CHAPTER 3
THERMAL COMFORT ZONE IN JAPANESE OFFICE BUILDINGS

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3.1 INTRODUCTION

Thomas Bedford issued a report on thermal comfort in 1936, which led to the development of the thermal comfort factors at work. These findings have been discussed since the 1930s (Bedford, 1936). Since then, thermal comfort studies have been conducted worldwide until today using the similar guidelines pioneered by Bedford (1936). The pattern of modern development and the issues regarding energy have given rise to interest in this subject these days. The need for building energy consumption to obtain thermal comfort has encouraged researchers to rethink this subject. In such situations, it is necessary to estimate to what extent the buildings are to be operated according to the comfort requirement of the occupant with regard to the outdoor and indoor environments. Thermal comfort is defined as "the condition of mind which expresses satisfaction with the thermal environment" (ASHRAE, 2017). The sequential developments of the current approach for thermal comfort are based on either climate chamber tests or field surveys. The prior study is based on research done by Fanger (1970), who established the variables that affect thermal comfort and its metrics that are used to measure predicted mean vote (PMV) and predicted percentage dissatisfied (PPD).

However, as a limitation, this model does not consider occupant adjustment mechanisms and demographic and psychological variables as the study evolved from the climate chamber tests.

Nevertheless, this methodology was the theoretical foundation for developing the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and the International Organization for Standards (ISO). These recognised international standards were considerate of occupant's ability to adjust to the changes in the thermal environment. ASHRAE (2004) considers age, origin, gender and the occupants' adaptation processes, which was introduced in 2004 within the ASHRAE standard.

According to research released by the International Energy Agency (IEA), 30% of Japan's total energy consumption is accounted for in the commercial sectors (IEA, 2023). The Japanese government has always taken the initiative to preserve the building occupants' comfort and promote the idea of sustainable and energy-efficient office buildings. The most popular initiations carried out by the Japanese government are "Cool Biz", which was launched in 2005, and "Warm Biz", which was launched in 2009 (Enomoto et al., 2009). These campaigns have effectively brought awareness towards the need for sustainable clothing practices and reduced office energy use. As mentioned by the Ministry of the Environment, Government of Japan (2019), since the initiative's inception, "Cool Biz" has reportedly cut electricity usage by an estimated 4.4 billion kWh. At the same time, "Warm Biz" has reportedly lowered greenhouse gas emissions by an estimated 1.12 million tonnes of CO_2 equivalent (MOE, 2019). In terms of saving energy, the Japanese government recommended an indoor temperature of 28 °C for cooling and 20 °C for heating in the year 2005 requires evidence from the field survey as stated by Takasu et al. (2017). The authors remark that this recommendation was only implemented to facilitate the office occupants' comfort in relation to the outdoor thermal environment. The authors further note that merely adjusting the temperature and changing occupants' clothing would not be sufficient enough to increase comfort and reduce energy consumption (Takasu et

al., 2017). Being one of the most developed countries in the world, Japan does not have an adaptive model of thermal comfort for the buildings apart from having the "Warm Biz" and "Cool Biz" recommendations.

According to ASHRAE 55, thermal comfort is achieved when the indoor environmental conditions satisfy 80% of the occupants (ASHRAE, 2017). Understanding the temperature range to which these occupants are mostly satisfied can be considered the thermal comfort zone. Aghniaey et al. (2019) stated that energy consumption can be reduced by adjusting the temperature range. Kim et al. (2020) emphasised the need to comprehend the thermal sensation and the comfort zones to maximise energy-saving efforts. For heating, ventilation, and air conditioning (HVAC) office buildings in China, Wu et al. (2019) obtained a thermal comfort zone of 24.6–28.6 °C from 442 occupants, whereas a study conducted in the temperate climate of Romania, it was 22.6–26.0 °C (Udrea et al., 2018). These previous studies suggest that the thermal comfort zone can vary for different climatic zones.

With the above view, the primary objective of this study is to determine the thermal comfort zone through comparative analysis between mixed-mode (MM) and HVAC types of Japanese offices using the probit analysis method.

3.2 FIELD INVESTIGATION

This study presents the two thermal comfort field studies conducted in office buildings located in Tokyo, Kanagawa areas.

3.2.1 Location and Targeted Office Buildings

The two field measurements were conducted from August 2014 to October 2015 and August 2017 to November 2018 after obtaining the required approval from each office building. Collecting data for two years gathers data for different months or modes (Rijal et al. 2017, 2022). The total number of investigated office buildings during Survey 1 was 11, and Survey 2 was 16. These office buildings are of HVAC and MM