Comparison of Workers' Stay and Movement in Territorial and Non-territorial Workplaces: An Analysis Using a UWB Sensor Network

Xinnan Zhang*, Junzo Munemoto, Tetsu Yoshida, Daisuke Matsushita and Takashi Izato

1 Lecturer, Department of Architecture, School of Architecture, Tianjin University, China
2 Professor, Department of Architecture, Okayama University of Science, Japan
3 Associate Professor, Department of Architecture, Graduate School of Engineering, Kyoto University, Japan
4 Associate Professor, Department of Architecture, Okayama University of Science, Japan
5 Group Leader, Architecture & Engineering Division, TAISEI Corporation, Japan

Abstract
This study clarifies how workers stay in a place and move differently in territorial and non-territorial workplaces by using the UWB (Ultra Wide Band-impulse radio) sensor network. The results are as follows. All the investigated workers spent approximately 80% of their time for staying in the working territory in each workplace. Workers in the non-territorial workplace stayed in the "own-seat nearby zone" 8.4% more than those in the territorial workplace; they stayed 11.6% less in the "meeting corner zone", but 1.4% more in the "workstation zone". The working territory space in the non-territorial workplace was used more efficiently than in the territorial workplace, as indicated by its 8.5% higher proprietary occupancy rate and 2.8% higher flexible occupancy rate at workstations, as well as its 6.9% higher occupancy rate in meeting corners. The different work characteristics in terms of worker's post or specialty were also revealed: architects spent approximately 4.5% more time in the "own-seat nearby zone" than engineers, while engineers visited the architects' specialty areas more often; compared with regular staff, the rate at which project leaders stayed out of their workplace was the highest, at over 17%; while the temporary staff stay in the "own-seat nearby zone" the longest.

Keywords: non-territorial workplace; territorial workplace; stay; move; UWB sensor network

1. Introduction
1.1 Background
In an attempt to solve the problem of low occupancy rates in traditional territorial offices, where everyone has his/her own fixed workstation, a number of non-territorial offices have been created.

Territorial offices assign all employees fixed locations and desks where they can complete their individual tasks and store their personal belongings. Alternatively, non-territorial offices allow employees to freely select their location or desk that they can use for their daily work.

Non-territorial offices are also referred to as "hot-desking" or "free-address" offices, where they are configured according to several specific arrangements. One such arrangement uses mobile private work desks, which are arranged as needed in the morning and stored when not in use. Another arrangement uses fixed shared work desks, which employees may occupy freely, but these workstations can only be reserved on a daily basis and all personal belongings must be removed at the end of the day.

1.2 Previous Studies
The question has been raised as to whether, and in what way, non-territorial offices perform better or make users feel more comfortable than territorial offices. Yamada et al. conducted a series of studies on non-territorial workplaces that make use of foldable and movable desks. Employee satisfaction was evaluated before and after the office shifted to a non-territorial arrangement. It was proven that the frequency of employees' communication increased in common meeting places, rather than in personal workstation areas. Several studies have also been undertaken on the latter type of non-territorial offices, based upon evaluations by respondents. For instance, Voordt used a questionnaire to evaluate employee satisfaction with their physical environment and communication in a new non-territorial office. Shimamura et al. evaluated satisfaction via a comparison of a research office before and after it was changed to a non-territorial layout, and found that 60% of the subjects were satisfied with the new layout. Non-territorial office workers were satisfied with the common space, though they also complained about reduced visual and acoustic privacy.

Moreover, studies have been undertaken from an objective point of view, such as one that focuses on employee behavior. By analyzing respondents' answers to a questionnaire, Allen and Gerstberger found that the frequency of communication and the number of people...
that an individual communicated with increased in a non-territorial office that had changed from a cellular office, although the relationship between specific spaces and this increase in communication was not clarified. By observation, Mori clarified the relationships among circulation according to layout plan, work content, and frequency of movement, but his study did not focus on specific spaces. Yamada et al. compared the commonly used places of individual students in a university laboratory before and after a transformation, using photographs taken at intervals; they found that subjects tended to use places more frequently in the non-territorial arrangement, but this behavior with regard to space use was not quantified, and thus it was not clarified whether specific spaces such as personal workstations were used more or less.

A comparison of detailed information regarding how workers stay and move in the spaces of "territorial" vs. "non-territorial" workplaces is yet to be done due to a lack of objective and continuous data. In this study, therefore, location sensors were used to provide a means of monitoring the staying-movement behaviors objectively and continuously in a varied building worksite. Unlike earlier studies that aimed to detect an abnormal behavior pattern among subjects, more researchers have turned to the use of sensors to study normal human behavior patterns. For example, some researchers have used RFID (radio-frequency identification) systems to research the room occupancy behavior of residents or to monitor the daily patterns of human contact in homes. In this study, a UWB (ultra-wideband impulse radio) sensor network, which can continuously record worker locations inside a building, was used to research workers' stay and movement in their daily work in both non-territorial and territorial workplaces.

1.3 Purpose & Significance

The main purpose of this study is to clarify the differences between workers' stay and movement in territorial and non-territorial workplaces based on their location as revealed by the continuous and objective data recorded by the UWB sensor network. In addition to ascertaining the characteristics of the two workplaces, valuable information was obtained regarding the design of workplace layouts.

The study's aims are as follows:

1) To measure how long and how often workers stay in each territory, range, and zone in order to compare and clarify the difference of workers' stay in territorial and non-territorial workplaces.

2) To compare the different staying characteristics according to the workers' post and specialty in each workplace in order to clarify their different work characteristics in this regard.

3) To estimate and compare the different occupancy rates of the workstations and meeting corners in order to clarify the efficiency of the two different workplaces.

2. Method

2.1 Devices

Two types of sensors were used in the investigation: the UWB sensor network for location positioning and acceleration sensors for data correction. The UWB sensor network is composed of a tag, an antenna, and a computer server. The tag is a small chip (Fig.1.) worn by workers that sends signals every 1.5 s. The antenna receives signals from the tag and transfers them to the computer server wirelessly. The acceleration sensor (Fig.1.), which is worn on the worker's waist, can detect the worker's acceleration when he/she is walking. Information gathered on the duration of staying and walking was used for revising the location data collected by the UWB sensor.

2.2 Subjects

Two workplaces for architecture and engineering design specialties in an architecture construction company were chosen as the subject of investigation (Table 1., Fig.2.). They were located on the north and south sides, respectively, of the 28th floor of a 54-floor high-rise building. The two workplaces had the same territorial layout until one of them was transformed in 2007. Since the transformed workplace allowed employees to freely select their workstations, it was classified as a non-territorial workplace. Each workplace was used by one department, and their daily work and composition were almost the same. Both workplaces were used by architects, structural and equipment engineers.

As shown in Fig.2., the non-territorial workers were able to locate freely in their specialty area and had to completely clear their area at the end of the day. Work laptops, personal possessions, and shared documents were stored in lockers located on the south side of the workplace. The investigated area in the non-territorial workplace was composed of the main working territory and a service territory: specifically, the working territory comprised four groups of general-type workstations area and meeting corners that were evenly distributed (Fig.2. photographs), except for a row of document lockers that separated the workstations next to the window side from the general-type workstation area. There were no permanent partitions in the open plan of this workplace, and the service territory included a meeting space, administration space, centralized storage lockers, and a printer corner.

The territorial workplace was a
traditional workplace with fixed workstations that were surrounded by partitions and document storage shelves (Fig.2. photographs). In the working territory, five large meeting corners were located in the middle of the general-type workstation area, and four small meeting corners were located beside each group leader's window-side workstation. The printers (marked by ”P”) were located beside the windows, while the lockers for the storage of workers’ personal belongings were located beside the entrance to the main corridor; these two spaces were defined as the service territory (Fig.2.).

2.3 Investigation

The investigation in the non-territorial workplace, which lasted from 9:00 am to 8:00 pm, was conducted on working days from November 17–28, 2008. In the territorial workplace, the investigation lasted from December 1–12, 2008. On each day of the investigation, 27 sets of sensors (each set including a UWB sensor tag and an acceleration sensor) were assigned to workers randomly. When a worker was assigned a sensor set, his/her name, the time of assignment, post, specialty, and the workstation he/she selected were recorded by the investigator. If the tested worker left work before the investigation was over, the sensor assigned to him/her would be reassigned to another worker. In the period of investigation, 80 out of 100 workers were assigned sensors 260 times in the non-territorial workplace, while 53 out of 60 workers were assigned sensors 225 times in the territorial workplace (Table 2.).

2.4 Definition of staying locations

According to the locating accuracy of the UWB sensor network, the distribution of sensor antennas, actual division of the workplace layout, and distance between adjacent seats, the locations at which the subjects stayed were classified into 45 zones in the non-territorial workplace and 36 zones in the territorial workplace (Fig.3., Table 3.).

When a subject was in the workplace, his/her movement and stay were recorded by the acceleration sensor, based on which the actual coordinates of the location for the corresponding period could be recorded by the UWB sensor and converted to zones in the subsequent database revision process. The antenna could not receive the signal when a subject left the workplace to go to other places in the building; these periods were revised as "out".

In the service territory, the zone in which a subject stayed was directly defined by the function range it
3. Comparison of T and N-T Workers' Stay and Movement in a Workplace

In order to differentiate workers' different staying and movement patterns within two workplaces, the DR (duration rate) of their stay in each range of working territory and in the places in the service territory were calculated, as well as the movement duration rate in each workplace. The relevant items were then compared using Z test.

3.1 Comparison of T and N-T workers' stay and movement in ranges of workplace

As presented in Table 5., in terms of staying out of the workplace and movement, there was no significant difference between the workers in the T and N-T workplaces. In addition, the duration of workers' stay in the working territory was almost the same (DR [%]: T, 80.7; N-T, 78.7) However, the N-T workers' DR was significantly higher for staying in the "own-seat nearby zone" (DR [%]: T,
58.7; N-T, 67.1), but significantly lower for staying in the "same specialty range" (DR [%]: T, 18.3; N-T, 8.2). In the "service territory", however, the DR of the N-T worker was significantly higher.

3.2 Comparison of T and N-T workers' stay and movement in zones of "working territory"

As analyzed in 3.1, in each workplace, workers spent most of their time staying in the "working territory", with a significant difference in their stay depending on their "same specialty range". In 3.2, in order to learn more details about workers' different staying patterns in each zone of the working territory in different workplaces, their stay in each kind of zone in the "working territory" was compared by the following items:

| DR: Duration rate - proportion of duration at different defined places where each worker stayed on average. |
| F: Frequency - how frequently each worker stayed on average. |
| AD: Stay duration per unit time - how long each worker stayed on average per unit time. |

In particular, the frequency of movement in the "own-seat nearby zone" was calculated in order to compare the difference in each workplace worker's movement towards adjacent workstations in his/her "own-seat nearby zone" (Table 6).

As shown in Table 6., when staying in zones other than their "own-seat nearby zone" in the "working territory", both T and N-T workers stayed longer and more frequently in the "meeting corner zone" than in the "workstation zone" in both ranges.

As compared with T workers, the N-T workers' DR for staying in the "meeting corner zone" in the same specialty range was significantly lower, but their frequency of movement in the "own-seat nearby zone" and the DR of their stay in the "workstation zone" in each range were significantly higher. Moreover, the DR quotient for staying in the two types of zones was different in each workplace. The DR quotient for T workers was approximately 10 (quotient of DRs: 16.7/1.6 and 3.3/0.3), which is higher than the DR quotient for N-T workers, which was approximately 2.5 (quotient of DRs: 5.9/2.3 and 2.5/1). The causes of these results might be as follows. In the T workplace, the general-type workstation surrounded by a partition and a storage locker is not convenient for staying or communication with other visiting workers. Because workers whose own seat is located there must move to the meeting corners for discussion or communication with visiting workers, their rate of stay at their own-seat workstation is lower; hence, it is left vacant and unused. On the contrary, in the N-T workplace, workers would more often use their own seat in general groups for communication with visitors. This is indicated by their higher frequency of movement in the "own-seat nearby zone"; they therefore spent a longer duration staying in the "own-seat nearby zone", which results in a lower movement duration rate.

In the T workplace, compared with the "general-type meeting corner", the "window-side meeting corner" in each range is visited less, in terms of DR and F. The reason for this might be that the window-side meeting corner is further from the general groups (where most subjects' own seats are located); therefore, most workers prefer the general-type meeting corner.

In the N-T workplace, compared with the general-type workstation, the DR and F of staying at the window-side type is much lower, since the document storage locker located there made it an inconvenient place for visiting workers to stay.

4. Comparison of Stay and Movement According to Workers' Roles in Each Workplace

After clarifying all the investigated workers' various staying and movement in the T and N-T workplaces, their stay and movement were also compared according to the specialty or post, and the results showed the same tendency toward differences that are given in the above analysis. In order to identify workers' different work characteristics in terms of the post and specialty, in each workplace, their stay and movement were compared.

4.1 Comparison of different specialty workers' stay and movement in each workplace

As shown in Table 7., in both the T and N-T workplaces, compared with engineers, architects' DR in the "own-seat nearby zone" was significantly higher (DR [%]: T, 59.6 vs. 55; N-T, 68.6 vs. 64.3). Their DR in the "other specialty range", however, was significantly lower (DR [%]: T, 3 vs. 5.2; N-T, 2.2 vs. 5.1). This result indicates that engineers visited the architects' specialty range more often. Architects may have stayed longer in the "own-seat nearby zone" due to visits from engineers.

In the N-T workplace in particular, compared with architects, when engineers stayed in the "same specialty range", their DR in the "workstation zone" was significantly higher. In addition, their AD in the "workstation zone" was approximately the same as that for their AD in the "meeting corner zone" (AD [min/time]: 4.7 vs. 5). This result indicates that engineers used the "workstation zone" to the same degree as the "meeting corner zone", which might be due to the greater number of vacant seats in their specialty range. The
Table 7. Comparison of Workers’ Stay and Moving According to Specialty Attribute in Each Workplace

| Item | T or N-T | Specialty attribute | Overall Scope | Same Specialty range | Other Specialty range |
|------|----------|---------------------|---------------|----------------------|----------------------|
|      |          |                     | Meeting corner side zone | Workzone Zone | Meeting corner side zone | Workzone Zone |
|      |          |                     | general type | general type | SUM | general type | general type | SUM |
|      |          |                     | same side | same side | SUM | same side | same side | SUM |
|      |          |                     | move | move | SUM | move | move | SUM |
|      |          |                     | workzone | workzone | SUM | workzone | workzone | SUM |
|      |          |                     | move inside | move inside | SUM | move inside | move inside | SUM |
|      |          |                     | move outside | move outside | SUM | move outside | move outside | SUM |
|      |          |                     | outside | outside | SUM | outside | outside | SUM |
|      |          |                     | same scope | same scope | SUM | same scope | same scope | SUM |
|      |          |                     | D.R. (min/h) | F (times/h) | SUM | D.R. (min/h) | F (times/h) | SUM |
|      |          |                     | T or N-T | T or N-T | SUM | T or N-T | T or N-T | SUM |
|      |          |                     | near seat | near seat | SUM | near seat | near seat | SUM |
|      |          |                     | same seat | same seat | SUM | same seat | same seat | SUM |
|      |          |                     | window side | window side | SUM | window side | window side | SUM |
|      |          |                     | move inside | move inside | SUM | move inside | move inside | SUM |
|      |          |                     | move outside | move outside | SUM | move outside | move outside | SUM |
|      |          |                     | outside | outside | SUM | outside | outside | SUM |
|      |          |                     | same side | same side | SUM | same side | same side | SUM |
| Item | No. | Post attribute | One-Sided Seat | Nearby | Adjacent Seat | move | move | move | move |
|------|-----|-----------------|----------------|--------|---------------|------|------|------|------|
| N-T | 10.5 | Architect | 1 | 6.7 | 1.5 | 18.4 | 2.8 | 2.8 | 0.2 | 0.2 | 0.6 | 3 | - | 6.7 | 10.5 |
| N-T | 6.5 | Engineer | - | - | 1 | 5.6 | 1.3 | 12 | 1.5 | 0.2 | 0.2 | 0.6 | 3 | - | 6.5 | 9.8 |
| T | 6.5 | Architect | 2.6 | 18.4 | 2.6 | 2.8 | 0.2 | 0.2 | 0.6 | 3 | - | 6.5 | 10.5 |
| T | 6.5 | Engineer | - | - | 1 | 5.6 | 1.3 | 12 | 1.5 | 0.2 | 0.2 | 0.6 | 3 | - | 6.5 | 9.8 |
| N-T | 10.5 | Architect | 1 | 6.7 | 1.5 | 18.4 | 2.8 | 2.8 | 0.2 | 0.2 | 0.6 | 3 | - | 6.7 | 10.5 |
| N-T | 6.5 | Engineer | - | - | 1 | 5.6 | 1.3 | 12 | 1.5 | 0.2 | 0.2 | 0.6 | 3 | - | 6.5 | 9.8 |

4.2 Comparison of workers' stay and movement in each workplace for different positions

As presented in Table 8., in both the T and N-T workplaces, compared with RS, the PL's DR for "out of workplace" was significantly higher (DR [%]): T, 18; N-T, 17.2). It might be due to PL needing to leave for other workplaces more often for inter-departmental cooperation. Their stay in the "same specialty range" was significantly lower (DR [%]: T, 16.4; N-T, 6.1), mainly due to their significantly lower DR in the "meeting corner zone" (DR [%]: T, 14.9; N-T, 4.3). Their movement in the "own-seat nearby zone" was significantly higher (F [times/h]: T, 1.6; N-T, 2.6), which indicates that PL use the adjacent

Table 8. Comparison of Workers’ Stay and Moving According to Post Attributes in Each Workplace

| Item | T or N-T | Post attribute | One-Sided Seat | Nearby | Adjacent Seat | move | move | move | move |
|------|----------|----------------|----------------|--------|---------------|------|------|------|------|
| N-T | 10.5 | Architect | 1 | 6.7 | 1.5 | 18.4 | 2.8 | 2.8 | 0.2 | 0.2 | 0.6 | 3 | - | 6.7 | 10.5 |
| N-T | 6.5 | Engineer | - | - | 1 | 5.6 | 1.3 | 12 | 1.5 | 0.2 | 0.2 | 0.6 | 3 | - | 6.5 | 9.8 |
| T | 6.5 | Architect | 2.6 | 18.4 | 2.6 | 2.8 | 0.2 | 0.2 | 0.6 | 3 | - | 6.5 | 10.5 |
| T | 6.5 | Engineer | - | - | 1 | 5.6 | 1.3 | 12 | 1.5 | 0.2 | 0.2 | 0.6 | 3 | - | 6.5 | 9.8 |
| N-T | 10.5 | Architect | 1 | 6.7 | 1.5 | 18.4 | 2.8 | 2.8 | 0.2 | 0.2 | 0.6 | 3 | - | 6.7 | 10.5 |
| N-T | 6.5 | Engineer | - | - | 1 | 5.6 | 1.3 | 12 | 1.5 | 0.2 | 0.2 | 0.6 | 3 | - | 6.5 | 9.8 |

N-T, 17.2). It might be due to PL needing to leave for other workplaces more often for inter-departmental cooperation. Their stay in the "same specialty range" was significantly lower (DR [%]: T, 16.4; N-T, 6.1), mainly due to their significantly lower DR in the "meeting corner zone" (DR [%]: T, 14.9; N-T, 4.3). Their movement in the "own-seat nearby zone" was significantly higher (F [times/h]: T, 1.6; N-T, 2.6), which indicates that PL use the adjacent

The table shows the comparison of workers' stay and moving according to specialty attribute in each workplace. The data includes the duration rate (DR) and frequency (F) for different positions within the workspace. The p-values for some comparisons are also provided, indicating statistical significance. The table highlights the differences in behavior between T (terrestrial) and N-T (non-territorial) workplaces, with N-T showing higher movement frequency and lower duration rates compared to T.
meeting corner located in their "own-seat nearby zone", which might be more convenient, and is therefore used more frequently.

Compared with RS, in both the T and N-T workplaces, the TS's DR and AD in the "own-seat nearby zone" were significantly higher (DR [%]: T, 75.8; N-T, 78.9. AD [min/time]: T, 16.6; N-T, 14.3), but their frequency of movement in the "own-seat nearby zone" was the lowest. At the same time, their DR for staying in the "same specialty range", "other specialty range", and "out of workplace" was significantly lower. Moreover, in both workplaces, the TS's DR for staying in the "meeting corner zone" of each range was significantly lower and their AD for the "meeting corner zone" was significantly shorter. These results show that TS might need more than 10% more time for work to be done individually than other staff, which causes them to move less.

5. Estimation and Comparison of Usage Efficiency in Different Workplaces

The analysis in 3.2 revealed that the workers' daily work duration mainly consists of staying in the workstation and meeting corner of their "working territory"; hence, the occupancy rate of the workstations and meeting corners actually indicates the space usage efficiency of each workplace. To compare the space usage efficiency of the T and N-T workplaces, the authors defined three categories of occupancy. Also, since there were less UWB sensor sets than workers in each workplace, sensor sets could not be worn by all the workers in attendance on each day. The workers' attendance duration rate (Table 9.) recorded once per 30 min in the same investigation period and the DR values calculated in 4.1 and 4.2 are included in the calculation of the estimated occupancy duration rates in Formulas 1, 2, and 3.

1. **R**<sub>PRO</sub>: Proprietary occupancy rate-when the workstation is occupied by a worker whose own seat is located there (Formula 1).
2. **R**<sub>FLO</sub>: Flexible occupancy rate-when the workstation is occupied by a worker whose own seat is not located there (Formula 2).
3. **R**<sub>PUO</sub>: Public occupancy rate-when the meeting corner is occupied by a worker (Formula 3).

\[
\begin{align*}
\text{R}_{\text{PRO}} &= \frac{\sum_i (\text{DR}_{\text{PRO}} r_{\text{PRO}} i) T}{T \times Z} \times 100 \% \quad (1) \\
\text{R}_{\text{FLO}} &= \frac{\sum_i (\text{DR}_{\text{FLO}} r_{\text{FLO}} i) T}{T \times Z} \times 100 \% \quad (2) \\
\text{R}_{\text{PUO}} &= \frac{\sum_i (\text{DR}_{\text{PUO}} r_{\text{PUO}} i) T}{T \times Z} \times 100 \% \quad (3)
\end{align*}
\]

5.1 Comparison of workstation's occupancy

As shown in Table 10., compared with the T workplace, **R**<sub>PRO</sub> in the N-T workplace is 8.5% higher, while **R**<sub>FLO</sub> is also higher, at 2.8%. In the T workplace, **R**<sub>PRO</sub> of a general-type workstation is 3.9% lower than that for a window-side type, while in the N-T workplace, there is an opposite result, with a 6.2% higher **R**<sub>FLO</sub> for the general type.

The above results show that the N-T workstation performed more efficiently than the T workplace, which might be due to the spatial configuration of the different workstations, since the general-type workstation in the T workplace and the window-side workstation in the N-T workplace are blocked by a partition and storage lockers (Fig.2. photographs). This made it inconvenient for other workers to stay there to communicate with the workers whose seats were located there. In the T workplace in particular, the narrow entrance caused by the "L" shape of most general workstations made it inconvenient for other workers to stay there, even when the workstation was vacant. On the contrary, the convenience of the window-side workstation of the T workplace and the general-type workstation of the N-T workplace made it easy for other workers to stay there and communicate. The results also indicate that, since the workstation of the N-T workplace is twice as flexible (4.3/1.5) for other workers, it could induce the workers whose own seat is located there to communicate with visitors there, without leaving for the meeting corner, leading to the higher **R**<sub>PUO</sub>.

5.2 Comparison of meeting corner occupancy

According to Table 10., **R**<sub>FLO</sub> of the N-T workplace was 6.9% higher than that of the T workplace; while in the T workplace, **R**<sub>PUO</sub> of the general-type meeting corner was 5.9% higher than it was for the window-side-type meeting corner.

| T or N-T | Workers' attributes | Post attribute |
|----------|---------------------|---------------|
| T        | Specialty attribute | Architect      | 8   | 62% | 22 | 72% | 10 | 100% | 40 | 77% |
|          |                     | Engineer      | 2   | 68% | 17 | 75% | 1  | 100% | 20 | 77% |
| N-T      | Specialty attribute | Architect      | 13  | 64% | 35 | 72% | 17 | 93% | 65 | 100 |
|          |                     | Engineer      | 4   | 60% | 25 | 70% | 6  | 100% | 35 | 75% |

The above results show that the meeting corners of the N-T workplace were being used more efficiently than those of the T workplace. This might be due to the different number of meeting corners in different workplaces and the spatial configuration of the different meeting corners. To be more specific, in the T workplace,
there were many more seats in the meeting corner (four or eight seats) than there were in the N-T workplace (three seats). According to the observation record that operated during the same period (observing record once per 30 min), the average number of attendees per meeting corner was 2.3 in both workplaces, which means that in the T workplace, one to five seats remained vacant. In the T workplace, although the window-side meeting corners located beside the PLs' own seats might be convenient for use by leaders, since they were located further from other workers' seats than the general-type meeting corners, their \( R_{PUO} \) was much lower.

6. Conclusions
This study compared workers' staying and movement patterns in territorial and non-territorial workplaces. In the study, it was ascertained how differently workers used the space of each workplace, and the different staying and movement characteristics were clarified according to the workers' posts and specialties. The study further revealed the differences in space usage efficiency by comparing the estimated occupancy rates of the workstations and meeting corners in each workplace.

The study findings are summarized as follows:
1) In each workplace, the duration rate of the workers' stay in their working territory was approximately 80%. Compared with workers in a territorial workplace, the non-territorial workplace workers' duration rate of stay in the "own-seat nearby zone" was 8.4% higher. When leaving the "own-seat nearby zone" for other places in the working territory, non-territorial workplace workers stayed 11.6% less in the "meeting corner zone", but 1.4% more in the "workstation zone".

2) A comparison of different workplace workers' stay and movement according to their specialty or post showed the same tendency in terms of differences as was concluded in 1), while a comparison of the stay and movement of the different posts and specialty workers in each separate workplace appeared to be different. Architects stayed longer in the "own-seat nearby zone" than engineers, while engineers voluntarily visited the architects' specialty range more. Compared with the regular staff, project leaders left for other workplaces longer, and their more frequent movement in the "own-seat nearby zone" indicates that they use adjacent workstations or meeting corners more often. The temporary staff spend more than 75% of their work time staying in the "own-seat nearby zone".

3) In terms of estimated occupancy rates, the non-territorial workplace workstation had an 8.5% higher proprietary occupancy, and its 2.8% higher flexible occupancy rate indicates that the space of the workstations in the non-territorial workplace is used more efficiently and more flexibly. In addition, the 6.9% higher occupancy rate shows that the meeting corner in the non-territorial workplace was also used more efficiently.

In this study, the authors have only studied two specific cases of the workers' actual use of workplace represented only in terms of workers' stay and movement. However, the findings may be regarded as a small but important part of the general knowledge on how workers use the workplace. In addition, one of the motivating aims of innovation with a non-territorial workplace which is transformed from a territorial workplace is to increase the efficiency of space usage. The authors revealed that the space of the investigated non-territorial workplace is used more efficiently than the territorial workplace, as concluded above in 3). Although the comparison in this study is not equal to the direct comparison of productivity and cannot reveal that the productivity of the non-territorial workplace is higher, it does show that the space use efficiency of the investigated non-territorial workplace is higher. And according to productivity=output/input, as the workplace is one of the important items of input, its higher space use efficiency could be positive in making effective use of space in the input or reducing the input, which means that higher space use efficiency is positive for increasing the productivity.

Meanwhile, the findings of this study will be helpful in improving the current layout of territorial workplaces. For example, the meeting corners beside leaders' workstations and the window side could be located closer to the general groups to make them more accessible and inviting. In addition, the number of seats and the dimensions of the meeting corners in the general group could be reduced in order to save more space for workstations and to increase the flexibility of their usage. Finally, a detailed insight into how different posts or specialty workers stay and move in each workplace offers valuable information for the design of workplace layouts.

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