Study on the Actual Thermal Condition of Subway Station in Bangkok, Thailand -The Relationship between the Thermal Condition and Human comfort-

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Research Background

The deterioration of urban climate is a global issue. It is a matter of the whole world's relation to production and human activities in micro scale. The basic infrastructure in urban areas is transportation and how transportation relates to current environmental problems. For that reason, in some cities, there are controlling regulations.

Most of the regulations relate to air pollution and heat-trapping gases. However, most transportation is effected by internal combustion which produces extensive exhaust heat. According to this fact, it is believed that the system causes some adverse effect on the thermal environment in urban areas. Additionally, as a result of the development of traffic networks, rivers are frequently covered by roads. This also causes an adverse effect on the temperature in urban areas.

In some developed countries there are attempts to prevent the deterioration of the climate, such as the regulation for cars with a diesel system and the regulation of the number of cars in city centre. In other attempts there is the development of public transportation systems, such as the development of a railway network. Furthermore, development of the underground for a subway network is applied to reduce traffic congestion on the ground level.

For people living in urban areas a public transportation system is necessary. According to the extended time spent in transport and at stations, the energy consumption for air-conditioning is increasing year by year. For this reason it is

important to grasp the effect of thermal environment on humans in disconnected spaces such as underground areas and stations.

There are several research studies on the topic of the thermal environment of automobiles and their effect on humans. However, there are only a few studies on the effect of the thermal environment on trains.

Hashimoto et Al.(1966) generated a survey by using a mock train to grasp the effect of the thermal environment and its psychological effect in summer. They had experiments focusing on the relationship between the personnel density in the train and effect of the thermal environment on human psychology.

Sugawara et Al. (1997) had a survey on the thermal environment and its effect of existing trains. They proved that the thermal condition in summer is colder than that of winter.

The purpose of this research is to reduce energy consumption in Thailand to prevent the future global warming. As a first step the measurement of thermal conditions in subway stations is taken, based mainly on thermal comfort.

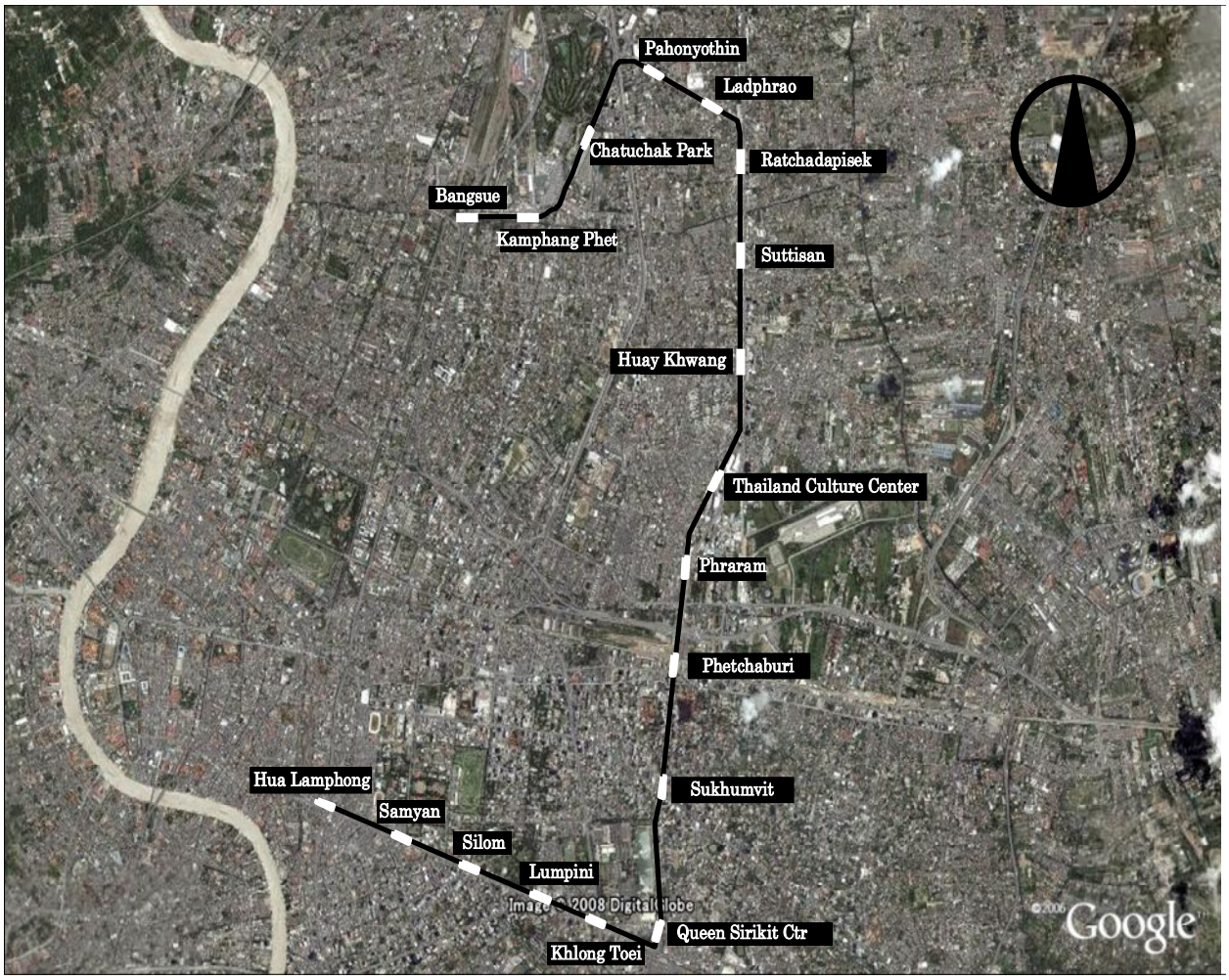


Figure.1 Bangkok Subway Map

Subway Overview

The subway map of Bangkok is shown in Figure 1. The subway opened on July 3rd, 2004. About 148 billion Baht (or about US$ 2.75 billion) with about five year term of work was spent for construction. The line runs from the Bangsue area in the north to stations to the south. The subway travels the whole line in 35 minutes, about the distance of 20 km. There are 18 stations on the line. At present, the subway train is mainly composed of three cars (six cars for the maximum capacity in the future) manufactured by Siemens.

In Bangkok, traffic jams are serious problems which cause many residual environmental problems, such as air pollution, noise pollution and deterioration of the thermal environment. The Thai government decided to establish the subway transport as a result of the huge traffic problems occurring in Bangkok.

Research Plan

This research is based on air temperature, global temperature, humidity, and wind speed. The instruments taken on this research are shown in Figures 2, 3 and 4.

Predicted Mean Vote (PMV) Meter, in Figure 2, is used to measure ambient temperature, global temperature, humidity, and wind speed. Thermometer, in Figure 3, is used to measure temperature and humidity; a fisheye lens camera, in Figure 3, is used to convey the subway space.

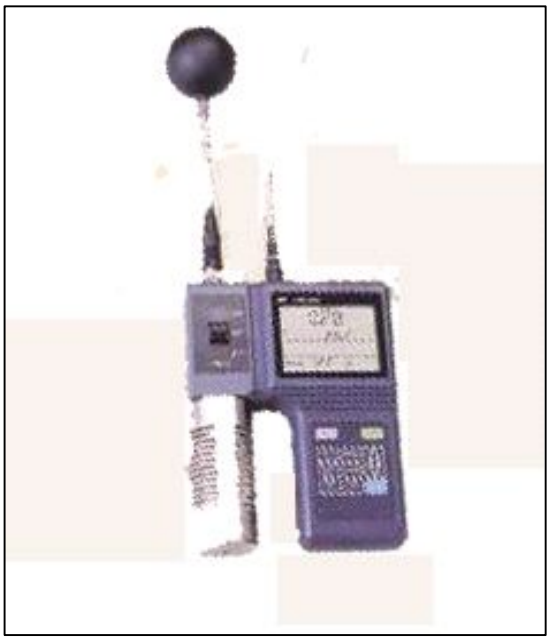


Figure.2 PMV Meter

Figure.3 Thermometer

Figure.4 Fisheye lens

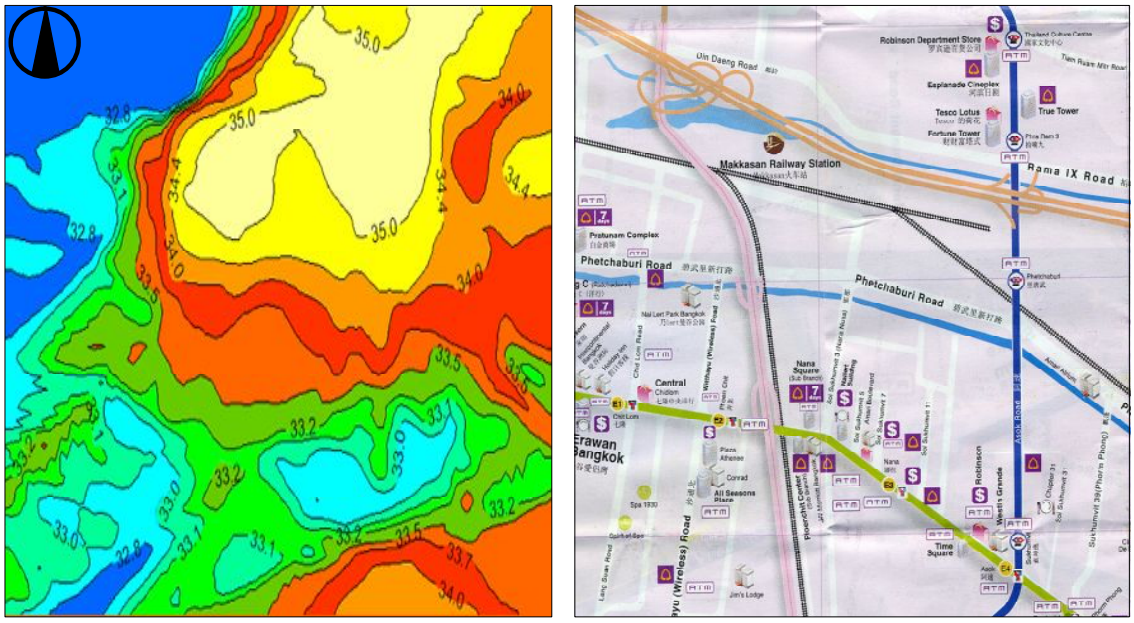
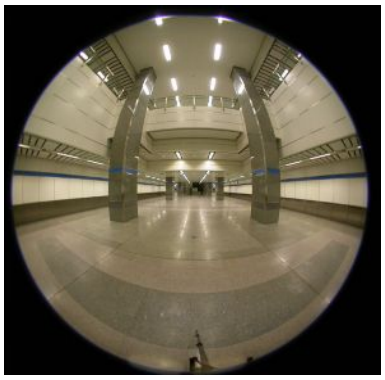


Figure.5 Result of the outside temperature measurement

Fiture.6 Subway car

Fiture.7 Platform



Fiture.8 Ticket Gate Floor

Research Method

There are three methods taken for this research. The first is the measurement of outside temperature by automobile to determine the thermal condition in Bangkok. The second method is the measurement of the thermal comfort on the subway platform and in the subway car by using a PMV meter. The third method is the measurement of human body heat in the subway car.

Figure 5 shows a thermal map in Bangkok drawn by the measured temperature. By the figure it is obvious that the temperature along Asoke road is higher than other places. It is probable that this disparity is caused by exhaust heat from automobiles stuck in traffic congestion.

Figures 6, 7 and 8, show fisheye photos of the subway car and the platform at the Thai Cultural Centre station.

Actual Thermal Condition on Subway Car

The temperature distribution in the subway car is shown in Figure 8. The centre part of the subway car marked the lowest temperature, and that is between 19 and

21 degrees centigrade. One reason is the air conditioner's emission is fixed in the centre of the ceiling. At the subway car's front and back parts, the tendency of the temperature formation is alike. These temperatures have a range between 21 and 24 degrees centigrade. The temperature marked beside a subway seat was the highest, with the temperature changing between 22 and 26 degree centigrade.

The Actual Thermal Condition of Inside and Outside of the Subway Station

The outside ambient temperature was about 32.5 degrees centigrade during the survey. At the ticket gate and platform, situated in underground spaces, there was not a big temperature difference. Comparing these two places, the ticket gate marked a little lower temperature than the platform. The difference of the temperature between the exterior and the interior of the subway station was over 6 degrees centigrade. This difference has been known to cause heat-stokes.

Comparing the temperatures in the subway car, the maximum temperature difference is 10.5 degrees centigrade. This huge difference in temperature causes heat-stress on the human body, noting a former study on thermal comfort.

Human Skin Temperature on Subway Car

Figure 11 shows the human skin temperature while in a subway car. The skin temperature relates to how a human body feels the temperature.

Thermo sensors were put on some parts of human bodies, such as abdomen, chest, forearm, hand, instep, thigh, forehead, and then the skin temperature (was averaged).

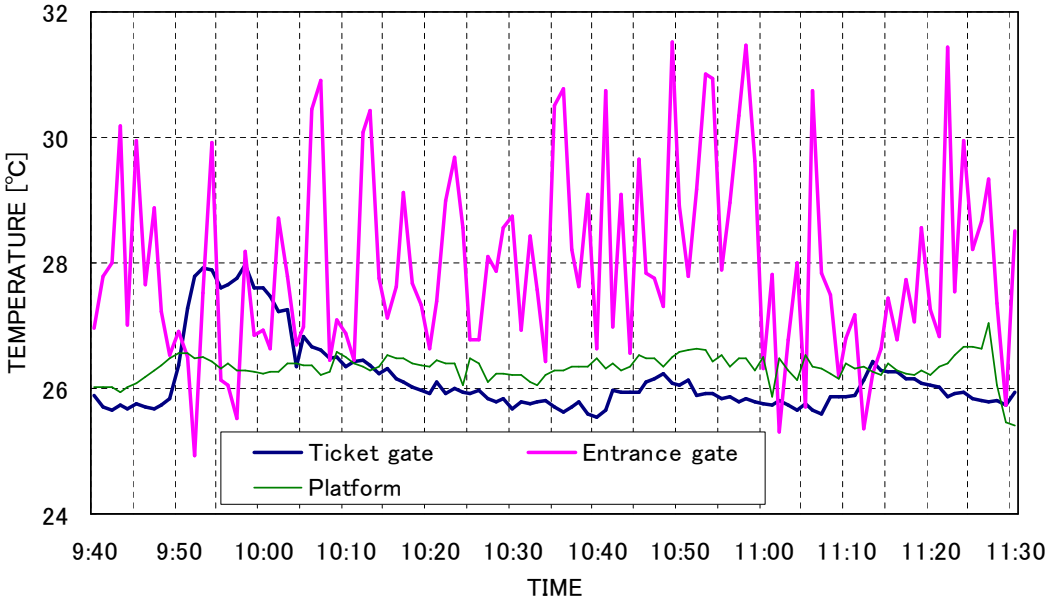


Figure.9 Temperature at Subway Station

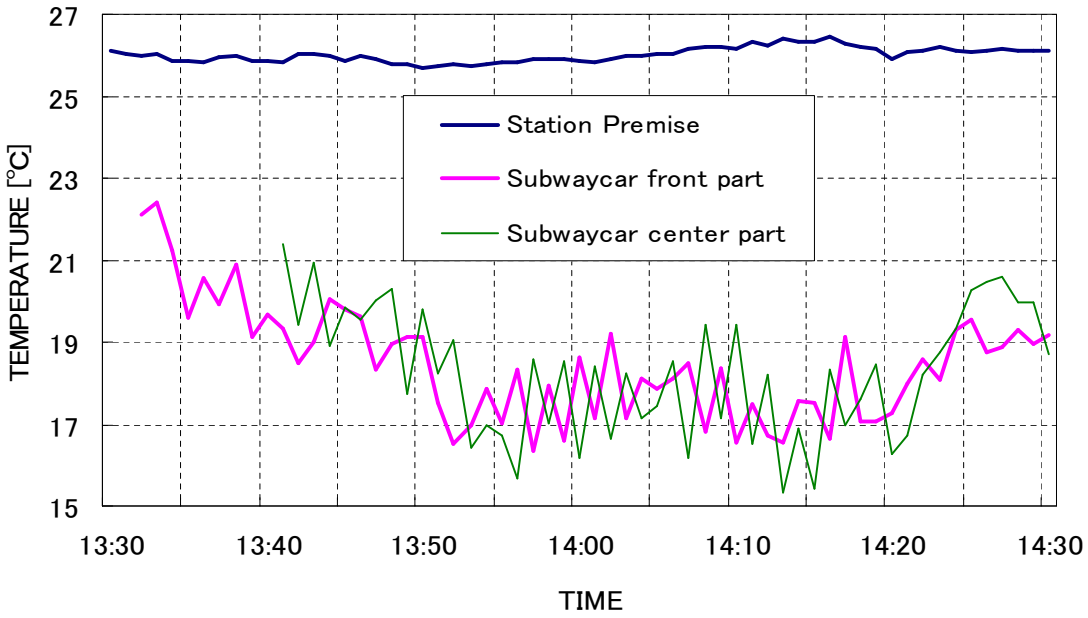


Figure.10 Temperature on Subway Car

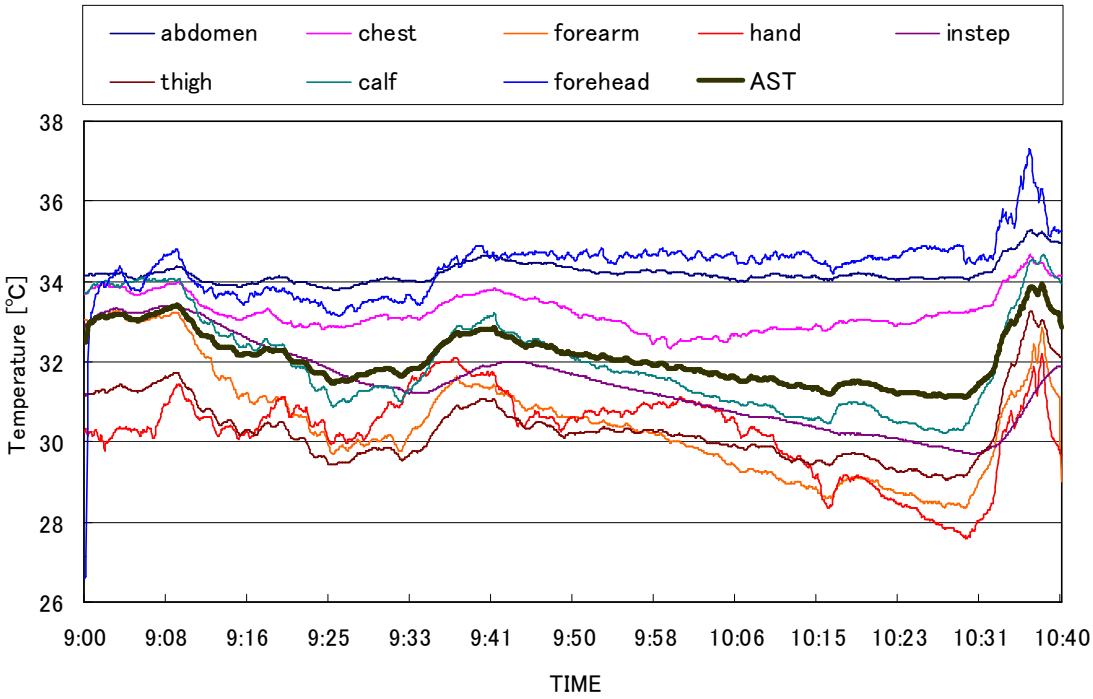


Figure.11 Skin Temperature on Subway Car

The time between 9:41 to 10:14 was the time which the data was collected on a subway car. The temperature at the thigh dropped about 3 degrees centigrade. The average skin temperature also dropped the same. However, the ratio of the temperature dropped gradually.

Focusing on the body parts the temperature on four limbs showed a clear tendency toward the ambient temperature of the subway car.

Predicted Mean Vote

Predicted Mean Vote (PMV), the index for human thermal comfort and the range for 'comfortability', is known to be between ±0.5. In Figure 12 the measurement is shown. The result on the platform and at the ticket gate is marked about 0.5 degrees centigrade. This proves that the thermal environment at those places is well designed. However, the thermal environment in the subway car, or the PMV, is less than -2 degrees centigrade. Negative effects on human health are possible if endured by passengers in such an environment for long periods.

Predicted Percentage of Dissatisfaction

Predicted Percentage of Dissatisfaction (PPD) is the index for the discomfort of humans. When the value of this index is less than 20%, the thermal environment is counted as adequate. According to the result in Figure 13 and 14, the entrance gate of the subway station (exterior) is rated as uncomfortable space. For the subway car, on the other hand, the measured result was 60±20%. This shows that the thermal environment in the subway car is not adequate for human satisfaction.

Conclusion

There is not much research that focuses on the thermal environment in underground spaces such as subway stations. For that reason, the data obtained by the September survey is believed to be quite valuable to the academic and practical fields. Furthermore, since there is no former study on the thermal comfort at subway stations, this research will be valuable data in developing more appropriate air conditioning usage. The results obtained are as following:

The thermal environment around a subway ticket gate and platform is between the PMV ranges of ±0.5, with a PPD range of less than 30%. This concludes that the air conditioning at those places is adequate. However, the thermal environment within a subway car needs to be ameliorated. The temperature setting of air conditioning can be higher than actual setting and in turn will provide a more comfortable thermal environment for passengers, as well as reduce energy consumption at subway stations.

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Notes:

When using numbers in writing, common practice is to spell out numbers up to ten, using whole numbers thereafter. Frequently, and particularly in research papers, you will find the use of both. e.g. ‘there were four (4) examples….’

1. Skin Temperature on Subway Car. I suggest making clear the difference between the subway car’s (metal) skin temperature, and a human’s skin temperature. Therefore: Human Skin Temperature while in a Subway Car
2. Predicted Percentage of Dissatisfy; Dissatisfy is a verb. Dissatisfaction is the noun. There is no such word as uncomfortability (or comfortability). When making up a new word use abbreviated quotes/apostrophes: ‘uncomfortability’. Best to use a known word: ‘discomfort’.