JR East has conducted development on comfortable train seats with an aim of proposing a more comfortable final stable form (midline shape and transverse cross-sectional shape) for train seats. First, using a seat form measuring device and a test seat for form examination, we measured the form of existing seats that are seen as being comfortable; and then we created a final stable form that incorporated the measurement results. The developed final stable form was evaluated and amended, and we proposed a comfortable final stable form. Incorporating that form, we produced test seats for sensory evaluation of seat comfort. In that evaluation, the test seats were rated higher than the seats for series E6 pre-mass production cars, proving that the comfortable final stable form would be well accepted when applied to actual seats.

Keywords: Midline shape, Transverse cross-sectional shape, Final stable form, Sensory evaluation
2.2 Form Plan Selection by Sensory Evaluation
We carried out sensory evaluation of the aforementioned midline shape plans reproduced on the test seat for form examination using 14 employees of different physical sizes (ten male and four female). The plans were evaluated in two positions: a reading position where people are seated at a reclining angle of 10° with their heads not on the pillow, and a resting position where people are seated at a reclining angle of 25° with their heads on the pillow. The subjects sat on the test seat for one minute, and then entered their evaluation in a questionnaire sheet. The plans were first evaluated per individual part of the seat in terms of the interface pressure of the shoulders and hips of the respondents for the backrest, and in terms of the interface pressure of their posteriors and thighs for the seat face, and then they were evaluated for the total seat comfort.

As shape plans 1 and 2 received high marks from persons of any physical size in the total seat comfort evaluation results, we decided to adopt these two plans as the more comfortable midline shape.

2.3 Development of Transverse Cross-sectional Shape
Based on the transverse cross-sectional shape when seated for the seat of the committee for seat comfort improvement, we simulated transverse cross-sectional shape on the test seat by attaching lateral shape adaptors shown in Fig. 4. To make the transverse cross-sectional shape fit people of any physical size and shape, it should not be constrictive but should sufficiently support the body. We thus carried out sensory evaluation and adjustment of the simulated transverse cross-sectional shapes with two larger males (181 cm/90 kg, 170 cm/90 kg) and two smaller females (149.7 cm, 153.4 cm), and from that we decided the shape to fit to both physical types of persons.

2.4 Sensory Evaluation by General Subjects
We reproduced on the test seat midline shape plans 1 and 2 selected as noted in section 2.2 and the transverse cross-sectional shape adopted as noted in section 2.3 (for both midline shape plans 1 and 2), and then we carried out sensory evaluation by 90 general subjects (45 males and 45 females). With that, we attempted to identify the advantages and points requiring improvement.

In the total evaluation, the total rate of the responses “excellent” and “good” in the reading position was 51% for midline shape 1 and 55% for midline shape 2, showing that midline shape 2 was slightly better. In the resting position, the total rate of the responses “excellent” and “good” was 50% for midline shape 1 and 63% for midline shape 2, showing that midline shape 2 was better. Accordingly, midline shape 2 received a higher rating than midline shape 1 as the form of a seat. We therefore designated midline shape plan 2 as a candidate for the more comfortable final stable form.

The points for midline shape 2 noted as needing improvement were the vertical interface pressure at the hips (too weak), the back-and-forth interface pressure at the posterior, and the back-and-forth interface pressure at the thighs (both too strong). Those points needing improvement were picked out by individual part of the seat and by individual direction, based on the evaluation results on the interface pressure (vertical, back-and-front and lateral).

2.5 Decision on Final Stable Form
Repeating sensory evaluation and improvement according to the points needing improvement picked out as noted in section 2.4, we decided on an improved shape (hereinafter, “improved shape 2”). We thus carried out sensory evaluation of improved shape 2 with 11 male and female employees of different physical sizes to verify the improvement effect.

In the sensory evaluation, the total evaluation of seat comfort of improved shape 2 showed that seven out of a total of eleven persons gave higher marks to improved shape 2 over that of the original midline shape plan 2. And, among five persons 165 cm or taller, four persons gave higher marks to improved shape 2, while nine of a total of 15 general subjects 165 cm or taller (five males and four females) evaluated midline shape plan 2 as being “slightly poor” in the resting position (no one replied “poor”). That verified the effect of improvement. We therefore decided to adopt improved shape 2 as the more comfortable final stable form. Fig. 5 shows the adopted more comfortable final stable form.
Production of a Prototype Seat

In order to introduce to actual seats the adopted more comfortable final stable form, we produced prototype seats based on the seats for new series E6 cars.

For the form of the prototype seat, we estimated the amount of deflection of the backrest and the seat face based on those of seats for new series E6 cars. Fig. 5 shows the form of the seats for new series E6 cars.

As the backrest form (midline shape), we adopted the form of empty seats for new series E6 cars without modification because the final stable form matched the form of occupied seats for new series E6 cars (amount of deflection from empty 7 mm) on the cross-sections shown in Fig. 5 (a) 5 - 9. On the cross-sections of Fig. 5 (a) 1 - 4, the form of occupied seats for new series E6 cars sagged by 3 - 4 mm from the final stable form, so we raised the form of empty seats for new series E6 cars by 3 mm. The cross-sections of Fig. 5 (a) 10 - 15 were in the non-deformed area, and the final stable form matched the form of occupied seats for new series E6 cars, so we adopted the form of empty seats for new series E6 cars without modification.

For the backrest form (transverse cross-sectional shape) of the prototype seat, we compensated the deficiency of the slanted parts on the both sides the seats for new series E6 cars to reproduce the final stable form, while the center form was adopted without modification.

For the seat face form (midline shape) of the prototype seat, we modified the form of seats for new series E6 cars to make the back part of the seat face cushion thicker (to make the seat face slope gentler) because the final stable form was higher than the form of occupied seats for new E6 cars.

For the seat face form (transverse cross-sectional shape) of the prototype seat, we adopted that seat form without modification because the cross-sections in Fig. 5 (b) 3 - 6 of the seats for new series E6 cars almost matched the final stable form. On the cross-section of Fig. 5 (b) 7 and 8, the rise angle on both sides was changed to 10° of the final stable form because they differed from that of the final stable form. The cross-sections of Fig. 5 (b) 1 and 2 had little effect on the feel. We thus adopted the seat face form of the seat for new series E6 cars, taking into account continuity with the cross-section of Fig. 5 (b) 3.

Seating Comfort Evaluation of Prototype Seat

We carried out sensory evaluation with 50 employees (41 males and 9 females) for the prototype seat that incorporated the more comfortable final stable form.

The subjects evaluated the prototype seat as Seat A and the seat for new series E6 cars as Seat B, but they were not informed of which was which. The seats were evaluated in the reading position and the resting position as noted in section 2.2; however, the reclining angle in the reading position was changed from 10° to 15°. This change was made because there was the concern that the upper body could be too upright and the head could be too low at 10°.

The evaluation items were also the same as noted in section 2.2, but this time we conducted comparative evaluation of seating comfort of the prototype seat and the seat for new series E6 cars. The subjects gave their comparative evaluation after sitting on both the prototype seat and the seat for new series E6 seat.

Fig. 6 and 7 show the absolute evaluation results of seating comfort of the prototype seat and the seat for new series E6 cars respectively. In the total evaluation of comfort when seated in the reading position, the total rate of the responses “excellent” and “good” was 58% for the prototype and 44% for the seat for new series E6 cars, showing a 14-point higher score for the prototype. In the resting position, the total rate of the responses “excellent” and “good” was 48% for the prototype and 42% for the seat for new series E6 cars, with no remarkable difference.
between the two. However, the total rate of the responses “poor” and “slightly poor” was 20% for the prototype and 44% for the seat for new series E6 cars, showing a 24-point higher score for the prototype. In the total evaluation of seating comfort, the prototype seat received a higher rating than the seat for new series E6 cars.

Fig. 8 and 9 show the comparative evaluation results of seating comfort of the prototype seat and the seat for new series E6 cars. In comparative evaluation of comfort when seated in the reading position, the total rate of the responses “excellent” and “good” was 62% for the prototype and 30% for the seat for new series E6 cars, showing a 32-point higher score for the prototype. In the resting position, the total rate of the responses “excellent” and “good” was 54% for the prototype and 32% for the seat for new series E6 cars, showing a 22-point higher score for the prototype. The comparative evaluation results of seat comfort showed that the prototype seat received a higher rating than the seat for new series E6 cars.

### Conclusion

The development results can be summarized as follows.

1. We measured when empty the midline shape of the form of the four types of existing seats seen as being highly comfortable. By making improvements based on the measurement results, we created new midline shape plans. The proposed midline shape plans included those plans and the design shape of an existing seat. We further decided on a transverse cross-sectional shape that would be accepted by both of large males and small females, based on the transverse cross-sectional shape of the existing seat when empty that was produced taking into consideration the transverse cross-sectional shape.

2. We produced a prototype seat that incorporated the more comfortable final stable form. Before that, we measured the midline shape and transverse cross-sectional shape of seats for new series E6 cars, and we estimated the amount of deflection of the prototype seat from the amount of deflection of the backrest and seat face of seats for new series E6 cars. Based on those, we decided the final form of the prototype seat.

3. In sensory evaluation of the prototype seat and the seat for new series E6 cars, the prototype seat received higher marks than the seat for new series E6 cars in terms of seat comfort both in total evaluation and comparative evaluation. This result verified that the more comfortable final stable form would be well accepted when incorporated to an actual seat.

### Reference: