Impacts of implementing activity-based working on environmental satisfaction and workplace productivity during renovation of research facilities

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Impacts of implementing activity-based working on environmental satisfaction and workplace productivity during renovation of research facilities

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Abstract
Activity-based working (ABW) is attracting attention as a new style of working to improve workplace productivity in Japan. The purpose of this study is to clarify the changes in the working style of office workers by implementation of ABW. In this paper, a questionnaire survey was conducted in a research facility: once before the ABW renovation and twice after the renovation. We found that accustoming to the ABW leads to changes in the style of working, such as the choice of seats, and that being able to work where you want to work leads to increased workplace productivity.

Keywords
activity-based working, questionnaire, seat selection, self-efficacy, workplace productivity

1. Introduction
Japan’s rapidly aging population and declining birthrate is expected to cause a decline in its workforce; hence, maintaining the physical and mental health of workers, promoting their motivation to work, and improving their workplace productivity to attain sustainable economic growth has become a major social issue.¹ Additionally, the development of information technology has increasingly diversified office spaces and work styles.

The term productivity is commonly used to imply labor productivity.² In economics, labor productivity refers to the production activity-related efficiency of workers. This study used “workplace productivity” to imply workplace productivity associated with intellectual activities in offices to distinguish it from labor productivity in factory production.³ Productivity is an economic indicator calculated as the ratio between the output and input. When considering “workplace productivity” in offices, “input” refers to the cost factors of office operations, such as labor cost, office rent, and indoor climate control; “output” refers to the profit obtained from office work activities.¹ The labor cost of office workers accounts for the majority of cost factors related to office operations.² Since there was no significant change in labor cost expenditures before and after the renovation at the site in the context of which this study took place, the value of input was assumed to be constant. In contrast, regarding output, it was difficult to directly measure the gains from the performance of the surveyed office workers or the work performance in the surveyed office.² Therefore, this study referred to the workplace productivity evaluation method described in the Workplace Productivity Research Committee Report⁶ and evaluated workplace productivity using self-reports from workers of a research facility on output indicators, namely “ease of engaging in intellectual
activities in the office,” “satisfaction with the office environment,” “work efficiency,” and “work capacity.”

Activity-based working (ABW) has been adopted in workplaces because it leads to increased workplace productivity. In such workplaces, workers themselves choose the most suitable location from a variety of workspaces according to the content of their work, preferences, and other factors. Compared to the free address work style, which allows people to be seated wherever they like at a primarily uniform office desk, ABW allows people to choose their work setting from a diverse range of workspaces, ensuring an optimal work environment for each individual worker. ABW is thus becoming increasingly popular.

Since the 1990s, in Europe and the US, research has been conducted on the relationship between new workplace styles like ABW and workplace productivity. Engelen et al. conducted a systematic review to understand the impact of ABW on workplace productivity. Seventeen articles in line with this study’s survey objectives revealed that more positive reports were associated with the applications of ABW in terms of communication, control over office hours and privacy, and environmental satisfaction, but there were more negative reports regarding the same in terms of storage space and privacy. Wohlers et al. also studied the impact of ABW on workers through a literature review. Their results indicated that satisfaction with ABW varied slightly from job position; team members were more satisfied and felt more productive within ABW compared to the open plan workplace.

Research on ABW has been on the rise since 2020. MacHe et al. analyzed effects of a transition to open workspaces including ABW on employees’ working conditions. After the transition to ABW, job autonomy, team collaboration and satisfaction with communication climate increased, and levels of occupational stress decreased significantly over time. Divett et al. evaluated perceptions of leaders and team members on productivity and satisfaction within ABW environment. They found that satisfaction with ABW varied slightly from job position; team members were more satisfied and felt more productive within ABW compared to the open plan workplace.

Although there are only few research cases of offices that have introduced ABW (hereafter, ABW offices) in Japan, Shiyoyama et al. showed that simply introducing ABW does not necessarily contribute to improving work efficiency and workplace productivity, and it is important to plan according to the working style and work content of individual workers. Previous studies have shown that increasing the ease of performing in-office activities is important for improving workplace productivity, and in ABW, the worker’s own seat choice determines their work environment.

Sato et al. used a small office as a case study of seat selection in a non-territorial office and clarified the trends in employees’ seat selection upon arriving at work by means of a behavioral survey and questionnaire. Oguro et al. showed that being able to sit in one’s preferred seat, from the perspective of the thermal environment, improves workplace productivity. Although other factors like spatial and visual environment as well as thermal environment are considered as factors in seat selection behavior, there are not many examples of research on such behavior of office workers and workplace productivity.

As a measure to prevent the spread of COVID-19, telecommuting has been recommended by many companies since 2020. Even after the COVID-19 pandemic is over, the telecommuting implementation rate may continue to increase. The relationship between telework and ABW has also been mentioned in some papers since 2020. Franssila et al. studied the impacts of ABW change on several knowledge work performance in three governmental organizations. Their results indicated that environmental satisfaction from the traditional offices to ABW made telework more acceptable. Chimoto et al. found that the ABW with a work style that combines office work and telework further increased the workplace productivity of occupants. Marzban et al. conducted a systematic review to describe findings from research conducted in ABW offices with a view of informing post-COVID-19 workplace places of the positive and negative attributes of ABW. Their study showed that the inter-connection between the three key ABW pillars (organizational, human and physical environment) is crucial to the success of this concept specifically in the context of the post COVID-19 workplace.

This study determined the changes in environmental satisfaction and workplace productivity of office workers as a result of implementing ABW in the context of workplace renovation in a research facility. There are many existing studies that have compared and evaluated ABW before and after implementation. Evidently, it takes some time for each office worker to establish a work style and become comfortable in an ABW office, since it entails a major change in work style. Therefore, to examine the impact of ABW over time, we compared the results of and conducted three surveys. One was conducted before the introduction of ABW. The others were conducted 3 and 10 months after the introduction of ABW, respectively.

The results presented in this study include those published in previous reports.

2. Survey Summary

2.1 Surveyed facility

Table 1 [Note 1] shows an overview of the surveyed facility before and after renovation, and Figures 1 and 2 are photographs of the workspaces. The research facility is located in Chiba Prefecture, Japan. Its construction was completed in 1993, and it included one basement floor and four floors above the ground. The facility has approximately 210 employees, of whom 230 are office workers.

<table>
<thead>
<tr>
<th>TABLE 1. Specification of surveyed target office</th>
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<tbody>
<tr>
<td>Before renovation</td>
</tr>
<tr>
<td>Numbers of workers</td>
</tr>
<tr>
<td>Numbers of all seats</td>
</tr>
<tr>
<td>Numbers of seats for ABW</td>
</tr>
<tr>
<td>Area per person</td>
</tr>
<tr>
<td>Area of each room</td>
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<tr>
<td>Total floor area</td>
</tr>
</tbody>
</table>
which about 85% are engaged in research and 15% in clerical work.

Figures 3 and 4 show the cross-sectional views, and Figures 5 and 6 show the floor plans. Before the renovation, the space spread long, from east to west, and it was divided by a north–south courtyard. Fixed seats for each researcher were distributed across five rooms for each research field, and interaction between researchers from different fields was limited.

The facility’s workspace was completely renovated with the aim of creating a spatial configuration to promote interaction between researchers and increase workplace productivity. Operations at the renovated office commenced in April 2019. Post renovation, all the office workers were gathered in one large, connected space. ABW was introduced, creating a space in which each person could freely choose their place of work according to their own preference, mood, and content of their work. This was done to improve environmental satisfaction and workplace productivity. The aim was also to create a workplace where people could engage in healthy and creative research by enjoying diverse stimuli from the surrounding environment and by stimulating communication.

The space was renovated in the following manner:

- The outdoor atrium (courtyard) that divided the old research building was covered with a roof to turn it into an indoor space, creating a large, unified space connected vertically and horizontally and from north to south.
- The ceiling height and line of sight through the building were varied, creating a diverse spatial composition that would instill a sense of change.
- A variety of areas were created, including open seating, individual booths, cafeteria space, lounge areas, and outside workspace; various fixtures were arranged in each area based on the concept of the zone.
- Personal fans, radiant panels, and task lights were installed for many seats to improve the ability to control the environment.
- The volume of documents was reduced, and a paperless system was implemented [Note 2]; personal lockers and shelves for storing personal belongings were installed.

The ABW was primarily directed toward the research staff members, who constitute the majority of the employees. However, as an exception considering the work characteristics, fixed seats on the second floor were provided for clerical workers, and a “assigned seats with desktop computers” was provided for workers who perform high-load calculations. Additionally, each research department was provided with its own “assigned area of each department” to be used exclusively for any specific purpose. The floor space per worker (office
space) was 10.1 m² before the renovation. This reduced to 9.3 m² post renovation.

As shown in Figure 1, before the renovation, each researcher was assigned a uniform fixed seat consisting of an office desk, storage cabinet, and bookcase. In contrast, post renovation, each floor was divided into 6 to 10 areas, and a variety of furniture was arranged based on the concept of each area. A total of 283 seats were available for the 230 employees to choose from.

2.2 Questionnaire summary

Table 2 summarizes the questionnaire survey. It was conducted to determine changes in workplace productivity, work style, and environmental satisfaction of office workers as a result of facility renovations and the introduction of ABW. A survey link was sent to the e-mail addresses of the target respondents, asking them to respond via a web browser.

The survey period was from February 7–16, 2018, before the renovation (hereinafter “before”); from July 18–26, 2019, which was 3 months post renovation (hereinafter “after 3 months”); and from February 7–21, 2020, 10 months post renovation (hereinafter “after 10 months”). There were 88 valid responses, with a 38% response rate (before); 113 valid responses, with a 48% response rate (after 3 months); and 148 valid responses, with a 70% response rate (after 10 months). At the time of the February 2020 survey, there was no impact of COVID-19 on the work style of occupants at the target office.

The Mann–Whitney U test and Chi-square test were used for statistical analysis in this study [Note 3].

3. Degree of Satisfaction with Various Types of Office Space

This section describes changes over time in the degree of satisfaction with the indoor environment before and after the renovation and in the impression evaluation of the office post renovation.

<table>
<thead>
<tr>
<th>TABLE 2. Outline of questionnaire</th>
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<tbody>
<tr>
<td><strong>Type of office</strong></td>
</tr>
<tr>
<td>Survey period</td>
</tr>
<tr>
<td>Number of respondents</td>
</tr>
<tr>
<td>Content of questionnaire</td>
</tr>
</tbody>
</table>
### 3.1 Indoor environment

Figure 7 shows the degree of satisfaction with each aspect of the indoor environment [light, temperature, indoor air quality (IAQ), sound, and the information and communication technology (ICT)]. Compared to before, after 3 months, satisfaction with the sound and light environment decreased, but satisfaction with the thermal and ICT environment increased. Satisfaction level with light, temperature, IAQ, and acoustic environment after 3 months improved further after 10 months. Satisfaction with the temperature, IAQ, and ICT environment after 10 months improved compared to before.

Figure 8 shows the results of the survey in which respondents were asked to select the items (multiple responses allowed) that they considered dissatisfying regarding the light, thermal, IAQ, sound, and ICT environment. Since the questionnaires before and after 10 months were conducted during the winter season, and the questionnaire after 3 months was conducted during the summer season, “hot overall” and “too humid” were frequently reported as a dissatisfying factor regarding the thermal environment. In contrast, a comparison of the questionnaire results before and after 10 months, which were conducted in winter, showed that highlighting “cold overall,” “too dry,” and “temperature difference between upper and lower body” as dissatisfying factors significantly reduced post-renovation. This may have contributed to the improved satisfaction with the thermal environment.

“Construction noise” was the most common dissatisfying factor regarding the sound environment (67%) after 3 months. Renovation of the adjacent building during this phase may have contributed to the dissatisfaction. Therefore, the elimination of dissatisfaction with “construction noise” immediately post-renovation may have contributed to the improved satisfaction with the sound environment after 10 months.

Prior to the renovation, a high percentage of respondents reported dissatisfaction with the ICT environment in terms of the “Internet environment,” “PC performance,” and “location of power outlets,” but post-renovation, the number of respondents reporting dissatisfaction decreased.

The percentage of respondents selecting dissatisfying factors for light and IAQ environments was relatively low, and all of these items constituted <30%.

Figure 9 shows the level of satisfaction with various factors of the visual and spatial environment. For spatial environment, respondents were asked to reflect their satisfaction level using a seven-point scale, referring to existing literature.22 The percentage of respondents reporting dissatisfaction regarding the view (“very dissatisfied,” “dissatisfied,” and “slightly dissatisfied”) was 46% after 3 months, 28% before, and 27% after 10 months.

Since ABW offices are often configured as open plans, dissatisfaction regarding privacy was reported.23 Immediately post-renovation, there were concerns that the situation would worsen, but after 10 months, the level of dissatisfaction regarding this declined. Since there were no changes to the facility 3 and 10 months post-renovation, this might have happened because the office workers adapted to the open-plan environment. In the items of the flow line (ease of movement), cafeteria, and comfort of the furniture, satisfaction improved significantly after 3 months compared to before. However, satisfaction with storage space decreased after 3 months compared to before. Perhaps the decrease in storage space and increased distance between the storage space and seating arrangements post-renovation in ABW offices increases the number of complaints reported immediately after a renovation. The percentage of dissatisfied reports regarding storage space was 59% immediately post-renovation compared to 49% after 10 months. Since neither the amount of storage nor the location changed 3 or 10 months post-renovation, this was considered to be the impact of the workers’ adapting to the changed environment.

Figure 10 shows the overall environment-related satisfaction. The percentage of satisfied respondents (“very satisfied,” “satisfied,” and “slightly satisfied”) gradually increased from 18% before to 35% after 3 months and 55% after 10 months. Ten months post-renovation, the satisfaction level had further improved due to the elimination of construction noise and the workers adapting to the environment.

### 3.2 Ease of performing office activities

Figure 11 shows the ease of performing office activities. Intellectual activities in the office were categorized into seven,24 an item regarding concentration was added, and these were surveyed using a five-point scale (“difficult,” “slightly difficult,” “neither,” “slightly easy,” and “easy”). Compared to before, after 3 months, “information processing” (routine work, regular reporting, etc.) and “knowledge processing” (investigation research and processing, etc.) were less likely to be performed, while “informal communication,” “relaxation,” and “refreshment” were more likely to occur. After 10 months, “knowledge creation and innovation,” “informal communication,” “relaxation,” and “refreshment” were easier than before. Comparing changes over time, 3 and 10 months post-renovation, improvement was observed in individual tasks, such as “information processing” (routine work, regular reporting, etc.), “knowledge processing” (investigation research and processing, etc.), and “knowledge creation and innovation.”

The number of responses citing difficulty after the renovation for tasks related to routine work and regular reporting...
increased, as paper materials were no longer always readily accessible due to the promotion of a paperless system and increased distance from storage space. The improvement in the ease of relaxation and refreshment could be attributed to the new cafeteria and lounge area in the office, which are spaces that could be used for relaxation and refreshment.

Although there have been cases of decreased concentration reported in ABW offices, there was no decrease in the ease of concentration at the facility in this study. One of the reasons for this may be the appropriate zoning according to intellectual activities, such as separating the areas for work needing concentration from the areas for meetings, after referencing the findings of previous studies, to avoid distractions. Additionally, this can be attributed to the variety of seating options that enabled workers to select their own seats with the least concentration inhibitors, depending on their individual work behavior and preferences.
3.3 Self-efficacy

Figure 12 shows the results of self-efficacy wherein respondents were asked to report whether they were able to work where they wanted to work, using a five-point scale ("strongly disagree," "disagree," "neither," "agree," and "strongly agree"). Self-efficacy is the sense that one is capable of exerting some influence over the external world. ABW offices allow people to choose their own seating, which may improve their sense of self-efficacy regarding work environment and work style. In this study, the questionnaire was developed with reference to previous literature.

To the question “Are you able to work where you want to work?” the percentage of responses in the affirmative (agree, strongly agree) was 47% before, 51% after 3 months, and 57% after 10 months. There was a significant increase in the number of respondents who thought they were able to work where they wanted to.

3.4 Communication

Figure 13 shows the level of satisfaction with regard to communication according to counterparts. The surveyed facility has an organizational structure that has multiple groups within each department. Compared to before the renovation,
satisfaction with the respondent’s own group and department decreased in the 3 and 10 months post renovation, while satisfaction with communication with other departments increased. Prior to the renovation, each person was assigned a fixed seat within their department, so communication within their own department was easy. On the one hand, post renovation, workers in the same group or department were no longer required to be in close proximity with each other. Therefore, communication between workers within in their own department or group became difficult. On the other hand, post renovation, workers could work in a common office with those from other departments, which increased communication opportunities.

As a result, the percentage of respondents who expressed overall satisfaction with communication went from 34% before to 43% after 10 months, but there was no significant difference between the pre- and post-renovation periods. While ABW is advantageous in facilitating communication with workers in other departments, maintaining and facilitating communication within a department requires operational measures arranged by the organization, such as providing regular opportunities for communication.

As a result, the percentage of respondents who expressed overall satisfaction with communication went from 34% before to 43% after 10 months, but there was no significant difference between the pre- and post-renovation periods. While ABW is advantageous in facilitating communication with workers in other departments, maintaining and facilitating communication within a department requires operational measures arranged by the organization, such as providing regular opportunities for communication.

### 4. Seat Selection Behavior

Figure 14 shows the results regarding the intention and behavior of the workers to change seats during the day. The percentage of workers who responded with “yes” to “Have you ever felt the need to change your seat during the day?” was about 50% after 3 months and about 40% after 10 months. About 50% and 60% of the workers responded that they had changed their seats during the day after 3 and 10 months post renovation, respectively, but the majority of them did so less than once or twice a month. This confirmed a strong tendency to work the entire day at the seat they chose when they arrived at work. In other words, it can be said that clarifying the tendency for seat selection when arriving at work would lead to an understanding of the reality in ABW offices.

Figure 15 shows the “important factors for seat selection” in the ABW office 3 and 10 months post renovation. In this section, workers were asked to respond to (multiple answers allowed) 22 items (listed in Figure 18) that they felt were applicable. The top three items were “surrounding users [Note 4],” “crowdedness,” and “desk space” both 3 and 10 months post renovation. While the percentage of respondents who chose “access to personal storage” was 43% after 3 months, this dropped to 23% after 10 months. Ten months after renovation, “availability of a monitor” and “content of work” had increased in the ranking order. When workers first started working at the renovated facility, an important factor in deciding the workspace was “access to personal storage,” but as they became accustomed to the ABW office, they changed their work style to one that emphasized the ease of carrying out their work.
5. Work Efficiency

5.1 The impact of the indoor environment on work efficiency

Figure 16 shows the results of responses to the “impact of the current indoor environment of the office on work efficiency.” The percentage of workers who thought the indoor environment improved their work efficiency increased gradually, from 11% before to 24% after 3 months and 43% after 10 months.

Figure 17 shows the results regarding the change in work efficiency compared to pre-renovation. Three months post-renovation, 18% of the respondents reported that their work efficiency had improved (“increased slightly,” “increased,” or “increased greatly”) compared to before renovation (the “improved efficiency group”), while 32% of the respondents reported that their work efficiency had decreased (“decreased slightly,” “decreased,” or “decreased greatly”) (the “group with decreased efficiency”). In contrast, 10 months after renovation, 29% of the respondents were in the “improved efficiency group” and 19% in the “group with decreased efficiency,” reversing the ratio of those who declared they were on the “improved” side to those on the “decreased” side.

5.2 Relationship between work efficiency and seat selection

As mentioned above, about 20% of the workers complained of decreased efficiency in the survey conducted after 10 months. Since the aim of ABW is to improve the workplace productivity of each worker, it is necessary to focus on not only those workers whose work efficiency improved, but also those whose efficiency decreased.

Therefore, the respondents were divided into three groups, namely the “improved efficiency group,” the “unchanged group,” and the “group with decreased efficiency,” based on the results of their reported work efficiency compared to that
before the renovation, and the items that were important when selecting seats were analyzed.

Figure 18 shows the percentage of responses to each of the “important factors when selecting a seat” for each of the three groups with increased, unchanged, and decreased work efficiency. In the survey conducted three months after renovation, the top responses for all groups were “surrounding users,” “crowdedness,” and “desk space.” The improved efficiency group also emphasized “content of work.” In contrast, the group with decreased efficiency also emphasized “access to personal storage” and “availability of a monitor.” As items of importance when selecting seats, the improved efficiency group selected an average of 5.1 items, the unchanged group 5.3 items, and the group with decreased efficiency 7.8 items. At the time of the survey three months post renovation, the group with decreased efficiency had more items of importance than the other groups, and more of them chose the functions and conveniences that were omitted in the new office. Thus, the workers who had not fully adapted to the major changes in the office environment and who wanted an environment similar to that of traditional fixed seating, had many requests in order to fill the gap. As a result, they were forced to choose seats that did not meet their needs, which may have resulted in reduced work efficiency.

The group with decreased efficiency constituted 32% of the total after 3 months and 19% after 10 months. The decrease in the percentage could be attributed to the fact that they eventually adapted to the new office. The number of items that the group with decreased efficiency emphasized when selecting seats decreased from an average of 7.8 items after 3 months to 4.0 items after 10 months, while the improved efficiency group slightly increased from an average of 5.1 items to 5.4 items after 3 and 10 months, respectively.

Ten months after renovation, “surrounding users” and “crowdedness” were still the top responses for all groups. Further, the improved efficiency group placed more importance on “content of work,” “familiarity with the seat or location,” and “availability of a monitor,” while the group with decreased efficiency placed more importance on the “visual environment.” Perhaps over time, the number of office workers seeking a traditional fixed seating environment decreased because they became accustomed to the ABW office and were more likely to choose seats that were comfortable to work in, while focusing on “content of work” and “surrounding users.”

5.3 Relationship between work efficiency and the advantages and disadvantages of ABW

Figures 19 and 20 show the results regarding the “items considered to be advantages or disadvantages of the renovation” (multiple responses allowed) 3 and 10 months post renovation, respectively, for the three aforementioned groups.

In both surveys, the improved efficiency group tended to view more items as advantages than the other groups, while the group with decreased efficiency tended to view more items as disadvantages than the other groups. Of the 12 items presented as advantages, the average number of items selected by the improved efficiency group was 2.4 after 3 months and 3.7 after 10 months. This suggests that over time, ABW benefits were perceived in terms of more items.

Although the ratio of the group with decreased efficiency in relation to the total number of workers decreased after 10 months, it can be confirmed that some workers continued to strongly perceive the disadvantages of the ABW office. In the group with decreased efficiency, the percentage of respondents who reported “less storage space” was particularly high, and more than 40% of the workers felt that “difficulty in communication” and “worse sound environment” were disadvantages. Specifically, a large difference in response rates was observed between the improved efficiency group and the group with decreased efficiency in relation to whether or not “less in storage space” was considered a disadvantage. Even after the introduction of ABW, it may be effective to provide sufficient storage space near the desks for workers who have difficulty in transitioning to a paperless office.

Meanwhile, the number of workers who viewed “worse thermal environment” as a disadvantage decreased in both groups.
This may be due to the improved operation of the facility’s systems, although it is also quite likely that the different seasons in which the survey was conducted had an impact.

5.4 Relationship between being able to work where one wants to work and work capacity

Figure 21 shows the relationship between workers’ feeling of being able to work where they wanted to and work capacity. Work capacity was measured using numbers from 0 to 100 used to answer the following question: “If your maximum work capacity when the indoor environment is optimal for you is 100, what do you think your work capacity would be in the current indoor environment?” The results of respondents’ reported work capacity were averaged by using the scale of response to the following question: “Do you feel like you can work where you want to?”

In the survey 3 and 10 months after renovation following the introduction of ABW, the average reported work capacity improved for those who felt they were working where they wanted to. The study confirmed that while some workers were able to demonstrate high work capacity due to their adaptation to ABW, including the seating choice, the reported work capacity was low for workers who felt they were not able to work where they wanted to.

The results of subjective reporting on work capacity are generally recognized as one of the indicators to assess workplace productivity, as mentioned in Section 1 of this study. In order to improve workplace productivity in ABW offices, it is essential not only to increase the number of options for places to work, but also to increase the self-efficacy of each worker in being able to work where they want to. By changing the seating arrangement to take into account the characteristics of how workers select seats and by improving the operation of items that are seen as disadvantages of ABW, it is important from the perspective of increasing workplace productivity in ABW.

FIGURE 19. Advantages of office after renovation grouped by changes in productivity from before renovation

FIGURE 20. Disadvantages of office after renovation grouped by changes in productivity from before renovation

FIGURE 21. Relationship between work capacity and being able to work where one wants to work
The top three items of importance when choosing a seat working may have shifted the emphasis on the ease of carrying out one’s work.

- Responses to the “impact of the indoor environment of the office on work efficiency” showed an increase in improvement post renovation compared to before the renovation. About 20% claimed improved work efficiency compared to the status prior to the renovation, and about 30% claimed decreased work efficiency after 3 months of renovation. However, 10 months after renovation, about 50% claimed improvement in this regard, while about 20% reported decreased work efficiency. Thus, the percentage of those who reported improvement increased over time.

- Factors that influence seat selection were compared by dividing the respondents into three groups according to work efficiency before and after the renovation, i.e., the improved efficiency group, the unchanged group, and the group with decreased efficiency. All three groups emphasized on “surrounding users” and “crowdedness.” Three months post renovation, the improved efficiency group also emphasized on “work content” while the group with decreased efficiency also emphasized on “desk space,” “access to personal storage,” and “availability of a monitor.” Ten months after renovation, the group with decreased efficiency tended to place more importance on the “visual environment” than the improved efficiency group, while the improved efficiency group tended to place more importance on the “surrounding users” and “content of work.” Immediately post renovation, workers seeking a space similar to the previous fixed seating arrangements complained of decreased work efficiency, but over time, the number of such workers decreased. There was a growing tendency to choose seats that were comfortable to work in, with a focus on “content of work,” “surrounding users,” and other factors.

- The respondents were asked to select the advantages and disadvantages of the office after renovation, and the results were analyzed according to the three aforementioned groups. In all the surveys, the improved efficiency group tended to consider more items as advantages than the other groups, while the group with decreased efficiency considered more items as disadvantages than the other groups. Workers in the group with decreased efficiency continued to feel strongly about the disadvantages of converting to an ABW office even 10 months post renovation, with many of them reporting “less storage space” as a particular disadvantage. It may be effective to provide sufficient storage space near the desks of some workers.

- In the surveys after the implementation of ABW, the more workers who reported their work environment was easier for them to work on, the more their reported work capacity improved. The percentage of workers who felt they were working where they wanted to work increased over time, and their evaluation of work efficiency also improved.

Thus, while some workers improved their work efficiency by adapting to the ABW work style, including the freedom to select seats, some workers complained of decreased efficiency compared to the same before the renovation. Since many of the office workers who complained of decreased work efficiency felt that they are not able to choose where they wanted to work, to improve workplace productivity in ABW offices, it is not only essential to increase the options of where one can work, but also to increase each office worker’s sense of self-efficacy being able to work where they want to.
Acknowledgments
This study is a part of the results of a collaborative research project between Waseda Research Institute for Science and Engineering, and Takenaka Corporation. We would like to express our deepest gratitude to Mr. Reo Sugino for his cooperation during our research.

Disclosure
The authors have no conflict of interest to declare.

Data Availability Statement
The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Notes
Note 1) The number of workers is the number of people actually working in the subject facility, including temporary staffs. The survey was administered to full-time employees only.
Note 2) The amount of personal storage has decreased from 5.3 ft^3/person before the renovation to 3.3 ft^3/person after the renovation. ft^3 = file meter (unit of document volume). The height in meters when the documents are stacked vertically.
Note 3) The Mann–Whitney U test was performed with regard to Figures 7, 9–13, 16 and 17; the Chi-square test was performed with regard to Figures 8, 15 and 18–20.
Note 4) In the responses to “important factors when selecting a seat” listed in Figure 15, there was no significant correlation between the responses and relations found. The main factor in the responses regarding “surrounding users” was not “crowdedness”, although it could include various individualistic factors like “related/not related in business”, “belonging to the same organization/not belonging to the same organization”, “acquaintance/not an acquaintance”, “same sex/opposite sex”, “close/far in age”, with the “surrounding users”. However, specific factors were not investigated in this survey.

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