon) in Komatsu Station, Japan. It aims to obtain better aerodynamic effects, cooling effects, and the deposition of atmospheric particulate pollution. Firstly, the case study assessed the mitigation strategies (climate change, scale, and configuration) of the core area in the station square under extreme winter and summer weather conditions in the Hokuriku region as a holistic thermal environment using the NSs. The relationship between the building morphology and the green space configuration in the three small squares is explored under the USRs to regulate the three effects in a universal configuration for typical summer weather and thermal stress conditions. Secondly, greening indicators (tree configuration ratio, the ratio of number of deciduous and evergreen trees) were proposed in this study to analyze the mitigation and relevance to the thermal environment in two case studies. Finally, ENVI-met simulations validated and compared intervention scenarios with actual measured parameters to obtain more optimal planting patterns and configurations for urban station square areas.

The originality of this study lies in proposing the regulation of the thermal environment and exposure risk reduction in typical Japanese public spaces (Typology of station square orthogonally connected to the main parallel street) by greening indicators optimization strategy can be applied to 50% of the same typology of station squares in central cities within the Hokuriku region. Furthermore, the strategy studies (NSs and USRs) yielded the following results:

In the landscape design strategy of Chapter 4, the three types of landscape layouts are original in analogy to the peripheral, array, and scatter, and proposed co-adaptation responses for very cold and very hot climates. A comparison of the case studies showed that the tree configuration ratio (R_{DT}/R_{GT}) can regulate thermal comfort at night and during the day; the best mitigation performance of the three layout patterns is the array layout planted with trees. The large-scale tree configuration ratio is optimized for thermal comfort and microclimate conditions in winter and summer via scale regulation, alleviating extremely poor weather conditions in the central station square. Based on the results of the Komatsu station case study, it could be used as a reference to solve the problem

of the tree type, number configuration, and vegetation structure in the urban center station of the Hokuriku region; and to solve the problem of local winter wind resistance and summer shade in the inner and outer ring spaces of the station.

In Chapter 5, the regulation strategy is innovative by comparing small-scale spaces: block, courtyard, and canyon types and simultaneously using building indicators of aspect ratio (H/W) and greening indicators (the ratio of number of deciduous to evergreen trees) to co-quantify the station square area. The results indicated that in typical hot weather in summer by the USRs, the composite layer structure (T3) is a universal greening pattern that optimizes microclimate, thermal comfort, and atmospheric $PM_{2.5}$ distribution; the cooling effect of the thermal environment depends on the ratio of number of deciduous and evergreen trees (R_g). Moreover, the canyon square downwind with a higher H/W has a more significant $PM_{2.5}$ removal.

These studies provide constructive references and decisions for the engineering analysis of the thermal environment in station squares and optimizing design schemes to provide important landscape design guidelines for developing Japan's TOD model and Sustainable Development Goals (SDGs). With the completion of the Komatsu City Master Urban Plan in 2040 and the Komatsu Hokuriku Shinkansen in 2023, the station square as the central urban renewal area is used as an example environmental simulation area to contribute to future urban construction (including landscape design, street maintenance, infrastructure renewal) to mitigate climate issues (extreme cold and hot, urban heat island effect, heat waves), air pollution issues (station square exhaust emissions of $PM_{2.5}$), with a particular focus on the overall station spatial structure and building morphology characteristics integrated tree types configuration for resilience improvement.

Keywords: Microclimate simulation, Thermal comfort, $PM_{2.5}$, Optimal design, Climate-sensitive design strategies