The exterior space of the house (BD-B) is subject to many architectural restrictions (ex. the space for tree roots facing building and soil thickness on the semi-underground parking), and the effect of anticipated shade derived from tree growth on the outdoor thermal environment was visualized by the aforementioned analyses. The resultant future projection of passive performance, determinations of the type and amount of necessary tree planting, and the amount of incident solar radiation on the outside walls of the house was a topic of discussion between the architect and clients. For the commercial street zone (BD-C), the quantitative simulation results showing daily changes in the efficiency of water-retentive ground surfaces were used as the presentation to the clients.
As evidenced from the above, the possibility of the application of a thermal simulation tool in the landscape design process can be classified into three stages: design support, visualized materials, and performance estimation.

THE CAUSATIVE FACTORS INFLUENCING DESIGN CHANGE AND THE FUNCTION OF THE SIMULATION TOOL IN THE EXECUTION DESIGN PHASE

After several meetings among the LA, the architect and clients, we focused solely on the area modified by the simulation in the execution design phase, which was the exterior space of the house (BD-B). The LA revealed two drawings that displayed the growth in exterior space before and after the simulation; these showed an expansion by factors of 1.3 and 1.5.
Table 3 summarizes the design changes based on the drawing made during the first numerical analysis (phase 1), the drawing made for the second numerical analysis, as based on the results of the first numerical analysis (phase 2), and the final proposal as based on the results of the second numerical analysis (phase 3). From the drawings made during phases 1 to 3, we selected design change points that were numbered (1) to (6). Interviews with the LA were conducted on the causes of the five changes.
The locations of the sitting area (1) and the garden path (2) were retrieved from the numerical analysis results. By focusing on the cool spot formed throughout the day on the south side of the garden path, adjacent to a tree on the north side of the block to the south, it was confirmed that the walking area was moved from the north side of the garden path to the south side. The results of numerical analysis for the tall trees at the center of the garden path (3), which created large shadows throughout the day in the sitting area (1), were also taken into consideration. The analyses made during phase 2 were intended to increase the dimensions of the cool spot through its alignment with the trees planted on the north side of the block. However, this scheme was not changed in phase 3. Reasons for this included foundation problems, and space issues. The points changed in (4) and (6) did not directly affect the numerical analysis results, or the following: influences on changes in canopy shape; tree sizes related to changes in tree types, due to growth tolerances on artificial ground and timing of the blooming period; adjustments to the tree canopy position given its prominence in the

eyesight of residents; and cost adjustments. In addition, it was also confirmed that the position of the tall tree on the south side was moved to secure a space for building water discharge.

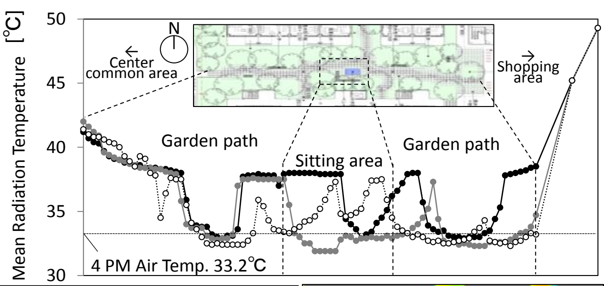
A COMPARISON OF THERMAL ENVIRONMENT CHANGES RESULTING FROM DESIGN CHANGES

Amongst the design change factors stated by the LA in phase 3, the thermal environments of phases 1 to 3 were compared, with focus on changes in the garden path and sitting areas (1, 2) and taking into consideration the numerical analysis results. Figure 3 shows the MRT distribution at an elevation of 1.2 m, at 4 pm on a clear summer day. The graph in figure 3 shows the MRT of the garden path area at 4 pm in intervals of 0.6 m, and the table provides the average MRT values at 9 am, 12 pm, and 4 pm.

From these results, the change to the southern side of the walking area position from phases 1 to 3 resulted in an approximately 1.5 degree decline in the average MRT for phase 3 in all time periods. In particular, there was a spot in which the MRT declined at a maximum value of 4°C at 4 pm. Because the large tree in the center of the garden path that was considered in phases 1 and 2 was absent from phase 3, there was a decrease in the surface area exhibiting low MRT values. As well, the average MRT of the garden path increased by approximately 0.6°C at 4 pm in the phase 3 sitting area, as compared to phase 2. This confirmed that the surface temperature and MRT distribution results could be validly used for an investigation of the positions of the sitting area, garden path, and planted trees, in consideration of the thermal environment.

CHALLENGES FOR FUTURE DESIGN METHODS

Factors such as the thickness of added soil and other design elements resulted in no changes in phase 3 for the tall tree examined in phase 2. Because it was possible to observe the imagery obtained by the LA with regard to the thermal environment, it was possible to examine methods that concerned particular tree types. These included



	9:00 MRT	12:00 MRT	16:00 MRT
Phase1	36.4 [°C]	41.6 [°C]	36.5 [°C]
Phase2	34.9 [°C]	40.1 [°C]	35.4 [°C]
Phase3	35.0 [°C]	40.3 [°C]	36.0 [°C]

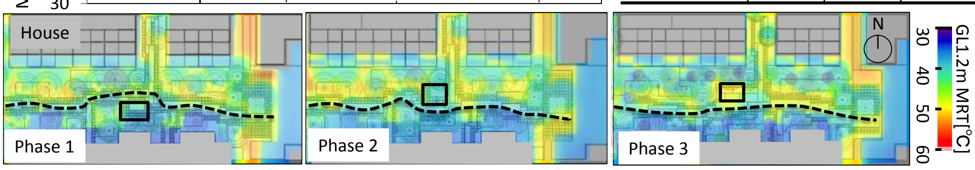


Figure 3. *A comparison of MRT distributions in BD-A*

schemes whereby the tree canopy was wider for a middle set of trees that could grow without much added soil, and which had the same effect as the tall trees that were examined in the aforementioned cases, as well as alternative methods whereby a wisteria trellis created cover. Moreover, in the examinations of tree types and canopy sizes, because design changes were made due to factors other than those obtained from numerical analysis, it can be said that these canopy forms and tree heights could serve as reference information for the LA in the selection of tree types. These factors, as well as differences in the planting parameters that influence tree width, are future subjects of study in the examination of immediately quantifiable methods.

The impact of the amount of heat received from solar radiation through building windows was shown in a time series that was compared with a case in which trees were absent, in each season. Although the LA recognized this impact, it was not considered to be a direct cause of the design changes. The results of the interview-based surveys revealed the necessity of information that considered the tradeoff between the impacts on the side of the building by changes in tree size, height, and distances from the building, with the extent of the shaded area outside.

CONCLUSION AND IMPLICATIONS

This study discussed the possible application of a thermal simulation tool for the landscape design process, concerning a passive residential project. In the basic design phase, the quantitative visualization results could potentially be used not only for presentation purposes, but also as a design support tool capable of testing the thermal environment with consideration of surface materials and tree shade positions.

In the exclusion design phase, it was confirmed that the analysis was useful for the selection of the sitting area and garden path positions. A future challenge is to satisfy the need for materials capable of quickly confirming quantitative variations when individual parameters change, such as minor changes in tree configuration and positions, at the exclusion design stage.

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