STUDY ON ENVIRONMENTAL FACTORS AFFECTING SUBWAY-PASSENGERS COMFORT

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The urban transit system is an important transportation form used in major cities around the world. In the case of Seoul, more than 8 million people are using the subway network across 9 different stations with 327.1km long railroad. The subway history of Seoul is particularly considered beyond simple transportation facility but as an underground living environment since it is connected with large shopping district and complex cultural facilities. Thus improving the public’s convenience and satisfaction is an important issue of the city. However unfortunately, we have limited research covering this kind of important issue. This paper comprises assessments of physical environmental factors which may affect the comfort of the passengers; such as thermal, light, acoustical and air environments. Moreover, a survey on diverse environmental factors was undertaken to analyze correlations. We also compared two separate stations, one which the passengers felt comfort and the other which was unpleasant, by measuring brain wave to derive biological reaction. The results were used to study the cause of environmental factors which the passengers actually feel and emotional factors.

Introduction

The subway system in Seoul is perceived as an important means of public transportation in Korea, and along with the continuous extension of subway operation routes, the number of passengers is also increasing. In particular, the number of transportation passengers seen as vulnerable is increasing due to an aging population, and the subway as an economical means of transportation for
ordinary citizens is increasing in importance more than ever before. Furthermore, providing a comfortable indoor environment to many public transportation passengers can be an important factor for improving health, comfort, and productivity because subway stations are shifting beyond a concept of a simple station to a commercial and cultural space.

Unlike conventional indoor spaces, subway stations are representative of semi-opened spaces and transitional spaces. In these subway stations, both the physical environment and the bodies of subway passengers are in fluctuating states. In other words, the stations are spaces where people stay for a short time and where people move and walk about. At the same time, there is a diverse range in the ages and genders of the subway passengers. Examining the comfort of a subway station, Abbaspour et al. (2008) evaluated the thermal comfort of a Teheran subway station in summertime, and the study concluded that an ideal, or even an acceptable, thermal environment was not provided to passengers. A study by Ordódy (2000) reached similar conclusions; passengers of a Budapest, Hungary subway station felt a little cold in winter and a little warm in summer.

In South Korea, studies related to subway stations have focused on measurements of the physical environment (Kim et al., 2008; Kim et al., 2009; Yeo et al., 2008), mainly on the thermal environment and indoor air quality, whereas studies investigating the comfort of passengers have been insufficient.

This study aims to examine how the physical environment of subway stations in Seoul changes depending on seasons; how the comfort of passengers changes; how the evaluation of comfort changes according to characteristics of passengers; and what the comfort evaluation characteristics of the stations are and how they differ from conventional buildings. The purpose of this study is to evaluate passenger’s comfort in subway stations.

Methods

Monitoring Stations
Six subway stations in Seoul were selected and a survey was carried out targeting subway passengers.

Questionnaire Survey
To evaluate the comfort of the indoor environment in subway stations, surveys of subway passengers were conducted. The survey was carried out on weekdays during August 12th-18th, 2014 in the summer, October 21st – November 6th, 2014 in the transitional season, and January 6th-22nd, 2015 in the winter. For the surveys, six busy transfer stations were selected from the subway stations in Seoul. The surveys were conducted at two locations in each of the six stations, i.e., platforms and concourses. Considering the fluctuation in the number of passengers over the course of a day, the survey was conducted from 08:00 – 22:00 at every station. To consider demographic factors, male and female passengers of various ages were selected. To evaluate the comfort of subway passengers, the on-site surveys were conducted. The questionnaire of comfort was consisted of
Figure 1. Schematics of monitoring stations indicated with the sampling points.

Figure 2. Measuring equipment on site.
five environmental factors; thermal, air, light, acoustic and overall comfort. Each items were consisted of a five-point scale for each comfort (1: So discomfortable, 2: Discomfortable, 3: Neutral, 4: Comfortable, 5: So comfortable). The surveys were carried out using tablet PCs so that quickly moving passengers could briefly and rapidly respond to questions. Physical quantity measurements were carried out simultaneously with the survey, and only the physical quantities observed between 08:00-22:00 were used in analyzing the results, which corresponds to the timeframe in which the passenger surveys were conducted.

Data analysis
SPSS v.21.0 was used to analyze the survey data. To identify the demographic factors of survey participants, a frequency analysis was completed, and to derive differences in comfort evaluations by group, a one-way ANOVA was used.

Results

Characteristics of the physical indoor environment in subway stations
Figure 3 shows the results of indoor temperature and humidity in each subway station with outdoor conditions during summer time. Indoor temperature of platform was higher than that of concourse or outdoor, however, humidity showed the opposite pattern with temperature.

Figure 3. Average outdoor and indoor temperature and humidity for each station during the rush hour.
Table 1 shows the thermal comfort index, predicted mean vote (PMV), of each station during the summer time. For concourse, station A1 showed the highest PMV value of 1.3 and A2 showed the lowest value of 0.7. For platform, A1 showed the highest and C2 showed the lowest PMV values as shown in Table 1. Therefore, predicted percentage of dissatisfaction (PPD) of passengers using station A1 was about 50%.

According to the whole season analysis, air temperature was shown to be higher at the platforms than the concourses in all seasons. In the case of summer season, the temperature remained relatively consistent with time, and in the case of winter measurements, indoor temperatures were a little colder than usual. The black bulb temperature was also shown to be higher at the platforms than the concourses. The HVAC system for air cooling was operating in summer time, but there was no air heating for winter time in all subway stations of Seoul. For the humidity, the summer and winter values at the platforms and concourses were similar to each other, but differed from autumn levels. The highest average of air velocity was 0.23 m/s for the concourses in the winter, and the lowest average was 0.06 m/s in the summer. Although the air velocity of subway stations differed between seasons, the differences were not large.

Results of Questionnaire
The respondents were 1739 people of various ages. As a result of the survey on the evaluation of each comfort, most respondents answered they felt ‘neutral’ or ‘comfortable’ for thermal, air and light environment. The respondents who answered ‘discomfortable’ were more than other responses relatively for acoustic environment. And there were gender differences significantly for the evaluation of air and acoustic environment. The evaluation from male was better than on female. As a result of the relative weights of the four factors contributing to the overall comfort, all factors contributed significantly and air environment was the highest contribution to the overall comfort and there were also gender differences of relative weights of the factors.

The proportion of respondents responding ‘Neutral’ was higher than 50% in all three seasons, followed by ‘comfortable’ on the thermal environment and the overall comfort. For the comfort on the air environment, the response of ‘Neutral’ was highest, followed by ‘discomfortable’ in the autumn and winter. Females showed higher evaluation scores than males, and the average value for the light environment was highest for both males and females, respectively. During summer, the difference in comfort evaluation between genders in the air environment and acoustic environment were significant. In autumn, the differences were significant for thermal environment, air environment, and overall comfort; and in winter, air environment was significant. Regardless of season, evaluations of air environment from females were lower than that from males. As the result of the age difference on each comfort, statistically significant differences were shown in the thermal environment, light environment, and overall comfort in the summer; and in all factors by age for
Table 1. Thermal comfort index during operating hour (average and standard deviation)

<table>
<thead>
<tr>
<th>Subway station</th>
<th>PMV (-) Concourse</th>
<th>PMV (-) Platform</th>
<th>PPD (%) Concourse</th>
<th>PPD (%) Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>1.3±0.3</td>
<td>1.8±0.4</td>
<td>41±17</td>
<td>64±17</td>
</tr>
<tr>
<td>A2</td>
<td>0.7±0.2</td>
<td>1.2±0.3</td>
<td>15±7</td>
<td>39±17</td>
</tr>
<tr>
<td>B1</td>
<td>1.1±0.2</td>
<td>1.3±0.2</td>
<td>33±9</td>
<td>39±10</td>
</tr>
<tr>
<td>B2</td>
<td>0.9±0.3</td>
<td>1.4±0.2</td>
<td>23±12</td>
<td>46±11</td>
</tr>
<tr>
<td>C1</td>
<td>1±0.5</td>
<td>1.5±0.2</td>
<td>31±25</td>
<td>53±13</td>
</tr>
<tr>
<td>C2</td>
<td>1.1±0.3</td>
<td>0.4±0.4</td>
<td>34±12</td>
<td>12±8</td>
</tr>
</tbody>
</table>

Figure 4. Percentage of each factor on comfort

autumn and winter. Teenagers responded with the highest comfort evaluations and people in their 40s and 50s offered overall low comfort evaluations.

Conclusion

As a result of the physical indoor environment measurements in the subway stations, it was concluded that the relative humidity was high in the summer, and
the temperature was generally low in the winter. Comfort evaluations of subway passengers based on environmental factors had the greatest response of ‘Neutral’ for all factors and for the overall comfort evaluation. The relative humidity was high in subway stations during summer, and the temperature was very low in the winter, demonstrating how environmental factors can create discomfort for subway passengers. However, most passengers felt that the comfort rating of the subway stations was either ‘Neutral’ or ‘comfortable’. According to Chun et al. (2005), the thermal comfort of transitional spaces is determined by the relative temperature of the current location compared to the temperature of the space a person was previously in; this is due to rapid temperature changes caused by individuals walking in a space, and those in transitional spaces experience a wider range of thermal sensations. Subway stations are transient spaces where passengers remain for a very short time, approximately 2–3 minutes, unlike time spent in conventional indoor spaces. The air velocity also differs because passengers continue walking to the platforms once they have come inside the station. Furthermore, individuals wear different clothing and this is expected to result in differences from individuals in conventional office buildings, for example. On the other hand, the expectation for a comfortable indoor environment is low in subway stations compared to conventional offices or houses and the comfort evaluations were relatively high. As a result of the gender difference on each comfort, the overall score was lower for females than males. Comfort evaluations of subway passengers by environmental factor by age, in all seasons, were the highest for teenagers and lowest for those in their 40s and 50s. Large differences in user age by station or time frame could be helpful in environmental management.

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References