A Design Approach for Visual Environment of Passenger Rooms for Public Transport to Increase Comfort

Takayuki HIRASAWA and Yoshihiro SUDA

Advanced Mobility Research Center (ITS Center), Institute of Industrial Science, The University of Tokyo

Received August 8, 2013, Accepted May 26, 2014

ABSTRACT

A design methodology for both comfortable and accessible passenger rooms for public transport has been developed based on observation and modeling of seat-taking behaviors. The developed model consists of variables of visual environment of passenger rooms, whose parameters are identified through full-scale mockup experiments. The model enables quantitative comparisons between design alternatives of seat arrangements and door usages, thus this has been applied to propose seat arrangements for railway vehicles, light rail vehicles and a new unmanned energy-saving small urban transport system called “Eco-Ride” with small additional procedures for model extension.

KEYWORDS: design method, behavior model, comfort evaluation, visual environment, passenger room, public transport

1. Introduction

To promote the usage of energy-saving public transport expected to enhance town mobility in aging societies, efforts to make public transport services more attractive are always desired. In the 1st-ranked “Smart City”, Vienna (Austria), results of policies to promote the usage of public transport by charming public transport services in the city network (found fare adjustment organization over operators, densely locate transit stops, supply varieties of user-friendly tickets, increase the number of low-flooried light rail vehicles etc.) have achieved the modal split of 36% in 2011 which was targeted almost 40 years ago\(^5\). As Suzuki surveyed\(^9\), out of many comfort factors claimed by railway passengers, visual factors accounted for 26.0% which was even larger than riding comfort (15.6%) and noise (9.0%). These above support the idea that proper engineering methods to improve public transport services are expected, and especially the designing models to improve visual environment of passenger rooms for public transport are anticipated. Thus this paper deals with designing model of passenger rooms for public transport: railway vehicles, light rail vehicles and a new unmanned energy-saving small urban transport system called “Eco-Ride”, to enable quantitative comparisons between design alternatives from viewpoints of both comfort and accessibility.

2. Needs of model-based design approach of passenger rooms for public transport

Nowadays the reasons to increase the share of public transport modes have been shared with the keyword of sustainability, while every city in the world is still struggling to gain modal split of public transport through appealing means such as introducing fascinating light rails transit (LRT), coupling with convenient park-and-ride services, introducing fair-priced tickets or smart cards etc. Once the overall scheme of transport service is completed, it comes to the stage of designing concrete service forms in passenger rooms. The transport planning in the field of civil engineering does not support this microscopic level of designing problems even though they have developed methods to solve choice set selection problems among transport modes and have applied to transport planning\(^1\). The environmental psychology in the field of architecture deals with designing methods in detail such as publishing guidelines for lighting environment design\(^5\), while there existed no macroscopic methods to evaluate comfort of passenger rooms of public transport from the viewpoint of providing evaluation formula to compare diverse seat arrangements and door usages until the proposal of physical models for railway vehicles by Suda et al.\(^4\) and for light rail vehicles (LRVs) by Hirasaki et al.\(^5\).

While as denoted by Suzuki\(^9\), claimed comfort of railway express vehicles was composed of physical factors (33.5%) including vibration (15.6%) and noise (9.0%), seat factors (40.5%) including seat pitch length (9.3%) and seat size (7.6%), and visual factors (26.0%) including interior design (13.6%) and over-window scenery (5.9%). This supports the necessity of systematical designing methods for comfortable cabin environment of railway
vehicles from viewpoints of seat and visual environment. This paper thus intends to provide a feasible design procedure of comfortable passenger rooms for diverse public transport by developing comfort evaluation formulas which are composed of variables of passengers’ visual environment and explain seat-taking behaviors.

3. Formulation of passengers’ seat-taking behavior

3.1 Fundamental model for railway commuter vehicles

The original comfort evaluation model proposed by Suda et al. was derived from observation of seat-taking behaviors in operating railway commuter vehicles (Figure 1). The digits in the lower columns show averaged orders of taken seats in each seat arrangement. In the box seat with seat pitch 1500 mm (Figure 1(a)), the first selected seat was the seat “a” which faces the running direction of the train and has best over-window view. The second and third taken seats were “d” and “b” because the passengers want to keep away from the personal spaces of the arrived other passengers on the seat “a” and “d”. The last taken seat “c” was often left vacant because the legs of passengers between the seats “b” and “d” disturbed the aisle. In the long seat (Figure 1(b)), the first and second seats were the edge seats “a” and “g” whose distances from the boarding/alighting doors are the shortest. The following normal seat-taking orders also showed their inclinations to keep the personal spaces with each other.

These observations above suggest that passengers choose and take a vacant seat in the room considering space environment (walking distance, disturbance on the aisle) and visual environment (seat direction, view from the seat). And thus the authors simply assumed the comfort maximization principle that every passenger standing at the doorway of railway vehicle chooses the most comfortable seat from those available in the room considering seat conditions, passenger density and distance from/to the door, and modelled the comfort value of a seat arrangement per passenger $Ev$ as formula (1) using total passenger number $n$ and comfort value $et[i][j]$ for passenger number $j$ and passenger boarding order $i$.

$$ Ev = \left( \sum \max (ev[i][j]) \right) / n \quad (1) $$

In railway vehicles with no restrictions in the door usage, doors for boarding and alighting can be regarded equal. Hence the comfort value $et[i][j]$ was simply formulated to describe boarding situations with variables of in-vehicle visual space components from the door and travelling time $t[i]$ as given from formulas (2) to (4) corresponding to the seat types: 1: sitting seat, 2: standing seat and 3: semi-standing seat (standing seat in front of sitting seat with possibility $p$ of getting a sitting seat).

$$ ev_1[i][j] = - L[i][j] - a \cdot \text{phs}[i][j] + \beta \cdot \text{Cs}[i][j] \cdot t[i] \quad (2) $$

$$ ev_2[i][j] = - L[i][j] - a \cdot \text{phs}[i][j] + \gamma \cdot \text{Us}[i][j] \cdot t[i] \quad (3) $$

$$ ev_3[i][j] = - L[i][j] - a \cdot \text{phs}[i][j] + \gamma \cdot \text{Us}[i][j] \cdot t[i] \cdot (1 - p) + \beta \cdot \text{Cs}[i][j] \cdot t[i] \cdot p \quad (4) $$

$$ L[i][j] = Lr[i][j] / \delta \quad (5) $$

Here $L[i][j]$ is the distance between the door and the seat occupied by the walking distance $Lr[i][j]$ divided by coefficient $\delta$ to consider the psychological resistance by the physical disturbance of the other arrived standing passengers on the aisle as formula (5). $a$, $\beta$, $\gamma$ are coefficients to be multiplied with physical resistances by the legs of arrived other sitting passengers on the route $\text{phs}[i][j]$, comfort values of sitting seat $\text{Cs}[i][j] (>0)$ and standing seat $\text{Us}[i][j] (<0)$. The values of $\text{phs}[i][j]$, $\text{Cs}[i][j]$ and $\text{Us}[i][j]$ are updated with the occupation of seats by the other arrived passengers. The passenger density was fixed to 100% and the ratio $p$ was fixed to 50% both for simplification.

In addition to the comfort descriptions above from viewpoints of passengers’ convenience, discussions on accessibility from viewpoints of operators’ efficiency are also vital as mass transit for daily use. Suda et al. introduced the accessibility index $Et$ as getting-off time of half the passengers which is explained by the getting-off time of one passenger from the farthest seat to the alighting door $ef[i][j]$ and the coefficient $\tau$ as formula (6).

Here $ef[i][j]$ was composed as the measured average walking speed on the aisle $V$ [m/s] (0.67 [m/s]) plus additional required time to detour the legs of arrived sitting passengers on the route as formula (7).

$$ Et = \tau \cdot \max (et[i][j]) \quad (6) $$

$$ et[i][j] = Lr[i][j] / V \cdot \delta + \text{phs}[i][j] \quad (7) $$

Thus the comfort and accessibility of any seat arrangement of railway vehicles were expressed with variables of space factors and visual factors in the behavior context of boarding from a door and walking to
the best-evaluated vacant seat. All the parameters were identified through boarding experiments at the real-scale railway cabin mockup to best describe the sitting order of subjects as below: \( \alpha = 5.01 \), \( \beta = 4.79 \), \( \gamma = 2.90 \times 10^{-5} \), \( \delta = 0.77 \).

### 3.2 Extended model for light rail vehicles and more

Based on the comfort description model for railway commuter vehicles above, the extended comfort evaluation model proposed by Hirasawa et al.\(^7\) went further to express influences of steps at doorways and different door usages in boarding and alighting, also derived from observations of seat-taking behaviors in operating low-floor (without steps) and high-floor (with steps) LRVs.

To cope with different factors of LRVs on physical structure (steps at doorways) and operational conditions (door usage, fare transaction), the authors classified the LRVs with the train length (Single car/Linked train), steps at doorway (with Steps/with No steps) and the type of door usage (from type 1 to type 3) as Tables 1 and 2.

**Table 1** Types of fare transaction and door usage of LRVs\(^7\)

<table>
<thead>
<tr>
<th>Train length</th>
<th>Steps at doorway</th>
<th>Type of door usage in boarding and alighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>S: Single car</td>
<td>S: with Steps</td>
<td>1: board from the middle door and alight from the front door</td>
</tr>
<tr>
<td>L: Linked train</td>
<td>N: with No steps</td>
<td>2: both doors available in boarding and alighting</td>
</tr>
</tbody>
</table>

In the off-peak morning hours at two types of LRVs at Kumamoto municipal transport in Japan (SS1: high-floor, LN2: low-floor), the observed average travel times in inbound trips were about 15 min, and the passenger densities ranged from 50% to 90%; thus the standard evaluation conditions for the modeling target were set as: travel time=15 min, and passenger density=50%.

To explain the observed inclination of passengers’ concentration to the alighting door due to the separate usage of doors in boarding and alighting caused by the in-vehicle fare collection at the driver or conductor, the authors introduced an extended model to express the changes in seat-taking behaviors.

The discomfort by the walking distance \( L_{ij} \) and the psychological resistance \( phs[i][j] \) at the comfort evaluation formulas from (2) to (4) at railway vehicles were for LRV models replaced with the walking distances from the boarding door \( La[i][j] \) and the alighting door \( Ld[i][j] \) and the psychological resistances in the aisles from the boarding door \( phsd[i][j] \) and to the alighting door \( phsd[i][j] \). If we name these parts of discomfort as \( Ud[i][j] \) and \( Ud[i][j] \), the total discomfort in boarding and alighting accessibility \( Ud[i][j] \) can be modelled with the extension ratio of psychological walking distance \( d \) as the increase of psychological discomfort by door separation, and the weighting function \( \varepsilon (0<\varepsilon<1) \) as the alighting contribution factor to describe the inclination to the concentrate to the alighting door as formulas from (8) to (10).

\[
Ua[i][j]=-La[i][j]-\alpha \cdot phsd[i][j] \tag{8}
\]

\[
Ud[i][j]=-Ld[i][j]-\alpha \cdot phsd[i][j] \tag{9}
\]

\[
Uad[i][j]=(1+d) \cdot ((1-\varepsilon) \cdot Ua[i][j]+\varepsilon \cdot Ud[i][j]) \tag{10}
\]

The ratio \( d \) was further simply modeled as linear summation of passenger density \( \eta \%\) and the distance between doors \( LD[m] \) with coefficients \( A \) and \( B \):

\[
d=A \cdot (\eta-1)+B \cdot LD \tag{11}
\]

Another factor to express the discomfort by passing the steps at doorways per step were modelled for upward \( \delta_u \) and downward \( \delta_d \) whose values were borrowed from at-depot experimental data of double-deck railway commuter vehicles with staircases \( \delta_u=1.08 \), \( \delta_d=0.68 \), where \( Nu \) and \( Nd \) are numbers of steps upwards and downwards.

\[
-\delta_u \cdot Nu-\delta_d \cdot Nd \tag{12}
\]

In addition, another psychological resistance of path narrowing effects by the other arrived standing passengers on the aisles was also introduced as additional walking extension time per location \( narrowPhs[i][j] \) multiplied by coefficient \( a \) as follows:
\[-a \cdot \text{narrowPhs}[i][j]\]  \quad (13)

In the end, the shapes of extended formulas for LRVs became as follows:

\[
e_{v_1}[i][j] = Ua_d[i][j] + \beta \cdot Cs[i][j] \cdot t[i] - \delta_a \cdot Nu - \delta_d \cdot Nd
\]

\[
e_{v_2}[i][j] = Ua_d[i][j] + \gamma \cdot Vs[i][j] \cdot t[i] - \delta_a \cdot Nu - \delta_d \cdot Nd
\]

\[
e_{v_3}[i][j] = Ua_d[i][j] + \gamma \cdot Vs[i][j] \cdot t[i] \cdot (1 - p)
+ \beta \cdot C_e \cdot t[i] \cdot p - \delta_a \cdot Nu - \delta_d \cdot Nd
\]

(14)  
(15)  
(16)

As to accessibility, the evaluation index for railway commuter vehicles is also applicable for LRVs by additionally dealing with new resistances of steps at doors and aisle narrowing effects, however the situations of half-passenger alighting were not observed in the operating conditions and thus another model to describe dwell time at transit stops were modeled in detail as in another article\(^9\).

The above discussed extended models for LRVs can further be also applicable to other public transport modes by introducing necessary additional factors, and the authors actually already have used in designing a cabin space (door location, seat arrangement) for a new unmanned energy-saving small public transport system called “Eco-Ride”\(^10\) as described in a following chapter.

4. Parameter Identification of developed models

4.1 Experiments at full-scale mockup

To identify the parameters introduced in each comfort and accessibility evaluation model, it is almost impossible to compare all the interested conditions in operating vehicles. It is also quite hard for the subjects to precisely imagine the detailed differences of conditions and answer questionnaire surveys. Thus the full-scale mockup for railway commuter vehicles in the Chiba Experimental Station, the Institute of Industrial Science, The University of Tokyo (Figure 2) was applied for LRV experiments by adjusting the cabin width, the number of sitting seats per vehicle to be realistic.

A series of measurement experiments were conducted using this full-scale vehicle mockup as described in articles (6) and (7). This chapter outlines the essential procedures at the extension for LRVs.

4.2 Seat-taking experiments for comfort model

A series of conditions at the full-scale LRV mockup were designed as shown in Table 3 and seat-taking experiments were conducted three times for each condition. The experimented cases were from SN1 to SN3 defined in Tables 1 and 2.

To efficiently simulate different passenger density conditions within the prepared 26 subjects, full-scale dummies were placed on several seats to compensate for the shortage of subjects and thus the visual environment of in-vehicle spaces were realistically simulated.

Each subject was instructed to assume a common travel time and sequentially move from the boarding door to take one of the vacant seats (including standing seats) in an ordered queue with sufficient time interval from the previous subject, so that the order of taken seats can be regarded to describe that of most comfortable vacant seat in the LRV mockup.

The parameters \(d\) and \(\varepsilon\) were heuristically sought that best describe the averaged seat-taking order of first ten subjects out of three-time experiments, where the value of \(d\) was explored from -1.0 to 1.0 by 0.1 steps and that of \(\varepsilon\) was explored from 0 to 1 by 0.1 steps.

First from the experiment No. 4 with short travel time where subjects are supposed to follow the perfect alighting standard (\(\varepsilon=1\)), the value of \(d\) that best describe the experiment result was explored as \(-0.3\) (Figure 3).

From another comparison between No. 3 and No. 5 (the same \(\eta\) and \(LD\) in formula (11)), the values of \(\varepsilon\) were

<table>
<thead>
<tr>
<th>No.</th>
<th>Case classification</th>
<th>Travel time [min]</th>
<th>Passenger density [%]</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SN1 (mockup)</td>
<td>15</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>SN1 (mockup)</td>
<td>15</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>SN1 (mockup)</td>
<td>15</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>SN1 (mockup)</td>
<td>5</td>
<td>50</td>
<td>(\varepsilon=1)</td>
</tr>
<tr>
<td>5</td>
<td>SN2 (mockup)</td>
<td>15</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>SN3 (mockup)</td>
<td>15</td>
<td>50</td>
<td>(\varepsilon=\text{any}, \ L=0)</td>
</tr>
</tbody>
</table>
explored to be $\varepsilon=0.7$ (No. 5) and $\varepsilon=0.5$ (No. 3). This tendency of larger weight on alighting than on boarding supports the convergent seat-taking behaviors near the alighting door at LRVs in commercial operation. From the experiment No. 6 ($L=0$, $\varepsilon=$any) boarding and alighting from any door, the value of $d$ was explored as $-0.5$. And thus the parameters at the formula (11) are solved as: $A=1$, $B=0.04$. This highlights the negligible effect of door usage restriction to the increase in discomfort of in-vehicle walking path compared to that of passenger density. Finally from experiments No. 1 to No. 3 with the same door usage and travel time, the values of $\varepsilon$ were explored as: 0.7 (No. 1: $\eta=90\%$), 0.5 (No. 2: $\eta=70\%$) and 0.5 (No. 3: $\eta=50\%$). This result explains the tendency that passengers with poorer visibility from the boarding door in higher passenger density will think more of the convenience in the alighting. The validity of the developed model was thus certified by the ecological explanation of seat-taking phenomena.

4.3 Getting-off experiments for accessibility model

At the same full-scale LRV mockup, a series of alighting time of one passenger from the farthest seat from the alighting door at passenger density 100% were measured at three types of door usage (SN1, SN2, SN3) at the end of the above seat-taking experiments (as for SN3, both at the front and middle doors). To compare the measured time at experiments with simulated alighting time from the accessibility evaluation model for commuter vehicles, narrowPhs[i][j] per section is calculated to be 1.00 [s]. This additional modeling of path narrowing effect has realized good explanation of alighting time for accessibility simulation model (Figure 4).

5. Model application and discussion

5.1 Usage and usability of the developed model

The above procedure has provided designers of passenger rooms for public transport with quantitative methods to compare design alternatives from viewpoints of comfort and accessibility. If they input parameters of line conditions (travel time, passenger density), room geometry (seat arrangement, amount of steps at doorways, door positions) and service operation type (door usage, fare transaction), the developed model outputs the comfort (comfort evaluation value) and accessibility (alighting time from the farthest seat) in digits (Figure 5).

This means that service providers of public transport becomes able to digitize their current service status and pursue better alternatives that make full use of limited resources of passenger rooms. The point with this evaluation model is that this even provides designers who hit upon virtual improvement ideas of seat arrangements with numerical outputs from viewpoints of both users (comfort) and operators (accessibility).

The developed behavior models also follow the Gibson’s ecological approach\(^{[1]}\), namely the literal description of interactive behaviors of passengers with circumstances (in-vehicle visual space) and each other (the other passengers) using simple variables of visual environment of passengers regarding simplified standard conditions (such as same travel time, passenger density etc.).

---

**Figure 3**  Seat-taking order for LRVs\(^{[7]}\)

**Figure 4**  Alighting time of one passenger from the farthest seat\(^{[7]}\)

**Figure 5**  Chart of comfort and accessibility evaluation

*Newly Introduced variables for LRVs*\(^{[7]}\)
5.2 Application samples for railway vehicles and LRVs

As described at railway commuter vehicles, the last seat in the 4-seater box seat is often left vacant due to poor accessibility by the legs of arrived other passengers. This phenomenon can be solved just by widening seat pitch from 1500 to 1600 mm as observed in operating vehicles (Figure 6), however it is sometimes even difficult to secure this length due to size limitations of the cabin.

Another and practical idea within the same in-cabin size is to add a sitting and form a 5-seater box seat as Figure 7. This seat arrangement enables to induce the second arriving passenger to the new additional seat and all the five seats have become taken.

Sample seat arrangements for 3; 4; 6-doored cabins to adopt this idea are given as HB3t; HB4t; HB6t in Figure 8. In the labels for these seat arrangements, HB mean that the half side of them are composed of box seats, the following digits show the number of doors, t is a suffix and the digits in the bracket is the number of total sitting seats.

The effects of adopting these 5-seater box seat arrangements can be expressed by biplots of calculated

![Figure 6](Observed seat-taking orders in box seats of railway commuter vehicles)

![Figure 7](Seat-taking orders in 5-seater box seats)

![Figure 8](Sample seat arrangements with 5-seater box seats)

![Figure 9](Comfort evaluation of proposing seat arrangements for railway vehicles)

*AL (All Long): all the seats are laterally placed, AC (All Cross): all seats are longitudinally forward placed, SB (Semi-Box): box seats and long seats are combined, HC (Half-Cross): half the seats are longitudinally forward placed and half the seats are long seats, RB (Random-Box): box seats are randomly placed, p: suffix for 1600 mm-pitch box seats
comfort and accessibility with other conventional ones as in Figure 9. All the three proposed seat arrangements have been plotted in the right-down area, which means that these seat arrangements show better performance than conventional ones in both comfort and accessibility. This is mainly because they succeeded in increasing the number of sitting seats in the middle of the vehicle cabins without spoiling the accessibility from/to the door.

Likewise service improvement scenarios of LRVs can be plotted as biplots as in Figure 10.

The simulation results about a series of LRV conditions are plotted in parallel with railway vehicles supposing travel time 15 min and passenger density 50%. For simplification, the complete alighting standard (c=1) and no psychological walking distance extension by door usage restriction (d=0) were assumed. The effects of introducing the three following service improvement scenarios were compared with the normal service level SSI (single car LRV, with steps at doorways, boarding from the middle door and alighting from the front door):

1) abolish steps at doorways (to be SN1)
2) abolish door usage restrictions in boarding and alighting (to be SS2)
3) combination of scenarios 1) and 2) (to be SN2)

At the scenario 1), the low level of comfort and accessibility of high-floor one-car LRV (SSI) is certainly improved but it still remains at the level of 2-door double-deck railway commuter vehicles (D-AB2p) just by abolishing steps at passenger doorways (SN1). At the scenario 2), the slightly inferior level to similar-sized 3-door railway commuter vehicles (AL6) with small number of seats is attained. At the scenario 3) by abol-

5.3 Further application sample for new transport

The authors are developing a new unmanned energy-saving small urban transport system called “Eco-Ride” which carries no on-board driving devices and runs using potential energy as the application of roller coaster technologies. The “Eco-Ride” has merits of low initial costs and high flexibility in constructing rail shapes. To decide seat arrangements for experimental “Eco-Ride” vehicles (Figure 11) with high comfort, accessibility and compactness within the definite sizes, the above discussed comfort and accessibility evaluation methods were extendedly applied to assist the judgment.

To compare four types of seat arrangements (Figure 12) and two types of ceiling heights (1650 mm, 1800 mm),

Figure 11 Profile of experimental “Eco-Ride” vehicles (Chiba Experimental Station, the Institute of Industrial Science, The University of Tokyo)

Figure 12 Discussed seat arrangements for Eco-Ride vehicles

![Figure 10 Simulated comfort and accessibility of LRV in comparison with railway vehicles (Travel time=15 min)](image-url)
the comfort and accessibility evaluation models for LRVs were modified partly replacing the seat comfort evaluation part from that of mini-van rear seats\(^{12}\) that have similar body width as formula (17).

\[
e_u[i][j] = a \cdot E_s[i][j] + \beta \cdot E_w[i][j]
= a(A \cdot V_p[i][j] + B \cdot V_o[i][j])
+ \beta(C \cdot L_a[i][j] + D \cdot \text{phs}_i[j] + E \cdot h)
\]  

(17)

Here the comfort value of seat \(e_r[i][j]\) was divided to seat comfort part \(E_s[i][j]\) and dooryway evaluation part \(E_w[i][j]\). \(E_s[i][j]\) was further modelled with physical volume \(V_p[i][j]\) [m\(^3\)] and visual volume \(V_o[i][j]\) [m\(^3\)] of passengers at the seat to express the discomfort by the shortage of personal spaces in small cabins with coefficients \(a\) and \(B\). The decrease of comfort by small ceiling height \(h[m]\) was newly introduced in the expression of \(E_w[i][j]\) with coefficients from \(C\) to \(E\).

A series of experiments were conducted at full-scale “Eco-Ride” mockups with woolen nets to simulate the ceiling and at experimental “Eco-Ride” vehicles (Figure 13).

Based on experiment results (Figures 14 and 15), the best-scored seat arrangement (typeA) in both comfort and accessibility was adopted as the seat arrangement for one of ‘Eco-Ride’ cabins. As no statistically significant differences were measured between the two height levels in comfort and accessibility, the lower height 1650 mm was selected from the viewpoint of pursuing the compact size.

6. Concluding remark

Based on former findings that visual and seat-related components play main roles in the comfort of railway vehicles, this study has provided a quantitative method to evaluate comfort and accessibility of passenger rooms, targeting the situations of choosing design alternatives of in-vehicles layouts for railway commuter vehicles, LRVs and a new energy-saving public transport system “Eco-Ride”.

The points in the developed evaluation method are:

1. the evaluation model are accompanied by explanations of passengers’ in-vehicle behaviors observed in operating vehicles
2. the model is simply formulated with variable of space and visual environment in the context of passengers’ seat-taking behaviors
3. the model can easily be extended even for new transport by introducing additional variables of new space and visual factors
4. the model parameters are identified through full-scale mockup experiments to be visually realistic

As the results, the proposed model has enabled us to compare even virtual scenarios in digits to improve ser-
serves from both user’s and operator’s viewpoints at the same time, dealing with not only seat arrangements but also service conditions such as door usage or fare transaction.

As further studies with this simple-structured evaluation method are expected to contribute to the improvement of existing public transport services, the authors have started to apply the proposed approach to designing variety of transport facilities such as parking facilities and transport nodes because there have similar aspects of being composed of controllable visual factors and been little researches to enhance comfort from viewpoints of users.

The authors would like to thank to all who assisted us in collecting data for this study.

References


(2) City of Vienna: Mobile in Vienna—Transport Master Plan 03/08 (2009).


