

Abstract

From the last century, the transition from other industries to knowledge work industry led to the innovation of the workplace, in order to increase the knowledge work productivity by increasing the occupancy for reducing input and the communication between workers for increase knowledge sharing.

In this dissertation, the author focused on the space use and verbal communication behavior of one type of knowledge workers, which specifically are the workers in architecture design and Construction Companies in renovated workplaces. Following, the author aimed to clarify how the performance of renovated workplaces responded to the renovation purpose. In addition, this dissertation also reveals the workers' behavior characteristic influenced by the work styles on the basis of post and specialty. There have been many studies focused on workers' space use behavior in renovated workplaces, which were conducted mainly by means of interval observation record. Compared with other type of workers, the behavior of knowledge workers is supposed to be composed of more flexible short time use of spaces and short time communication. Therefore, whether the studies conducted by means of interval observation record could grasp the whole accurate information of workers' space use or just part of segments remains as a question to be explored. Differing from previous studies, in this study, the author used sensing technology to research the knowledge workers' seamless temporal location and verbal communication in workplace objectively and precisely.

This dissertation comprises of three parts. The research background and the investigation methods are explored in the general introduction. Following, in the main body of the text, case studies are presented. Finally, conclusions are drawn.

Chapter 1 introduces the background, the purpose and the difference between this research and previous ones.

Chapter 2 presents how the author used the investigation sensors, which are the UWB sensor network, the voice sensor and the acceleration sensor, and the method of combining database. By the experiments, based on the characteristic of gaiting behavior, the author identified the acceleration values according to the subjects' acceleration data and video records on identifying the subjects' walking, which is helpful in revising the

temporal location data. In addition, based on the working principle of the UWB sensor, the author defined a location zone with dimension around 6-15 m². Following, by identifying the optimized position for the wearing voice sensor, the author defined verbal communication based on the characteristic of the data. Finally, the database creation process was presented.

In Chapter 3, firstly, by using the UWB sensor network, the author researched the workers' space use behavior in the non-territorial workplace. Following, the author focused on the workers' tendency of choosing the individual workstation, as well as on the correlation between the workers' space use characteristics and workstation location.

Findings showed that, in the non-territorial workplace, the workers spent 72.5% of their time on staying at the own seat and the place nearby. When workers left the individual workstation for other places, they used the "Meeting corner side zone" more with an average staying duration of 5 minutes. Although the workers also used the "Corridor side zone" quite frequently, their average staying duration per once was around 3 min. Analysis on workers' choosing individual workstation behavior showed that, 70% of the workers chose the same individual workstation, 90% of the workers chose the same or adjacent areas, and only 10% of the workers chose dispersed individual workstations.

Additionally, with regarding the post, the workers' space use behavior performed differently on the basis of individual workstation's spatial attribute. For instance, Project leaders chose the individual workstations beside the meeting corner and the inner main horizontal corridor more frequently. Once located there, project leaders' move duration rate is around 10%, the highest of all the staffs. Meanwhile, their duration rate was significantly lower on staying at the individual workstation and nearby, but significantly higher on visiting and staying at other workstations. Regular staff tended to choose the workstation located at the centre of the table area and beside the meeting corner table more frequently. Once located there, the regular staff's move duration was significantly lower. However, their duration rate was significantly higher on staying at the individual workstation and nearby. Temporary staff tended to choose the workstation located at the window side more frequently. Once located there, their frequency of staying at the same workstation range was significantly higher.

Findings of this chapter are helpful in improving the investigated non-territorial workplace layout. For instance: 1) As the bigger meeting space is seldom used, it should be removed from the workplace. 2) Half of the meeting corners should be located at

corridor side in order to be shared more easily by different specialty staff.

In Chapter 4, by the interval-recording and the UWB sensor network, the author aimed to concretely clarify the characteristics of workers' using way and space use behavior in territorial and non-territorial workplaces. Following, the author aimed to identify whether the non-territorial workplace is occupied more compared to the territorial workplace.

Findings showed that, regarding the using ways, the space of non-territorial workplace was used more flexibly, not only as its workstations were occupied more by both employees' working with PC and only by PC (7.3% higher) and other using way such as communication, but also as its meeting corners were shared used more by both architects and engineers. Meanwhile, the meeting corner table of the territorial workplace is used less evenly, as 4/9 of them are located further from most workers. The average number of attendees showed that there are 5 seats of the bigger meeting corner table in the territorial workplace were vacant in each communication.

By comparing the estimated occupancy rates, it was found that the non-territorial workplace workstation had an 8.5% higher proprietary occupancy rate and an 2.8% higher flexible occupancy rate than the territorial workplace. Additionally, the meeting corner also had an 6.9% higher occupancy rate. This result indicates that the space of the non-territorial workplace is occupied more frequently and more flexibly by various usages.

Finding of this chapter are helpful in improving the investigated workplace layouts. For example: 1) In order to increase the occupancy rate, the frequently used space for public sharing should be distributed evenly in the workplace. 2) In order to increase the occupancy rate, the workstation should be designed to be reached and stayed conveniently by not only its owners but also by other workers. 3) The suitable number of seats of the meeting corner table is quite important to increase the occupancy rate.

In Chapter 5, the author compared the knowledge workers' verbal communication characteristics in a big open plan workplace with and without inter-specialty partition walls. Following, the author clarified the influence of partition walls on the workers' space use and verbal communication was clarified. Furthermore the characteristics of the workers' space use and verbal communication behavior correlated with the workers' post and specialty attribute were revealed.

It was found that, in both workplaces, workers spent around 60% of their time on

staying at the individual workstation and nearby, where around 50% of their verbal communication occurred. Compared with the workers in the workplace with inter-specialty partition walls, workers in the big open plan workplace stayed 3.5% more and orally communicated 5.1% more at the other specialty ranges. Meanwhile, the proportion of their verbal communication on staying at the individual workstation and nearby was 13.6% more.

Finding of this chapter are helpful in improving the investigated big open workplace layout. For example: 1) Project leaders' workstations should be located close to the meeting space, in order to make it more convenient for them to visit and stay at the meeting space. Project leaders' proportion of verbal communication staying inside workplace is around 10% higher than that of the regular staff in both workplaces.

2) By removing the partition walls, the visual contact was increased and increased as well as workers' verbal communication. 3) In the workplace layout design, the frequently used public space, such as the meeting space, should be distributed evenly to each specialty.

Chapter 6 concludes with the findings regarding the knowledge workers' space use behavior and verbal communication behavior, aimed to propose the valuable information on improving the workplace layout design.

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Chapter 1 General Introduction

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1.1 Background

From the last century, the transformation from depending on manufacturing industry to knowledge industry has happened in the developed countries ¹⁾. The transition of industry also leads to the transition of the workplace. In the knowledge product process, there is a strong, on-going linkage between knowledge workers and innovation. And knowledge workers engage in “peer-to-peer” knowledge sharing across the organizational and company boundaries, forming networks of expertise ²⁾. In order to increase the productivity and respond to the development of the technique and the need of knowledge workers’ work style, some new types of workplaces have been developed.

The renovations of the workplace design involve, primarily, those that improve the performance and satisfaction of knowledge workers. The design of the workplace has firstly focused on factors that improve the efficiency of knowledge work, such as location of supplies and ease of use of tools ³⁾. The fields of human factors engineering and ergonomics, for example, have devoted extensive research to improve work efficiency through the design of lighting, furniture, climate and noise control, and even ambient odor ⁴⁾. Because of this work, most of today’s workers are given a space that provides physical comfort, adequate lighting, and a buffer from environmental noise, uncomfortable temperatures, and unpleasant smells. In fact, as a result of the advances in understanding of human factors engineering and ergonomics in the workplace design, organizations can, in theory, design workplace to accommodate physical human needs. By contrast, the more recent design has focused on the effects of the workplace design on information transfer among knowledge workers ⁵⁾. Since then, it has been a long way in making work environments more comfortable. However, the effects of renovated workplaces on today’s knowledge-intensive work processes have only begun to be understood ⁶⁾.

1.1.1 Knowledge industry and the new workplace type in Japan

The background mentioned above has showed the importance that keeping the high productivity of knowledge industry still holds in world economic competition. The renovations on the Japanese workplace layout had been applied since the 1970s. These could be classified into 3 general types: the non-territorial workplace, the big open plan workplace and the universal plan workplace ⁷⁾. And since 1987, with the implementation of FM conducted by JFMA and NOPA, the innovation of furniture design and the operation of FM management have been applied ⁸⁾.

1.1.2 The meaning of study on knowledge workers' behavior in workplaces

As the main motivation of workplace renovation is to increase the productivity of knowledge work, the evaluation on productivity should identify the performance of renovated workplace directly. The productivity can be defined as the relationship between outputs and inputs. And as described in Fig. 1-1, three important sets of factors can be derived from productivity: inputs, outputs and the process through which inputs are transformed into final outputs.

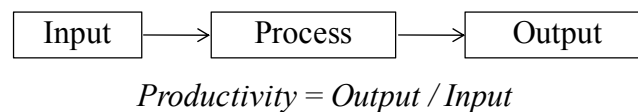


Figure 1-1 Definition and components of productivity ⁹⁾

However, in practice, it is very difficult to evaluate the knowledge work productivity which represented by Output/Input according to the six factors*¹ for knowledge work productivity defined by Drucker ¹⁰⁾. As mentioned by Drucker, productivity of the knowledge work is not a matter of the quantity of output, it makes the productivity of knowledge work difficult to be evaluated. As a result, there is few study can show how these new workplaces responded to or influence knowledge work by productivity objectively until now.

The resources used in knowledge work can have crucial implications to the outcome, and improving the process is also important for increasing the productivity. The essential factors of knowledge work are listed in Table 1-1 proposed by Antikainen⁹⁾. The essential factors are divided into three groups: input, process, and output. And the inputs are divided into organizational, personal and physical inputs.

Table 1-1 Drivers of knowledge work productivity ⁹⁾

Input	Process	Output
Personal: - Human capital - Innovative potential - Motivation - Job satisfaction - Personal network Organizational: - Organizational standards, practices and routines - Information systems - Quality of information - Networks - Time allocation Physical: <u>- Working environment</u>	- Organization of work - Division of tasks - Organization of decision making - Clarity of job descriptions - Teamwork - Delays and waiting - Ability to affect own work - Knowledge sharing	- Innovations - Quality - Utilization of innovations - Time-efficiency - Fulfillment of customer's expectations

Therefore, by changing the physical inputs, which especially is the working environment in this dissertation, the productivity of knowledge work could be improved. Although the direct influence of working environment is listed only in input, it still can influence the other item in input such as Job satisfaction, and the items listed in process such as the Team work and the Knowledge sharing.

In the factor of working environment, the increasing-productivity is achieved by the workplace's better support to workers' behavior (Fig.1-2), or in other words, by promoting the workers' better performance with influence by the workplace. Instead of knowledge work productivity itself, the research on workers' behavior could be used to evaluate the performance of the renovated workplace. In other words, the research concerning workers' behavior in workplace is helpful to reveal the performance of the workplace. Additionally, it can also directly identify whether the renovated workplace achieved the sub purpose, such as to increase the occupancy of space and communication. Moreover, from the inter-relationship among activities—behavior pattern—work style (Fig.1-3), the research on behavior is also helpful to reveal the knowledge workers' work style.

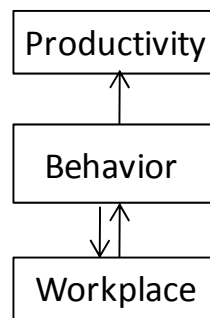


Figure 1-2 Interrelationship of Workplace, Behavior and Workplace

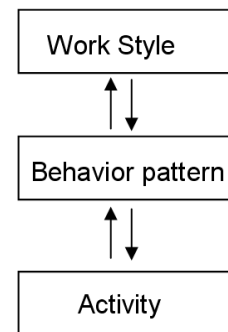


Figure 1-3 Interrelationship of Activity, Behavior pattern and Work Style ¹¹⁾

In this way, the evaluation on performance of renovated workplace by knowledge work productivity is transformed to

reveal the behavior of knowledge worker in workplaces, or in other words, transformed to reveal the characteristics of knowledge worker's behavior which are influenced by work style and workplaces ¹¹⁾.

The knowledge work is mainly composed of the collecting, analyzing and creating information responded to the specific purpose (or in other words, solving the problem) ⁶⁾, which would happen at the same time and would be mixed in the whole process. Therefore, the knowledge workers' behavior represented by dealing with information is too complex to be grasped. And the knowledge work behaviors are much more complex than the ones of product industry work. Therefore, until now, there is no one could summarize the exact behavior patterns as Frederick Winslow Taylor*² did to product industry work behavior pattern.

Additionally, from the Fig.1-4, working environment and its effect on productivity

can be broken down to the components. There have been many measuring ways on workers' satisfaction in order to make work effectively and reduce the input. For instance, POE (Post Occupancy Evaluation) emerges as a method to assess how well buildings match users' needs and satisfaction, in order to identify ways to improve building design based on users' response in specific designed environment.

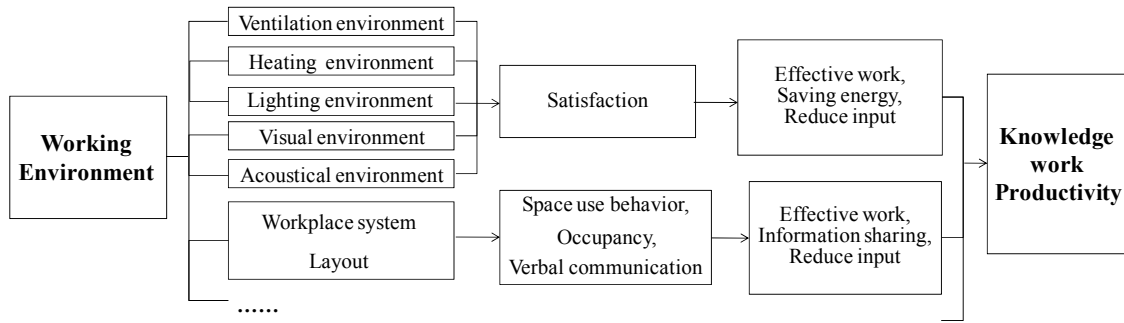


Figure 1-4 Definition and components of productivity

Meanwhile, by Fig. 1-4, the effects of workplace system and layout on productivity are also very important. The specific factors of effects are.

I. To respond to workers' space use behavior for making workers worked effectively. The workers' space use behaviors are different with regarding their work style caused by post and specialty. Therefore the workplace system and the layout are supposed to fully respond to workers' various need, make them work effectively.

II. To increase the occupancy rate for making the space occupied more effectively. In order to respond to various behaviors and increase attendance rates, the workplace is designed to offer more opportunity for workers' flexible use. Moreover, according to the perspective of manager, layout with high occupancy rates and flexible space usage is supposed to reduce the vacant space and reduce the input ¹²⁾.

III. To increase verbal communication for sharing information. The layout has strong influence on workers' verbal communication. The verbal communication between workers is supposed to be important for sharing information, forming good cooperation relationship, keeping high arousal of consciousness concentrated on work ¹²⁾. To increase verbal communication is an important workplace design purpose for increasing knowledge work productivity according to the knowledge management theory ¹³⁾. Although some research showed that too much verbal communication decreased the workers' satisfaction with acoustical environment ¹²⁾.

Therefore, in this study, rather than exact knowledge work behavior, the author focused on the knowledge worker' seamless temporal behavioral data in following discussion, in order to precisely reveal the relationship between workplace and workers'

space use, occupancies and verbal communication . Meanwhile, the clarification of the workers' behavior characteristic will offer us a better insight on understanding the workers' work style influenced by their post and specialty. Finally, this study also clarified the performance of workplace evaluated by workers' space use, occupancy and verbal communication in order to improve workplace for increasing productivity.

1.2 Research subjects, behaviors and investigated workplaces in this research

The relationship between subjects, behaviors and investigated workplaces in this dissertation is shown in Fig.1-5. The items in the figure are explained as follows:

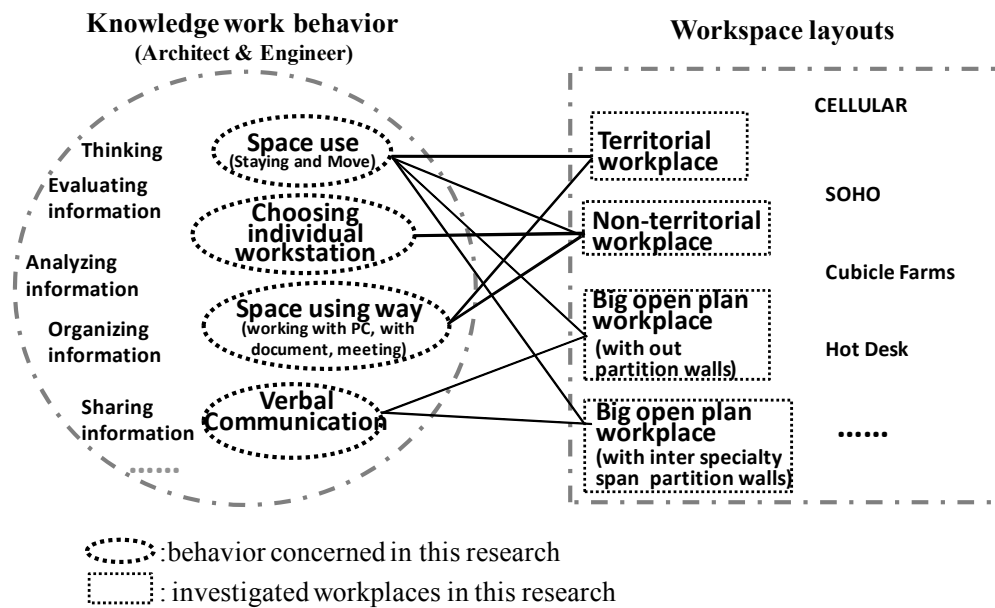


Figure 1-5 Behavior and investigated workplaces in this research

1.2.1 Knowledge worker

As Peter Drucker defined in 1959, knowledge workers in the workforce are individuals who are valued for their ability to interpret information within a specific subject area ¹⁴⁾. They will often advance the overall understanding of a certain subject through focused analysis, design and/or development. They use research skills to define problems and to identify alternatives. Fueled by their expertise and insight, they work to solve those problems, in an effort to influence the decisions, priorities and strategies of the company. Knowledge workers may not only be found across a variety of information technology roles, but also among professionals like teachers, lawyers, architects, physicians, doctors, engineers and scientists.

In this dissertation, specifically, the knowledge worker means the architects and the engineers in the architecture construction companies, which were selected as the

research subjects. As the architects and engineers are problem solvers, not merely methodical workers, they do not simply gain knowledge through memorization, but expand on it through critical thinking. For instance, architects and engineers apply their knowledge to design buildings, bridges and other structures with responding to the principles of cause and effect. Meanwhile, they make their working with knowledge and information for dealing with unique situations ¹⁴⁾ .

1.2.2 Behaviors

There have been three main definitions on knowledge work behavior on the basis of different perspectives: The 1st one is on the basis of the knowledge work creating process, according to the SECI model by Ikujiro Nonaka and Hirotaka Takeuchi¹⁵⁾ (Fig. 1-6). The knowledge work is composed of four conversion patterns, each of which request the complex ability of dealing with knowledge and has a close relationship with each other. The 2nd one on basis of knowledge information management theory, classifies the knowledge work behavior into 8 types: evaluating, organizing, analyzing, sharing, presenting, applying, storing and retrieving information ¹⁶⁾ . By the 3rd one, knowledge work behavior is classified into two types, acting and thinking ¹⁷⁾ , and each of these can also be classified into more detailed categories. However, focused on the classifications by these three theories, as these behaviors (such as thinking) are hard to be recorded, the classification by these three theories has not clarified the relationship between workplace and knowledge worker's behavior mentioned above either. In addition, several behaviors could and always happen at the same time and are too mixed to be clarified.

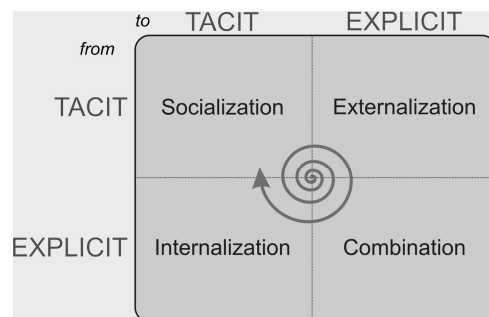


Figure 1-6 SECI model¹³⁾

Therefore, in this study, the author focused on the knowledge workers' space use behavior and verbal communication behavior, as all of knowledge work behaviors needs space to be realized, and the communication behavior plays the most important role in knowledge work process. Therefore, in this dissertation, the behaviors involved in the research are knowledge workers' space use behavior, which represented by their staying at or occupancy of the workstation and meeting table in the workplace, and the verbal communication behavior (without concerning the content). Additionally, in the part of research conducted by means of observation record will focus on the specific space

using way, such as work with PC at individual workstation or working with document at the individual workstation will be focused on.

1.2.3 The workplaces for investigation and research

In this dissertation, one territorial and one non-territorial workplace in the same company were selected for researching and comparing knowledge workers' space use behavior. Furthermore, one big open plan workplace was chosen for researching on knowledge workers' space use and verbal communication behavior in the condition with and without partition walls, which were set up between specialty ranges. Specifically, the layout and exact definition of each workplace is showed as follows:

- a. Territorial workplace: all employees are assigned to fixed individual workstations so they can complete their individual tasks and store their personal belongings. The tables, which are specially used for communications and meetings, are arranged in each specialty or group ranges.
- b. Non-territorial workplace^{*3}: all employees can freely select their location or workstation for their daily work. The tables, which are specially used for communications and meetings, are arranged in the space evenly.
- c. Big open plan workplace (with and without partition walls): in the big open space, it offered all employees at an individual workstation has 110 cm partitions which block the workers' sight when they sit at the workstation. The space, which is specially used for communications and meetings, is congregated. In this research, the partition walls, which separated specialties, were set up and removed in two different investigations to clarify the influence of partition walls on workers' space use and verbal communication behavior.

A detailed introduction about the investigated workplace cases are presented in Chapter 3, 4 and 5.

1.3 Purpose and Significance

The purpose of this dissertation is mainly to clarify the knowledge workers' space use behavior and verbal communication behavior in each investigated workplaces. By analyzing the duration rate and frequency of workers' staying and verbal communication, the author aimed to clarify the performance of workplace and identify whether the renovated workplaces achieved the renovation purposes. In addition, by comparing knowledge workers' space use and verbal communication behavior in terms of post and specialty, it is expected to reveal their work styles. The insight on workers'

space use behavior helps to improve the investigated workplaces and offers valuable information for workplace layout design.

1.3.1 Purpose

The main renovation purpose of non-territorial and big open plan workplaces is to increase the knowledge work productivity, by supporting the workers' behavior better and by increasing the opportunity of communication between workers. Additionally, the renovation of the non-territorial workplace layout also responded to the low occupancy ration problem in the workplace and made the workstations occupied more freely and used more flexibly. Therefore, the purpose of the workplace renovation is not only to increase the occupancy rate but also to increase the flexibility of space use. In this light, this study aims at identifying whether the renovated workplace achieved the renovation purpose, such as making the space occupied more efficiently and flexibility, or increasing verbal communication between workers. In addition, this dissertation is also aims at quantitatively revealing the knowledge workers' space use and verbal communication behavior in workplaces according to workers' post and specialty.

The detailed goals of the study of workers' behaviors in non-territorial workplaces are shown as the following:

- 1) To clarify the duration rate and the frequency of workers' staying at the places of non-territorial workplaces according to workers' post and specialty.
- 2) To clarify the characteristics of workers' choosing individual workstations behavior on the basis of their post.
- 3) To clarify the relationship between workers' choosing individual workstations tendency and worker's space use behavior according to workers' post.

Furthermore, the detailed goals for the comparison of workers' space use behavior in the territorial and non-territorial workplaces are the following:

- 1) To clarify the worker's occupancy frequencies at the workstation according to the using ways, and the occupancy frequencies at the meeting corner according to the attribute of attendees on hold communication in territorial and non-territorial workplaces.
- 2) To clarify the duration rates, the frequencies and the durations per time of workers' staying at the places of territorial and non-territorial workplaces.
- 3) To clarify the occupancy rates at the workstation and meeting corner in territorial

and non-territorial workplaces.

In addition, the detailed goals of the comparison of workers' space use and verbal communication behavior in the big open plan workplaces with and without partition walls are the following:

- 1) To clarify the influence of partition walls' on workers' staying and verbal communication in places of workplaces, by comparing the workers' space use and verbal communication behavior in two workplaces,
- 2) To clarify the characteristics of workers' staying and verbal communication in places of workplaces, according to the workers' post and specialty.

1.3.2 Significance

Since the subjects studied were specific cases (specific workplace and knowledge workers), the findings of this study cannot be interpreted as the general workplace use of all types of knowledge workers. They do, however, reflect the specific characteristics of space use that exist in the studied cases, and the precise behavior characteristic of one type of knowledge work, thus, making them concrete realities that should not be ignored. Moreover, besides the clarification of workers' space use behavior characteristic, the comparison of workers' space use and verbal communication behavior in workplaces reveals whether the renovated workplaces achieved its renovation purpose. This research is studied from a new, more specific and precise perspective not approached by the following previous studies.

Findings of comparing workplaces before and after transformed to the non-territorial workplace from territorial workplace in previous studies:

- Satisfaction with space environment: increased: Allen ¹⁸⁾, Shimamura ^{19) 20)}
- Knowledge work productivity: increased: Voordt ¹²⁾
- Noise disturbance and distraction: increased: Allen ¹⁸⁾
- Communication: frequency increased: Voordt ¹²⁾, Yamada ²¹⁾, Hanada ^{22) 23)}
places for communication increased: Yamada ¹⁹⁾ ;
with member in different group increased: Hanada ^{22) 23)}
- Privacy and relaxation feel at the individual workstation: decreased: Iwakiri ²⁴⁾

Findings of comparing workplaces before and after transformed to the big open plan workplace in previous studies:

- Satisfaction with space environment: increased: Boje ²⁵⁾ .

- Noise disturbance and distraction: increased: Sundstrom²⁶⁾ .
- Prohibits confidential conversations: increased: Sundstrom²⁷⁾ .
- Psychological privacy: decreased: Sundstrom²⁸⁾ .
- Friendship: decreased: Oldham²⁹⁾ .
- Disturbance & supervisor rating of performance: no relation: Sundstrom³⁰⁾ .
- Social contact with coworkers: no change (in 6 months): Sundstrom²⁶⁾ .
- Number of information requests received: decreased: Zalesny³¹⁾ .

As mentioned above, the findings in the above mentioned studies few focused on workers' space use behavior or analyzed only by frequency. Therefore, compared with previous studies, the findings of this study, by analyzing the continuous seamless location and utterance data, will help to compare the performance of workplaces. Moreover, they will offer a better insight into understanding the workers' work style in terms of post and specialty, and they will offer valuable information on improving the current layouts of the investigated workplaces.

1.4 Method

With data collected by sensors, the author analyzed the duration rate, frequency and lasted duration per time unit of workers' staying and verbal communication, aiming at clarifying the characteristic of workers' space use and verbal communication in workplaces. Moreover, the frequency of choosing an individual workstation and the frequency of space using way in territorial and non-territorial workplaces are also analyzed. The specific investigation methods used in this research are listed in Fig. 1-7.

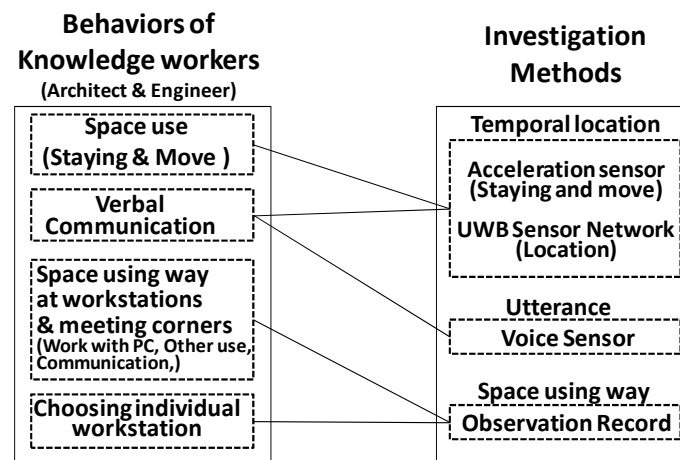


Figure 1-7 Relationship of behavior items and investigation methods

1.4.1 Obtaining of the prime data by seamless recording

The following devices were mainly used to precisely and continuously record the staying and move of architects and engineers who worked in the investigated workplaces.

- 1) UWB (Ultra-Wide-Band) sensor network: sensing device that can record the subject's temporal location inside the workplace.
- 2) Acceleration sensor: sensor that can record the acceleration of the subject. This facility helps to distinguish the subject's move (walk) duration from the staying duration.
- 3) Voice sensor: it was used to record the moment and the duration when the subject was talking, without recording the content.

A detailed description of the usage of the sensors, the database revising method and the combination process are presented in Chapter. 2.

1.4.2 Data analysis

In Chapter 3, the workers' spatial staying duration rate and frequency are analyzed to clarify the characteristic of workers' staying at the places in non-territorial workplaces on the basis of workers' post and specialty. Following, the workers' frequency and tendency of choosing an individual workstation are analyzed. Finally, a T-test is used to clarify the relationship between workers' space use and the spatial attribute of the selected individual workstation according to the workers' post.

In Chapter 4, the occupancy frequency is analyzed to compare the workers' space using ways, such as occupying the workstation for PC work or other ways. Moreover, the author compared the number and specialty attribute of attendees on holding communication at meeting corners in territorial and non-territorial workplaces. The T-test is used to clarify the workers' space use behavior in territorial and non-territorial workplaces in terms of duration rate, frequency and lasted duration per time unit. Finally, according to the workers' attendance rate and staying duration rate, the occupancy rate at the workstation and meeting corner in two workplaces are calculated and compared.

In Chapter 5, in terms of duration rate and frequency, the T-test and Z-test are used to clarify and compare the workers' staying and verbal communication in places of big open plan workplaces with and without partition walls. Additionally, the quotient of verbal communication duration and staying duration per one unit staying time are analyzed to reveal the probability of workers' verbal communication.

1.5 Previous studies and the difference between this study and previous studies

1.5.1 Literature regarding the territorial and non-territorial workplace

Studies focusing on workplaces can be classified into two types according to the research objects: worker's satisfaction with the environment of the workplace and worker's behavior. Furthermore, each can also be further classified into three types according to the layout of the investigated workplaces.

1) Literature regarding the worker's satisfaction with environment of workplace

① Layout: Territorial workplace

Akiyama et al.³²⁾ found that, the height of the partition, the layouts, and how a worker interacts with his or her coworkers, would influence workers' satisfaction with spatial environment of individual workstation for concentration work. Arisawa et al.³³⁾ classified workers into "Interaction" and "Autonomy" type, and suggested that for the "High Interaction" worker, a layout that helps worker's communication is preferred, however, the research did not propose the specific layout.

② Layout: Non-territorial workplace

Shimamura et al.^{19) 20)} found that, in non-territorial workplaces, workers' satisfactions increased not only through physical quality increase but also through the free address system itself. Yamada et al.³⁴⁾ found that the non-territorial workplace helps to enlarge a person's territory and increases communication while keeping the workers' privacy at the same time. Kinoshita et al.³⁵⁾ found that after the transformation to the non-territorial workplace, the non-territorial workplace led to cost reduction while keeping the same satisfaction level.

③ Layouts: Comparison of Territorial and Non-territorial workplace

Allen et al.¹⁸⁾ traced the variations in communication in a year-long investigation into a non-territorial office, and found that compared with territorial workplace, workers felt having more privacy and less distraction. Voordt¹²⁾ found that over 90% of subjects thought the non-territorial workplace influence positively on knowledge work productivity. Voordt¹²⁾ also found that subjects thought that the non-territorial workplace is better for information exchange and easier transfer of knowledge, but complained about too much communication. Additionally, 60% of the subjects were satisfied with the transformation from the territorial workplace to the non-territorial

workplace in Voordt's research ¹²⁾. Matsushita et al. ^{36) 37)} found that the post occupant evaluation of the non-territorial workplace was much higher than before, which proved this workplace type is effective. Iwakiri et al. ²⁴⁾ found that compared with territorial workplace, the non-territorial workplace was effective in the improvement of individual work space, and its workers felt less exhausted. Regarding the attendance rate, Ikuno et al. ^{38) 39) 40)} evaluated the weighing of objective spatial items (such as the width of a corridor), which could influenced the users' satisfaction, and concluded that the transformation from the investigated territorial workplace to the non-territorial workplace could increase the users' satisfaction with the spatial environment.

2) Literature regarding the worker's behavior

① Layout: Territorial workplace

Several studies focused on the workers' activity in the territorial workplace. By observation record, Naka et al. ^{41) 42) 43) 44) 45) 46)} clarified the relationship between communication content type and space, and found that the probability of communication at the meeting space (43%) and inter-action space (67%) are much higher than in other spaces. Moreover, Naka et al. found that around 50%~55% of the workers' behavior patterns could be defined as the SECI behavior which has a close relationship with the knowledge creating. Igarashi et al. ^{47) 48)} found that in workplace, 44% of workers' communication is about information sharing and 30% is about work solution. Le Roux et al. ⁴⁹⁾ developed "Model of Work Style Typology" with data on employees' time in the office and attendance rate. Shiozaki et al. ⁵⁰⁾ studied the relationship between communication frequency and the length of island type workstation, and found that the short length island workstation could support communication better than the long length island workstation.

Other studies focused on workers' behavior in certain parts of the territorial workplace. Peponis et al. ⁵¹⁾ indicated that controlling for departmental affiliation, faculties whose offices are located along well-connected corridors have a close cooperation relationship. Saji et al. ⁵²⁾ found that the exchange of valuable communication for office work was activated in buffer type boundary areas.

② Layout: Non-territorial workplace

Tsunekawa et al. ⁵³⁾ found that, in the non-territorial workplace, the side of the table which is closed to the corridor is occupied more frequently and that the workers' personal work territory is considered to be enlarged by it.

③ Layout: Comparison of the Territorial and Non-territorial workplace

Mori et al.⁵⁴⁾ clarified the relationship between the layout plan and the working style in an office. By analyzing the layouts of cases, the observation record of workers in workplaces, and the trailing record on two workers, Mori found that the communication frequency in non-territorial workplaces is more than that of territorial workplaces. Moreover, Mori clarified the interrelationship between trajectory and communication characteristics and between the work style and the layout, and proposed the planning methodology. Yamada et al.²¹⁾ found that, compared with territorial workplace, not only the communication frequency but also the places for communication is increased. Hanada et al.^{22) 23)} found that workers' communication frequency among members of different groups is higher in the non-territorial workplace.

The studies above showed that compared with the territorial workplace, the non-territorial workplace could make workers feel more satisfied^{18) 12) 36) 37) 24)} and communicate more frequently^{9) 52) 19) 20) 21)}. However, the value of these findings is limited by the investigation methods. The research which focused on workers' satisfaction and operated with questionnaire is a subjective one. The research which focused on workers' behavior and operated by interval observation record or photographing, only recorded the frequency, thus, causing the activities whose lasted duration different from each other are evaluated with the same weighing. As a result, the research conducted by means of interval observation record or photographing seems to be not so precise. Furthermore, the research conducted by means of interval record could ignore the behavior of which duration lasted for short duration. Although some research was conducted by means of investigator's trailing record, its sample size was limited to 10 workers per time, as too many investigators in the workplace would influence the workers' normal work and influence their privacy and usual work. Additionally, the trailing record investigation method may even decrease the workers' verbal communication or the rest in the relaxation space. Therefore, to quantitatively analyze the workers' space use in the territorial and non-territorial space or how they spend their time also remains as a research topic.

1.5.2 Literature regarding the big open plan workplace

The research topic in most of the previous studies on big open plan workplace is physical environment, which is specifically shown below:

Yoshino et al.^{55) 56)} studied the acoustic indoor climate in big open plan workplaces. Ernst et al.⁵⁷⁾ clarified the acoustic design and equipment installation in office blocks with big open plan areas. Smith et al.⁵⁸⁾ focused on noise conditions in big open plan workplaces and found that big open plan workplaces are related to negative outcomes such as job dissatisfaction, lower peaceful feel, and lower productivity. However, there are also several contradictions in the research domain. Maher et al.⁵⁹⁾ found that regardless the layout, workers' satisfaction and performance decreased for employees with poor stimulus screening or poor inhibitory ability, low perceived privacy, or complex tasks of personal work.

Stone et al.⁶⁰⁾ focused on the relationship of the big open plan workspace color and workers' mood, and found that the subjects performed either a low or high demand task in a blue or red workspace, regardless of a scenic poster. Stone also found that the subjects' performance was only significantly affected by the task type. Hirasawa et al.^{61) 62)} clarified the relationship of seat preference and the surroundings (such as the setting of the partitions) in big open plan workplaces and distinguished 3 types, which specifically are concentrated type, the communication type and the open type. Maeda et al.⁶³⁾ focused on workers' existence and visual contact in a big open plan workplace, and clarified the relationship between the personal sensation from others and effects of workplace layout. Goins et al.⁶⁴⁾ found that the partitions have a huge effect on influencing on workers' performance in big open plan workplaces.

Most of the previous studies mentioned above focus on the physical environment, such as the acoustic environment^{55) 56) 57)} and on the visual environment caused by the distribution of the workstation⁶³⁾, the interior color⁶⁰⁾ and the partition⁶⁴⁾. However. Only a few studies focused on the worker's behavior in this type of workplace. This might be due to the fact that the space of the big open plan workplace is too big to be investigated by the interval photograph investigation method or observation record which is usually used in the study of territorial and non-territorial workplaces. Although the findings of the studies above proved that the big open plan workplace may cause a negative influence on worker's work in noise problem, these studies have not focused on the communication between workers, which is one of the most important innovation purposes of innovation. Therefore, the research on worker's communication in big open

plan workplaces remains as an important research topic.

1.5.3 Literature regarding the sensing technology

The development of sensing technology shows potential for precisely observing activities in the buildings especially used for the study of resident activities in house rooms. Some studies have focused on the movement trajectory, Enta et al. ⁶⁵⁾ examined the accuracy of slipper-type RFID in sensing the walking of subjects in their experiment.

Sensing technology was also used to study routine behavior in the house. Matsuoka ⁶⁶⁾ investigated on residents' daily routine activities by using a CCD camera in an experimental house. Mori ⁶⁷⁾ built an experiment room, in which sensors were installed to measure the residents' daily activities. Minoh ⁶⁸⁾ detected the subjects' activities by camera and sensors in an experimental house. Tapia et al. ⁶⁹⁾ designed a system that can recognize certain human activities in a house by gathering data from sensors affixed to every object the resident touches. Enta et al. ⁶⁵⁾ used ring-type RFID to record the frequency with which the subjects used. Qu et al. ^{70), 71), 72)} used RFID to clarify the residents' room use in terms of actual time flow.

Few studies focused on workers' activities in the workplace by using sensor technology. Although, Choudhury et al. ⁷³⁾ developed the "Sociometer System" to research the knowledge workers' face to face communication in the workplace, the data collected is only about the subjects' ID, and the moment and duration of their oral communication while location information is kept unknown.

1.5.4 The difference between the method of this study and previous studies

For the reason mentioned in section 1.3, the study on the workers' behavior in the workplace is relevant in improving the workplace layout design and the workplace management which in turn could increase the knowledge work productivity. However, the study on knowledge workers' behavior in workplace, by using interval observation or photographing record, cannot record the workers' behavior efficiently since the interval record cannot collect the precise data or can ignore short duration behavior.

The most common study method on knowledge workplace is questionnaire, which is mainly represented by Post Occupancy Evaluation. Although, this method, on the basis of the subjective answers of the subjects, is helpful in understanding their satisfaction with renovated workplace environment, the self-reported data is also influenced by the discrepancy of the subjects' individual subjectiveness. Therefore,

previous studies tended to collect large amounts of primary data whose analysis could only contribute to general understanding on whether the workplace changed for better or for worse. In short, the research conducted by means of questionnaire is helpful in clarifying whether the workers are satisfied with workplace environment, but cannot find out the specific way in which workers use the space of workplace objectively nor precisely.

Some studies focused on knowledge workers' objective activities in workplace. The investigations were conducted by means of interval photograph, observation record or trailing record. The former two methods, whose shooting or recording frequency is usually one time every 15 minutes, mainly collected the data on the frequency, which means that the activities with different durations are evaluated with the same weighing. Additionally, as some of workers' behaviors, which are lasted for short duration per unit time, which is thought to be one important characteristic of knowledge work, might be ignored by the interval record. Therefore, the research conducted by means of interval record can only record the segments of workers' behavior, but is not able to grasp the whole seamless continuous behavior of workers. Even though the research conducted by means of trailing record can collect seamless temporal location data without any blank, the sample size is limited. This is because too many investigators in the workplace would influence the workers' normal work behavior and privacy. Additionally, the subjects' feel of being monitored could influence their routine activities and therefore influence the objectivity of the data.

Therefore, the author chose to record the knowledge workers' seamless temporal location data in the workplace seamlessly and precisely by using sensing technology. The precise and seamless data offers the possibility of getting a deeper understanding of the specific space use of knowledge worker. It is likely that we can see more details when focusing on them closely. Unlike studies conducted by means of interval photograph or observation record focused on record frequency, this study focuses on workers' space use and verbal communication duration as well as their frequency. Although the content of workers' activities and communication cannot be recorded, the precise and accurate data about workers' staying, move and verbal communication is also able to offers an important insight into how workers use the space of the workplace. In addition, this research is helpful in comparing and evaluating the performance of workplaces with different layouts.

Compared with the research conducted by means of interval photograph, observation record and trailing record, this study poses less burden on the subjects

during a day-long survey, thus, the influence on workers' activity can be ignored. Moreover, unlike the previous studies that aimed to use sensing technology to detect the resident behavior pattern in different rooms of a house or those which only focused on verbal communication behavior, this study uses the technology to identify the characteristics of workers' location in one workplace.

1.6 Framework

This dissertation comprises of three main parts (Fig.1-8). In the 1st part, the general introduction is presented (Chapter 1). Following, the used method of sensors, the definition of behaviors according to the data characteristics, and the data revising process are discussed (Chapter 2).

The 2nd part, which is the main part of this dissertation, comprises of three chapters, in which the author analyzes the cases of workers' behavior in workplaces.

Chapter 3 focuses on and analyzes the workers' space use behavior (staying and move) in the non-territorial workplace for revealing the characteristics of workers' space use in the non-territorial workplace. Moreover, the characteristics of workers' space use caused by the post or specialty are also clarified. In addition, the workers' tendency to choose individual workstations according to spatial attribute of the workstation is also clarified. Lastly, workers' space use according to different individual workstation is revealed by data collected using the UWB sensor network.

In Chapter 4, the space using ways that workers occupied workstations and meeting corners in each workplace is clarified and compared with the data collected by means of observation record. Furthermore, the author concretely clarifies and compares the workers' space use in territorial and non-territorial workplaces. Finally, the occupancy rates of workstations and meeting corners in two workplaces are distinguished according to the workers' attendance rate and staying duration rate,.

In Chapter 5, by comparing the workers' space use and verbal communication in big open plan workplaces with and without partition walls, the author clarifies the influence of partition walls on workers' space use and verbal communication. Furthermore, the characteristics of workers' space use and verbal communication, in terms of post and specialty, are also revealed.

Chapter 6 concludes the findings with regarding the workers' space use.

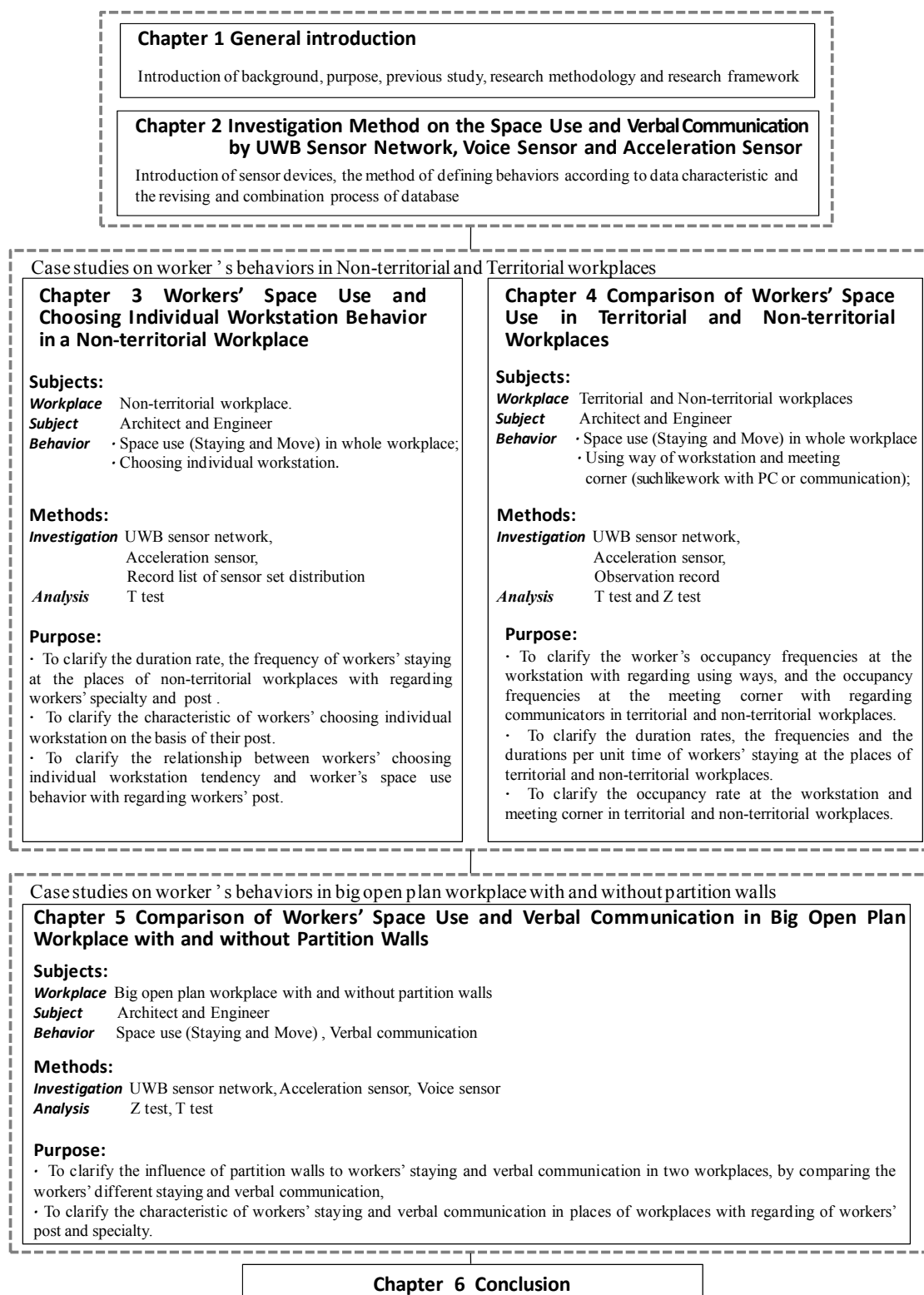


Figure 1-8 Framework of the dissertation

Note

*1 Six factors for knowledge work productivity defined by Drucker:

- ①. Knowledge work productivity demands that we ask the question: "What is the task?"
- ②. It demands that we impose the responsibility for their productivity on the individual knowledge workers themselves. Knowledge workers have to manage themselves.
- ③. Continuing innovation has to be part of the work, the task and the responsibility of knowledge work.
- ④. Knowledge work requires continuous learning on the part of the knowledge worker, but equally continuous teaching on the part of the knowledge work.
- ⑤. Productivity of the knowledge work is not — at least not primarily — a matter of the quantity of output. Quality is at least as important.
- ⑥. Finally, knowledge work productivity requires that the knowledge work is both seen and treated as an "asset" rather than a "cost."

It requires that knowledge work for the organization in preference to all other opportunities.

*2 Taylor was a mechanical engineer who sought to improve industrial efficiency. Taylor is regarded as the father of scientific management, and was one of the first management consultants and director of a famous firm. In Peter Drucker's description, Frederick W. Taylor was the first man in recorded history who deemed work deserving of systematic observation and study.

*3 The "Non-territorial office" system is also called as "Just in office" or "Free address" in USA, "Shared office" or "Smart office" in UK and "Future office" in Finland; while in Japan, it is called as "Free address workplace". This workplace system is characterized by non-territorial for workers' workstation location, in which workers do not "own" their workstation, but share them with others assigned to work in the same building or campus. There are three main types of execution in practice. One is that workers are assigned Same-owned workstations and allowed to move them to anywhere they wish. Another one is that, workers must reserve an office every time they need one, ensuring that an workplace that is not used 100% of the time by one worker is available to other workers. The last one, to which the investigated non-territorial workplace in this dissertation belongs, is that workers may occupy any workstation when doing personal work, but should take personal belongings (laptop or documents) away after finishing work, so that the vacant seat may be occupied or used anytime by other worker. These arrangements increase the occupancy rates of existing office space and thus further enhance organizational productivity. The non-territorial workplace investigated and researched in this dissertation is belonged to the last type.

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Chapter 2 Investigation Method on the Space Use and Verbal Communication by UWB Sensor Network, Voice Sensor and Acceleration Sensor

- 2.1 Purpose
- 2.2 The components of sensing system
- 2.3 Acceleration sensor and the definition of Staying vs. Move
 - 2.3.1 Discussion on assigning value of T for judging whether subject is moving
 - 2.3.2 Discussion on assigning value of N for judging whether subject is moving
 - 2.3.3 Discussion on assigning value of $\Delta\alpha^2$ for judging whether subject is moving
- 2.4 Location sensor and the definition of space use behavior
 - 2.4.1 The combination of acceleration and location data
 - 2.4.2 The method on revising location data in staying duration collected by UWB sensor network system
 - 2.4.3 The definition of location area for staying and the relevant space use
- 2.5 Voice sensor and the definition of verbal communication behavior
 - 2.5.1 Discussion on the wearing position of tiepin mike
 - 2.5.2 Definition of verbal communication on the basis of data characteristic
- 2.6 Conclusion

Note

Reference

2.1 Purpose

The investigations involved in this dissertation were mainly operated by the UWB sensor network system, and in some parts of dissertation the observation record investigation was used. This new investigation method on the basis of sensing technology, which has not been extensively used in the research on workers' behavior in workplace, could be seldom found in relevant previous studies.

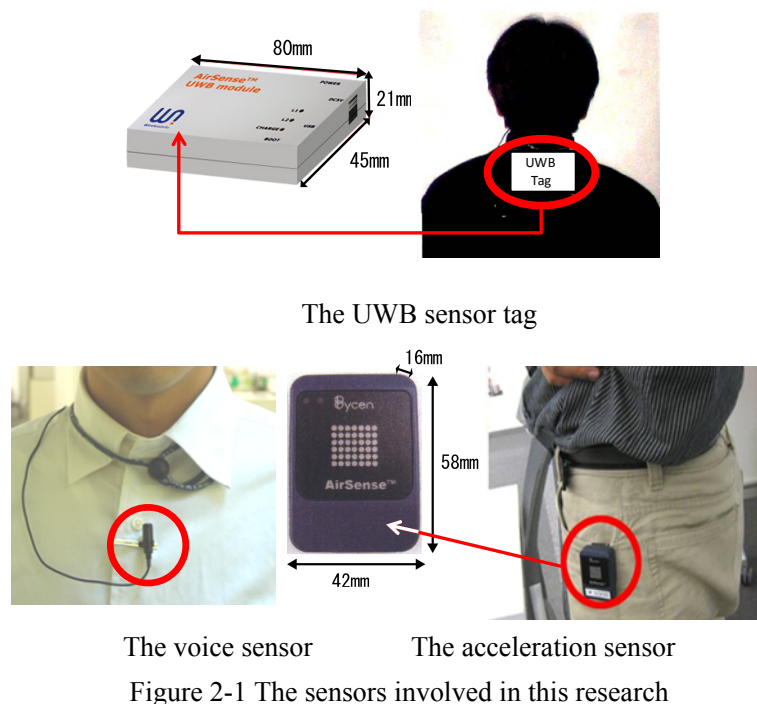
Therefore, in this chapter, the author aimed to define the behaviors involved in this research which is determined by the sensors' work principle, and finally explain the revising and combination process of database.

2.2 The components of sensing system

The sensing set which is used in investigations is composed of UWB sensor network system, the acceleration sensor and the voice sensor *¹.

The UWB sensor network system, which is composed of the UWB sensor tag, the wireless antenna, and the computer server, is used to record the subject's temporal location (represented by coordinate figure in original data).

Meanwhile, the acceleration sensor is used to detect the subject's moving; additionally, the voice sensor is used to detect the subject's utterance (Fig. 2-1).



2.3 Acceleration sensor and the definition of Staying vs. Move

The acceleration sensor, which is worn by subject on the waist, is able to detect subject's movement (Table 2-1, Fig. 2-2). Specifically, by sensing the subject's movement on the frequency 20 times/second, it records and calculates subject's acceleration value in three directions of three-dimensional coordinate set up by sensor itself. Meanwhile, it can calculate the square vector sum of subject's acceleration (Fig. 2-3).

Table 2-1 The specification of acceleration sensor*²

Items	Specification
Microcomputer	H8S2168F
Flash Memory	256 KB
RAM	40 KB
Working Frequency	8 MHz
Timing	RTC (Real Time Clock)
Acceleration Sensor	H30CD, 3 direction, $\pm 2G$, Accuracy 12 bit
File format	FAT 16
Display	LED 2 (one red, one green)
Switch	On/Off
File Saving Frequency	4 hour, 1 hour
Sensing Frequency	50 ms, 100 ms, 200 ms, 1s
Battery Working Duration	7 days
Size	H58mm X W42mm X D16mm
Weight	36g
Appendix	SD card 2GB



Figure 2-2 Specifications of the acceleration sensor

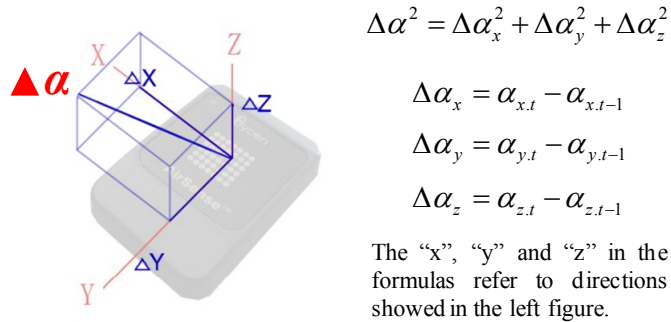


Figure 2-3 The acceleration in 3 directions and calculation of $\Delta \alpha^2$

In order to determine the acceleration value on clarifying the subject's move (walking), the experiment was conducted to test the relationship of $\angle \alpha^2$ and the subject's move. By the data of Fig. 2-4, it is found that the subject's move could not be clarified by judging whether the value of $\angle \alpha^2$ is over 0 or not, as the sensor is quite sensible to detect any movements or posture changes of subject. Therefore, it is necessary to find out a method to identify the move moment and duration of subject with defining the other duration as the staying at a certain place.

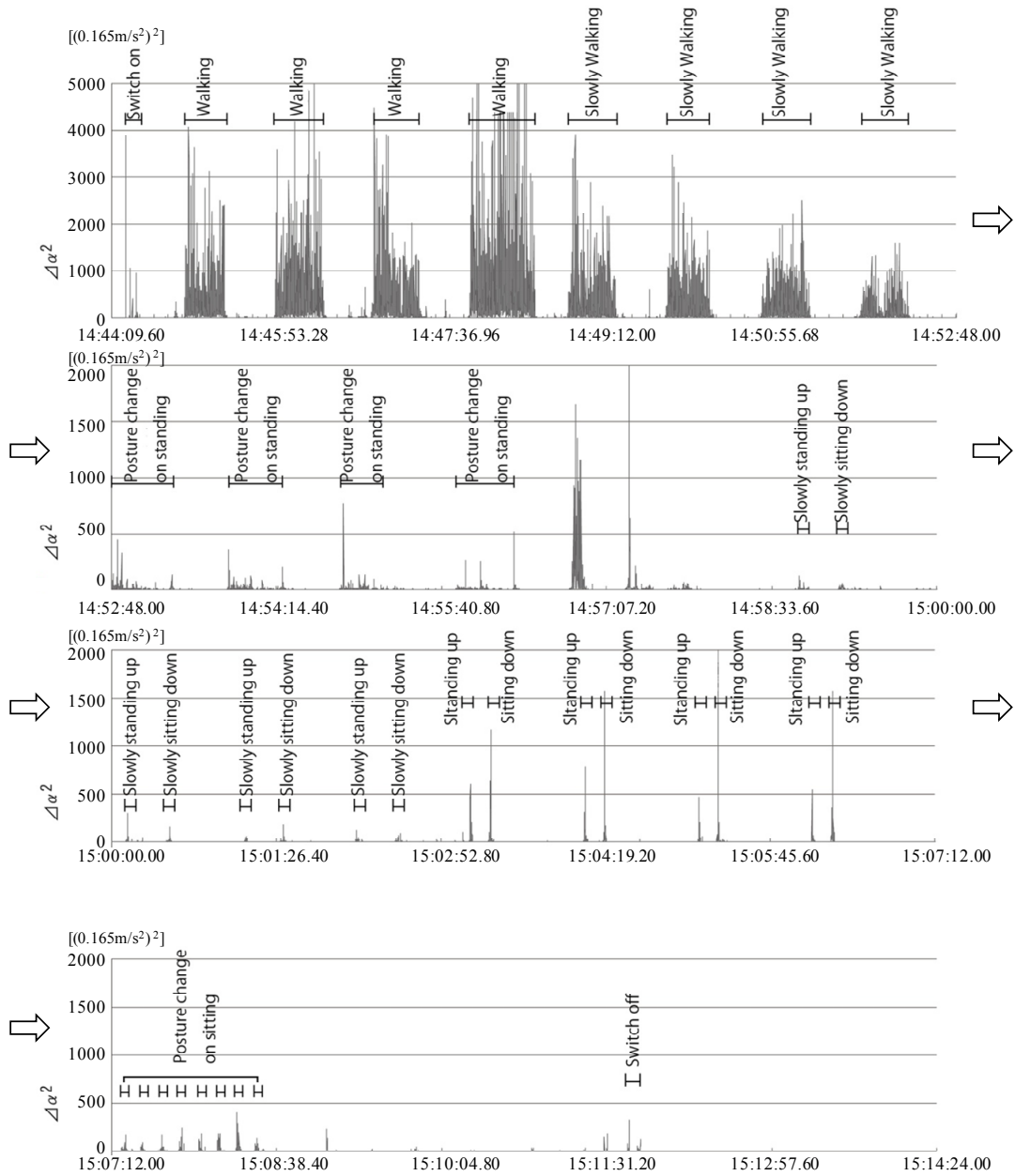


Figure 2-4 The relationship of $\angle \alpha^2$ and the subject's movements

With the analyzing on the characteristic of acceleration data (Fig. 2-5), the author set up three conditions on identifying the subject's move (Table 2-2), which is shown as following table and figure:

Since the conditions were set up, the following work is to assign the value of N, T and Δa_0^2 .

Table 2-2 The conditions on judging whether the subject is moving

Items	Unit	Meaning
Δa_0^2	$[(0.165\text{m/s}^2)^2]^*$	The standard value of Δa^2 on judging whether subject is moving.
N	-	The number of Δa^2 on judging whether subject is moving.
T	[second]	The move duration.

* When acceleration sensor is still and weighted by only G-force, its vector sum is around 59.4. Thus, its unit is equals to 0.165 m/s^2 , which is calculated by $9.8 \text{ m/s}^2 \div 59.4$.

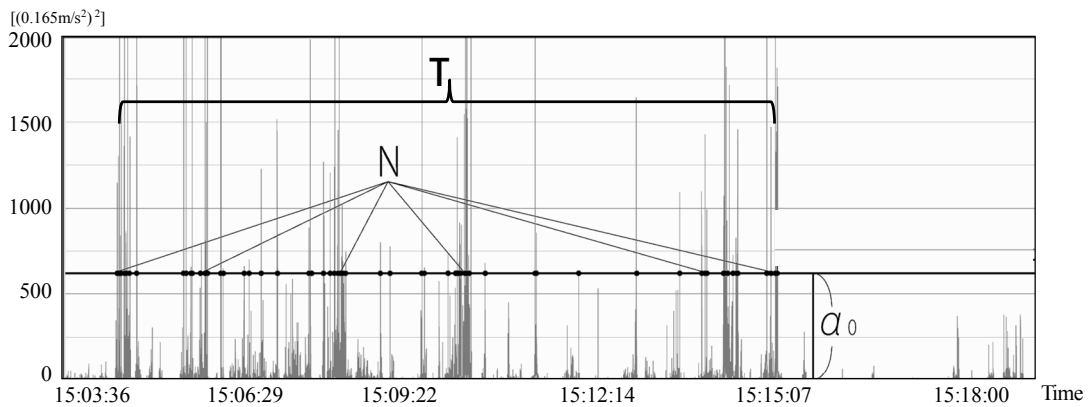


Figure 2-5 The conditions on judging whether the subject is walking

2.3.1 Discussion on assigning value of T for judging whether subject is moving

On considering the signal frequency of acceleration sensor (20 times per second) and the frequency of UWB sensor (1 time per 3second), the value of T is counted by 3 seconds.

2.3.2 Discussion on assigning value of N for judging whether subject is moving

According to the research of M. Nikola et al.¹⁾ and our analysis on the collected acceleration data, the highest change of acceleration in a gait circle appeared at the moment when one leg changed from standing to stepping forwards (Fig. 2-6 and Table 2-3). This means the duration between two peak values equals to the duration that

subject moves one step, in this way, the value of N should equal to the steps' number in T (3 seconds). By research of Sandra J Singleton et al ¹⁾, the average step time of adult is around 0.7 second/step (Table 2-4), this means in 3 second one adult could walked 4-5 steps. The value of N is assigned as 5, as there are 2 peak values in the process of the first stepping.

Table 2-3 Acceleration perpendicular to the foot sensor in the sagittal plane in four strides ¹⁾

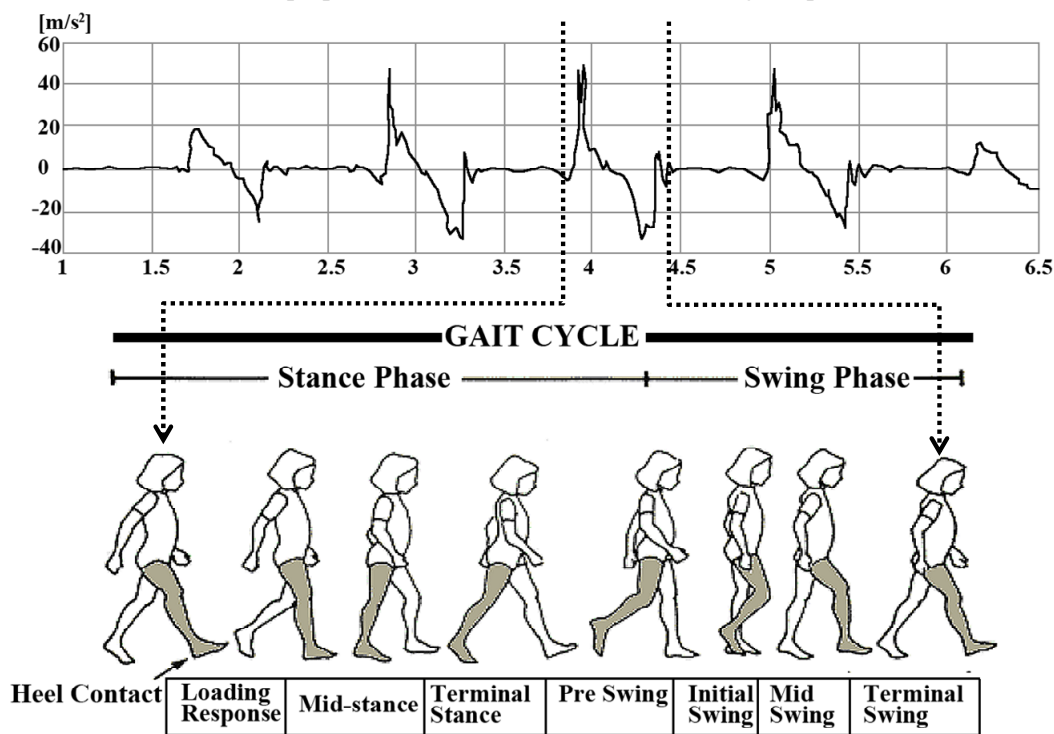


Figure 2-6 Diagram of the gait phase's characteristic for normal walking ¹⁾

Table 2-4 The actual and predicted step times for each walking condition ²⁾

		STEP TIME (seconds)			
		Left		Right	
		Actual	Predicted	Actual	Predicted
Symmetrical	Mean	0.716	0.706	0.736	0.747
	SD	0.026	0.073	0.039	0.089
Step Length	Mean	0.68	0.46 *	0.779	0.994 *
Asymmetry	SD	0.041	0.103	0.049	0.092
Step Time	Mean	0.599	0.688 *	0.825	0.737 *
Asymmetry	SD	0.038	0.042	0.049	0.059

* p<0.01

2.3.3 Discussion on assigning value of $\Delta\alpha^2$ for judging whether subject is moving

As presented in Fig. 2-3, the $\Delta\alpha^2$ is the squariance of acceleration discrepancy in 3 directions. By comparing the acceleration values of 3 directions in 3 seconds walking (Fig. 2-7), it is found that the value of $\Delta\alpha^2$ is mainly determined by the acceleration in the x and y axis, each equal to vertical and horizontal direction. The same found was also reported in the paper of M. Nikola et al.¹⁾ The reason is that, the heel touching on

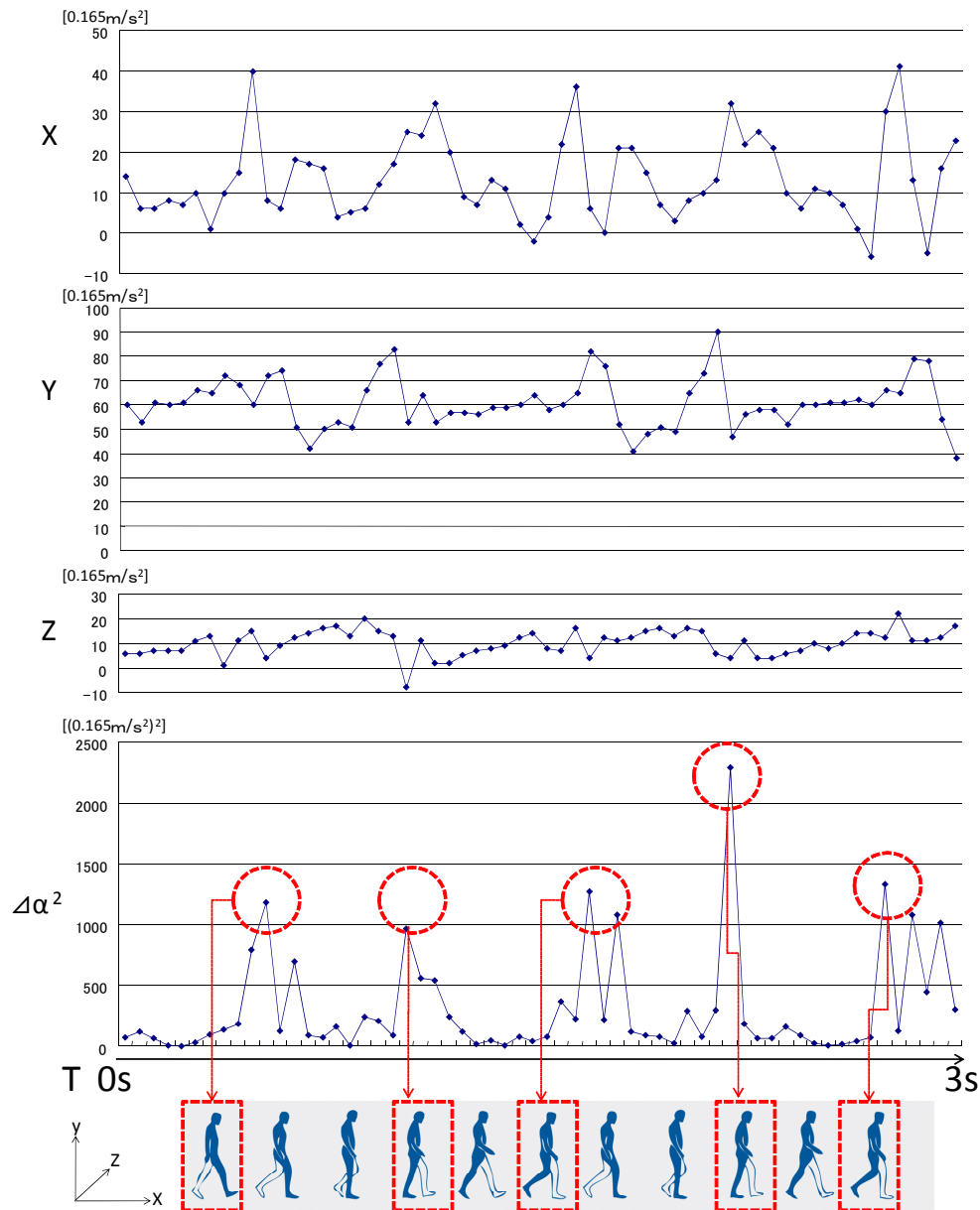
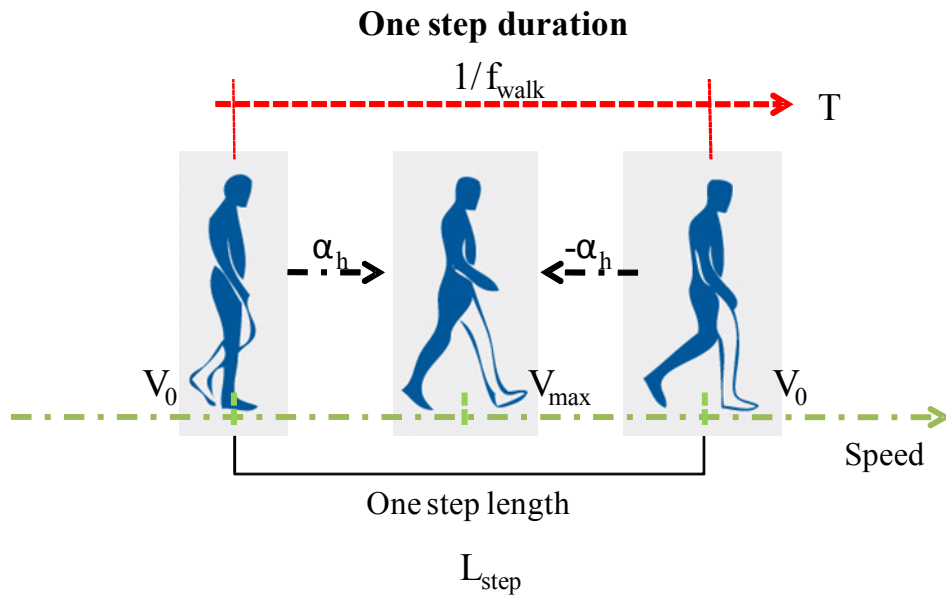


Figure 2-7 Comparison of changing of acceleration in 3 directions in 3 seconds

the earth in each step would cause the acceleration change in vertical direction. And in the same moment, the walking speed is also changed since the forwards moving leg turns to supporting, this change causes the acceleration change in the horizon direction.

According to Fig. 2-8, it is found that the acceleration in horizontal direction is determined by the walker's step length and stepping frequency. Also the wearing position and walking posture also influence it. So it is necessary to define the different Δa^2 value of subjects according to each personal walking style.



(For simplifying condition, V_0 is assumed as 0, while the acceleration is assumed as the same in half step)

$$\therefore L_{step} / 2 = a_h \times t^2$$

$$t = \frac{1}{f_{walk}} \div 2$$

$$\therefore a_h = 2 \times f_{walk}^2 \times L_{step}$$

t : the duration of on step
 f_{walk} : the frequency of walk gait
 L_{step} : the length of one step
 a_h : the acceleration in horizontal direction

Figure 2-8 The analysis on conditions which influenced acceleration in horizon direction

In the investigation on the non-territorial workplace, by checking 80 subjects' acceleration data in the walk duration on the basis of video record which was collected by digital video camera^{*3}, the $\angle\alpha_0^2$ values are classified into 6 levels. As showed in Table 2-5, the $\angle\alpha_0^2$ values are influenced by the subject's age and gender, which indicates the subject's walking speed; additionally, by author's observation, the $\angle\alpha_0^2$ value is also influenced by the height of subject.

Table 2-5 Classification of different subjects' walking acceleration
(Non-territorial workplace sample)

Worker ID	Post	Specialty	Aage	Gender	Value [(0.165m/s)]	Worker ID	Post	Specialty	Aage	Gender	Value [(0.165m/s)]
1	RS	ADS	60-69	m	A 500	41	PL	ADS	50-59	m	D 1300
2	PL	ADS	50-59	m		42	RS	SDS	30-39	m	
3	RS	SDS	50-59	m		43	RS	SDS	30-39	m	
4	RS	EDS	50-59	m	B 800	44	TS	ADS	40-49	m	
5	RS	EDS	50-59	m		45	PL	ADS	40-49	m	
6	RS	SDS	40-49	m		46	RS	ADS	30-39	m	
7	RS	SDS	20-29	f		47	RS	SDS	40-49	m	
8	TS	ADS	30-39	f		48	RS	SDS	40-49	m	
9	RS	SDS	40-49	m		49	RS	ADS	40-49	m	
10	PL	EDS	40-49	m		50	RS	ADS	30-39	m	
11	TS	EDS	40-49	m		51	RS	ADS	30-39	m	
12	RS	ADS	40-49	m		52	RS	ADS	30-39	m	
13	TS	ADS	40-49	m	C 1000	53	RS	SDS	40-49	m	E 1600
14	PL	ADS	50-59	m		54	RS	SDS	20-29	m	
15	RS	SDS	40-49	m		55	RS	ADS	40-49	m	
16	RS	SDS	20-29	f		56	RS	ADS	30-39	m	
17	TS	EDS	30-39	m		57	RS	ADS	30-39	m	
18	PL	ADS	50-59	m		58	RS	ADS	40-49	m	
19	RS	ADS	40-49	f		59	TS	ADS	30-39	m	
20	RS	EDS	40-49	m		60	PL	ADS	50-59	m	
21	RS	ADS	30-39	m		61	TS	ADS	30-39	m	
22	RS	EDS	30-39	m		62	RS	ADS	20-29	m	
23	RS	EDS	20-29	m	D 1300	63	RS	ADS	30-39	m	F 1900
24	PL	ADS	40-49	m		64	RS	ADS	20-29	m	
25	RS	EDS	30-39	m		65	RS	ADS	30-39	m	
26	RS	EDS	40-49	m		66	RS	ADS	20-29	m	
27	RS	ADS	20-29	m		67	RS	EDS	40-49	m	
28	RS	EDS	30-39	m		68	RS	EDS	40-49	m	
29	RS	EDS	50-59	m		69	TS	ADS	30-39	m	
30	PL	SDS	30-39	m		70	PL	ADS	30-39	f	
31	RS	ADS	30-39	m		71	TS	ADS	40-49	m	
32	RS	ADS	40-49	m		72	TS	ADS	30-39	m	
33	RS	ADS	40-49	m	D 1300	73	PL	EDS	50-59	m	
34	RS	ADS	30-39	m		74	TS	EDS	30-39	m	
35	RS	ADS	40-49	m		75	PL	ADS	20-29	m	
36	RS	EDS	40-49	m		76	RS	ADS	30-39	m	
37	PL	ADS	40-49	m		77	RS	ADS	20-29	m	
38	RS	ADS	30-39	m		78	RS	ADS	30-39	m	
39	RS	ADS	30-39	m		79	RS	ADS	20-29	m	
40	RS	ADS	30-39	m		80	TS	EDS	40-49	m	

PL: Project leader; RS: Regular staff; TS: Temporary staff.

ADS: Architecture design staff; SDS: Structure design staff; EDS: Equipment design staff.

Finally, based on the conditions discussed in this section, the author clarified the subjects' move duration from the staying duration.

2.4 Location sensor and the definition of space use behavior

As shown in Fig. 2-9, the UWB sensor network is composed of tag, antenna, and computer server. The tag is a small chip (Fig. 2-10), worn by the subject at his/her back and sends signals every 3 seconds. The antenna matrix receives the signals from the tag and transfers the signal to the computer server wirelessly. Following, the subject's temporal spatial location could be calculated by the triangulation location theory.

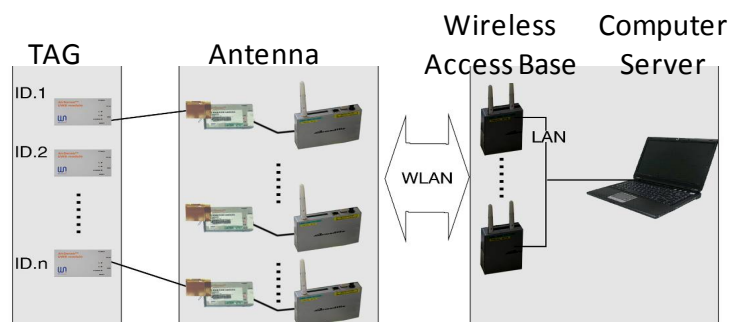


Figure 2-9 Compositions of UWB sensor network system

Table 2-6 The specification of UWB sensor tag*²

Items	Specification
Tag size	H80mm x W21mm x D45mm
Working Frequency	3.4 - 4.8 GHz, 2ns impulse
Sensing distance	250kbps, over 20m
Distance between antennas	10m~20m
Accuracy	30cm
Battery Working Duration	1 day

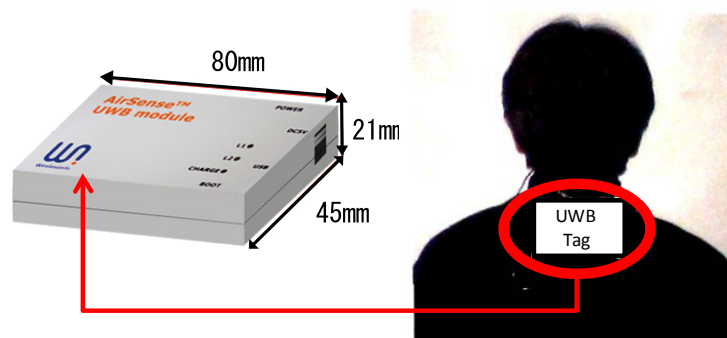


Figure 2-10 Specifications of the UWB sensor

2.4.1 The combination of acceleration and location data

On the basis of staying and move duration detected by acceleration sensor, the subject's staying location can be fixed by the location data collected by the UWB sensor network system, the combination process is shown as following Fig. 2-11.

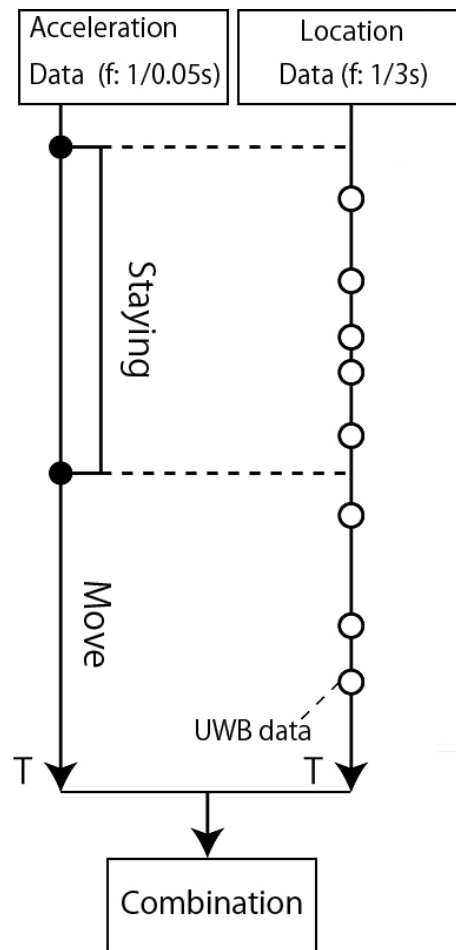


Figure 2-11 The combination process of acceleration data and temporal location data

Although, the content of subject's behavior cannot be clarified or recorded by the sensors, the location that subject stayed at can also reflect how he/she used the space to support work. Therefore, in this dissertation, the behavior, that subject's staying at the place in investigated workplace, are defined as space use behavior.

2.4.2 The method on revising location data in staying duration collected by UWB sensor network system

Although by manual of UWB sensor network system, the accuracy of temporal location data of single subject could be corrected to within 30cm compared with the subject's real location. In the investigation, it is found that the accuracy precision decreased, which is caused by the body posture of subject, the radio wave environment and the defect of UWB sensor network technology. For instance, when subject sits at his/her individual workstation, the radio wave sent by UWB tag, which is worn on the back, might be blocked by body and the chair-back, thus, could not be received by over 3 antennas and caused the wrong location data calculated*⁴. Meanwhile, the radio wave reflection caused by wall and ceiling will also influence the calculating result ³⁾. Additionally, by the explanation of the engineer of Hitachi Company, as there were 27 sets of sensors worked together in the same space, the ultra wide band waves of them might disturb the receiving accuracy of the antennas. Therefore, the location data of subject in a staying duration appeared to not being steadily at one place (Fig. 2-12).

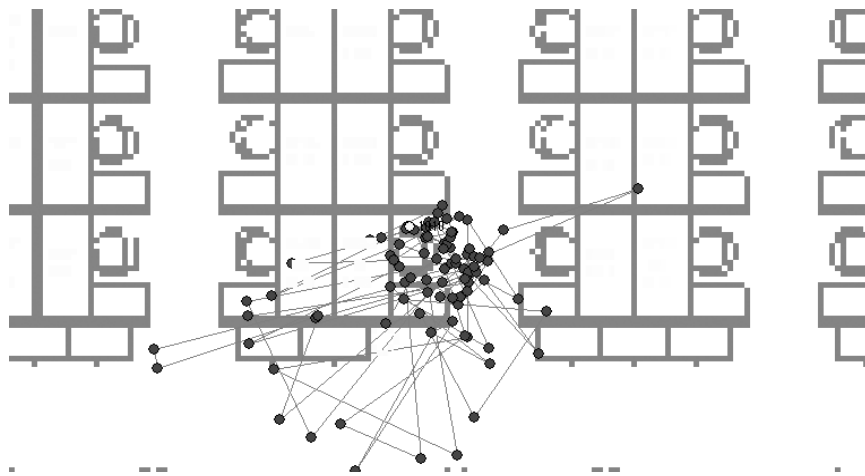


Figure 2-12 The original location trajectory in one stop duration recorded by UWB sensor network system (Big open plan workplace sample)

Therefore, the investigated workplaces are divided into location zones on the basis of workplace layouts and the distribution of UWB sensor antenna*⁵ (Fig. 2-13). Furthermore, the wrong calculated location data will be revised in the data combination process.

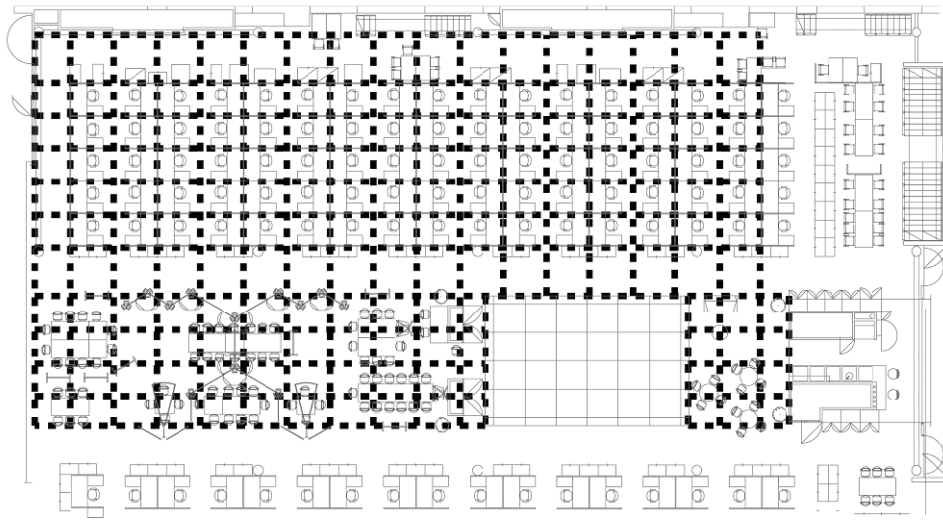


Figure 2-13 The division of location zones (Big open plan workplace sample, part)

By comparing the frequency of recorded location zones in one unit staying duration, the zone which is recorded most frequently will be defined as zone that subject locates in unit staying duration (Fig. 2-14).

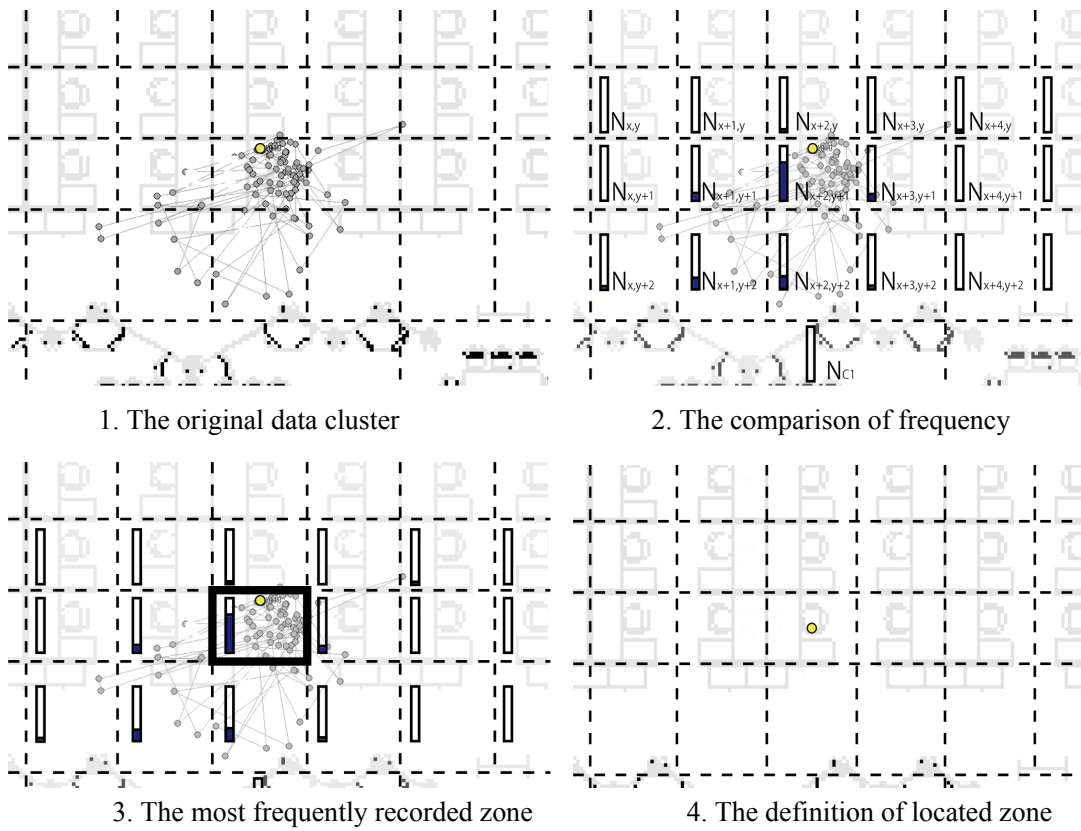


Figure 2-14 The division of location zones (Big open plan workplace sample, part)

2.4.3 The definition of location area for staying and the relevant space use

According to the functional distribution of layout, the investigated workplace is divided into different staying location area. When subject's location data in one staying time is recorded and revised in certain location area, that duration is defined as subject's staying in that area, with the meaning that the space of the area is occupied and used.

Take the layout of big open workplace for example (Fig. 2-15). In the "Public Territory", the place in which a subject stayed at was directly defined by its function. In the "Work Territory", the area that includes the subject's own workstation was defined as the "Own-Seat Nearby". Other places in the "Work Territory" were defined as the "Same-Group", "Other-Group" or "Other Specialty" according to whether or not the location attributes was the same as the subject's group or specialty. As shown in Fig. 2-15, if the black block "X" is where a subject's workstation located, when the subject stays in Rectangle OSN, his/her staying location is defined as the "Own-Seat Nearby". If a subject stays at Rectangle SG, the staying location is defined as the "Same-Group" in the same specialty. If a subject stays at Rectangle OG, his/her staying location is defined as the "Other-Group" in the same specialty. If a subject stays at other specialty ranges, the staying location is defined as the "Other-Specialty".

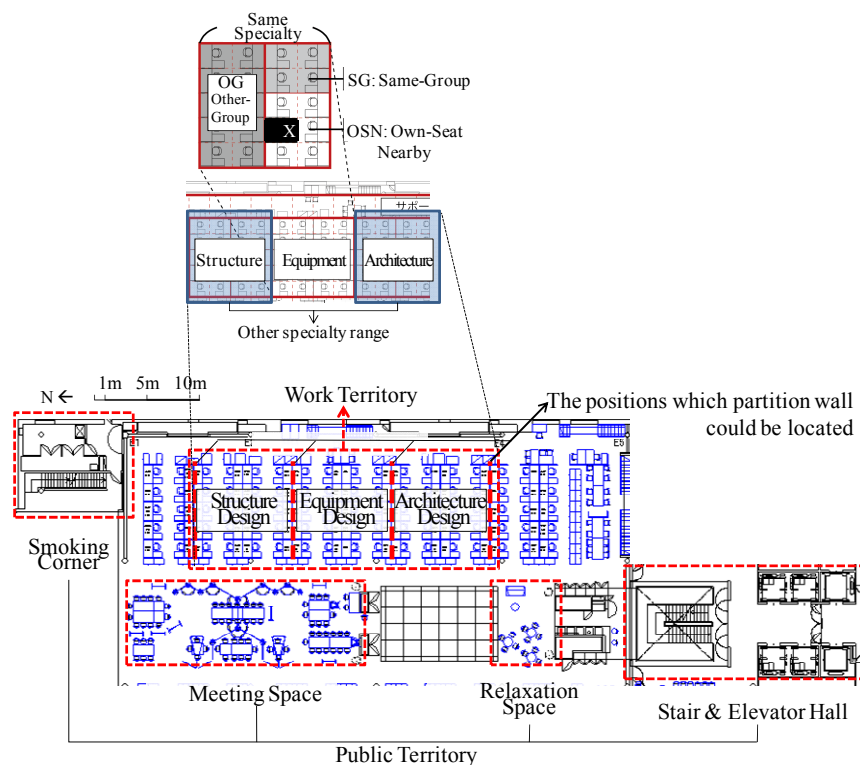


Figure 2-15 The definitions of stay location (Big open plan workplace sample, part)

2.5 Voice sensor and the definition of verbal communication behavior *¹

In the investigation on big open plan workplace, the voice sensor is used to clarify workers' verbal communication behavior pattern. (In the investigation on territorial and non-territorial workplace, the voice sensor is not involved.)

As shown in Fig. 2-16, the voice sensor composed of tiepin mike and sensing tag. The tiepin mike is worn at the top front of subject's shirt or tie and able to detect the utterance. Meanwhile, the tiepin mike is connected with a sensing tag, whose size is as same as UWB sensor tag for recording subject's location. When tiepin mike detects the utterance, the tag sends the signal of utterance moment to computer server with the frequency 1 time per 3 seconds (Table 2-7), but without recording the content of utterance.

Table 2-7 The specification of Voice sensor*²

Items	Specification
Frequency range	50-16,000Hz
Sensitivity	6mV/Pa/1kHz
Impedance	600 Ohm
Max. SPL	120dB
S/N ratio	> 40dB
Dimensions mic	Ø 13mm x 30mm
Cable length	1.2m
Tag size	H80mm x W21mm x D45mm
Tag sensing frequency	1/3s

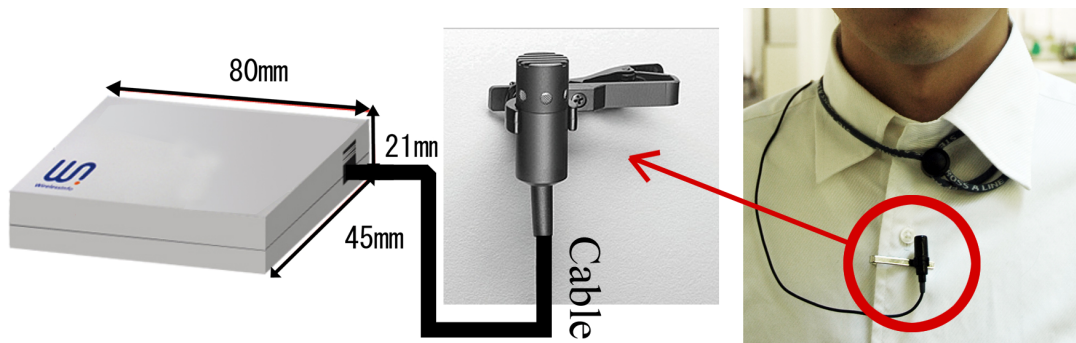


Figure 2-16 Compositions of Voice sensor

2.5.1 Discussion on the wearing position of tiepin mike

As the tiepin mike can only detect the sound without recognizing the voice of certain subject, it might also detect and record the voice of other worker, who communicates with subject, as subject's utterance. Therefore, the experiments are conducted to discuss the best wearing position of mike on a body, and to clarify whether the tiepin mike could detect the voice of other worker on communicating with subject.

1) Experiment 1: Discussion on the wearing position of the tiepin mike

The experiment 1 was conducted on discussing on the wearing position of the tiepin mike, in order to clarify whether the tiepin mike could detect the subject's utterance. Specifically, in each test the subject talked 60 seconds without break, and then the results of each test would be compared on checking whether the mike could detect subject's utterance.

According to table 2-8, it is found that when subject wears the tiepin mike at the position 1 and 2, the subject's utterance could be detected by mike no matter in which sound volume. However, as the position 1 is not easy for subject to wear and check by him/her, the position 2 is selected to be the position for wearing the tiepin mike.

Table 2-8 The result of experiment 1

Mike position		Position.1	Position.2	Position.3
Sound Volume	Weak	○	○	✕
	Middle	○	○	○
	Strong	○	○	○

○: can be detected; ✕: can not be detected.

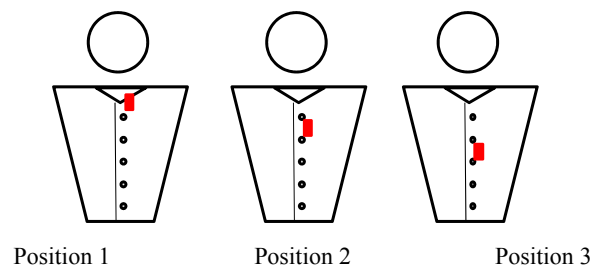


Figure 2-17 Different wearing positions

2) Experiment 2: Clarification on whether other worker's voice could be detected by subject's tiepin mike

In experiment 1, the author clarified the different defecting result on the basis of tiepin mike wearing position. Following, in experiment 2, several tests were conducted to clarify whether the other worker's voice could be detected when they talk on communicating with or not communicating with subject in different postures.

Test 1: Clarification of whether the other worker's voice would be detected when he/she face to face communicates with subject

According to the personal space concept introduced by Edward Hall ^{4) 5)}, the

distance between the other worker and subject in test 1 are set up as 0.75m *⁶, 1.5m and 3m. In the test 1, the subject kept silence while the other worker, who located face to face with subject, kept speaking for 60 seconds without break.

According to Table 2-9, it showed that when the distance between the other worker and subject is 0.75m, the other worker's voice could be recorded by subject's tiepin mike. Therefore, the data is defined as voice record of one communication rather than only recording subject's talking.

Table 2-9 The result of experiment 2-test 1

Sound Volume	Distance [m]		
	0.75	1.5	3
Weak	X	X	X
Middle	O	X	X
Strong	O	X	X

O: can be detected; X: can not be detected.

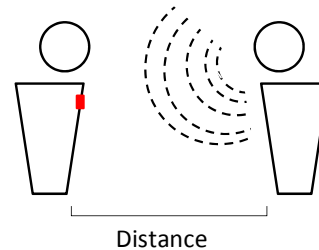


Figure 2-18 Diagram of test 1

Test 2: Clarification of whether the other worker's voice would be detected when he face to shoulder communicates with subject

The test is almost the same as introduced in test 1, but the distance is set up as only between 0.75m, while subject and the other worker located face to shoulder.

As presented in Table 2-10, it showed that only when the posture of subject and other worker were the same (both stand or sit), other worker's voice could be detected by subject's tiepin mike. In this situation, the data is also defined as voice recording of one communication rather than voice recording of only subject's talking.

Table 2-10 The result of experiment 2-test 2

Sound Volume	Distance= 0.75 [m]	
	Same posture	Sit with Stand
Weak	X	X
Middle	Y	X
Strong	O	X

O: can be detected;

X: can not be detected.

Y: can partly be detected.

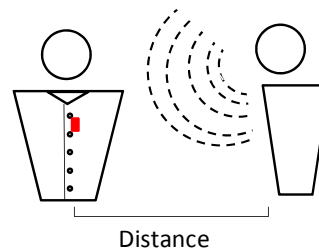


Figure 2-19 Diagram of test 2

Test 3: Clarification of whether the other worker's voice would be detected when he/she shoulder to shoulder communicates with subject

The test is conducted on considering the situation that subject may sit shoulder with shoulder to the adjacent worker when communicating at the meeting table. Therefore, the distance is set up as 0.9m, which is the average distance between two adjacent seats at the meeting space in big open plan workplace.

According to the test result showed in Table 2-11, it found that the other worker's voice could be detected by subject's tiepin mike. Therefore, the data is also defined as voice recording of one communication rather than voice recording of subject's talking.

Table 2-11 The result of experiment 2-test 3

Sound Volume	Distance= 0.9 [m]
	Same posture
Weak	X
Middle	O
Strong	O

O: can be detected;

X: can not be detected.

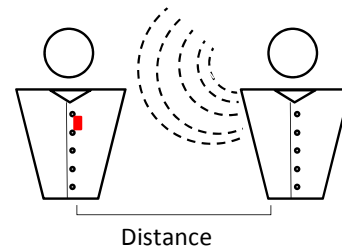


Figure 2-20 Diagram of test 3

Additionally, the author also clarified the influence of acoustical environment on tiepin mike, such like the working sound of copy machine, the radio broadcast at noon and the voice of typing keyboard, and found that none of them could be detected by subject's tiepin mike.

2.5.2 Definition of verbal communication on the basis of data characteristic

The verbal communication behavior is composed of talking, and operated by over 2 talkers. Simply, the process of verbal communication could be indicated by the Fig. 2-21. Judging by talkers' utterance and silence, the verbal communication duration is composed of speaking duration and silence duration, such like the duration spent on turn-taking or pause break. By the results in tests in 2.4.1.2), although the data collected by voice sensor could also include part speaking of other worker, with whom subject talked, as the subject's (such like the white circle showed in Fig. 2-22). By the definition of verbal communication, it could still offer accurate information on subject's verbal communicating moment and duration which is calculated by subtraction. For instance, in the case showed in Fig. 2-22, the duration of verbal communication is equal to $T_2 - T_1$. Moreover, as in some places of investigated big open plan workplace, the subject might orally communicate more than one time in a staying duration. Therefore, it is necessary to define the different calculation method to verify subject's verbal communication duration on the basis of places.

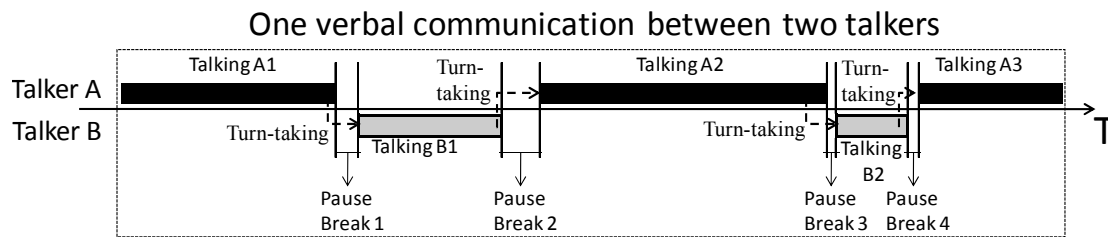


Figure 2-21 Diagram of verbal communication between two talkers

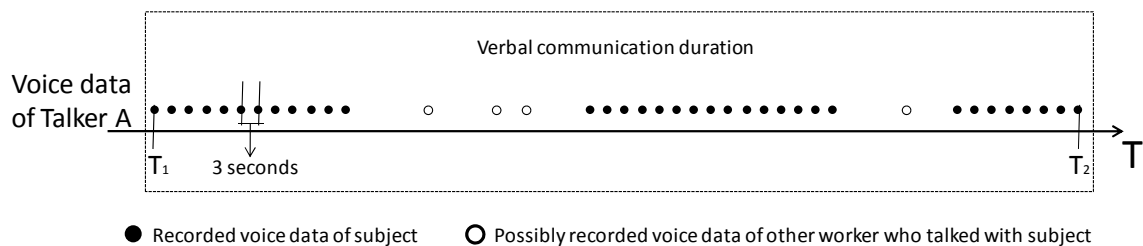


Figure 2-22 Sample of Subject's verbal communication data collected by voice sensor

1) The verification of different verbal communication in subject's individual workstation in one staying period

When subject stays at his/her individual workstation in the working territory, he/she could be visited by other workers and orally communicated more than once. Therefore, it is necessary to verify the different verbal communication duration occurred in one staying period.

Usually, subject communicates with only one or two other workers in his/her individual workstation at one time. According to the silence and speaking duration sequence (Fig. 2-23), the silence duration between two communications is able to be used as the judging condition to divide the voice data in a staying duration. Meanwhile, this silence duration should be longer than the pause break duration and the duration of one person's single talking which might not be detected by sensor (such as the grey circle showed in Fig. 2-23). Normally, in one verbal communication, the duration for pause break or turn-taking costs only several seconds. For instance, in the study by Yuka Shigemitsu ⁶⁾, the recorded pause durations are within 11 seconds. Meanwhile, in case that voice sensor could not record the voice of worker, with whom subject communicates, the duration of one's single talking should also be considered as one judging condition. The study by Joseph N. Cappella ⁷⁾ showed that one's single duration in informal verbal communication is usually within 4 minutes. Moreover, as the verbal communication of Architects and Engineers might be conducted with drawing diagram and prolong the silence duration. In this dissertation the author defined that if the value of silence duration (T_j) between two adjacent voice data is over 5 minutes, the latter pile of data is defined as another verbal communication.

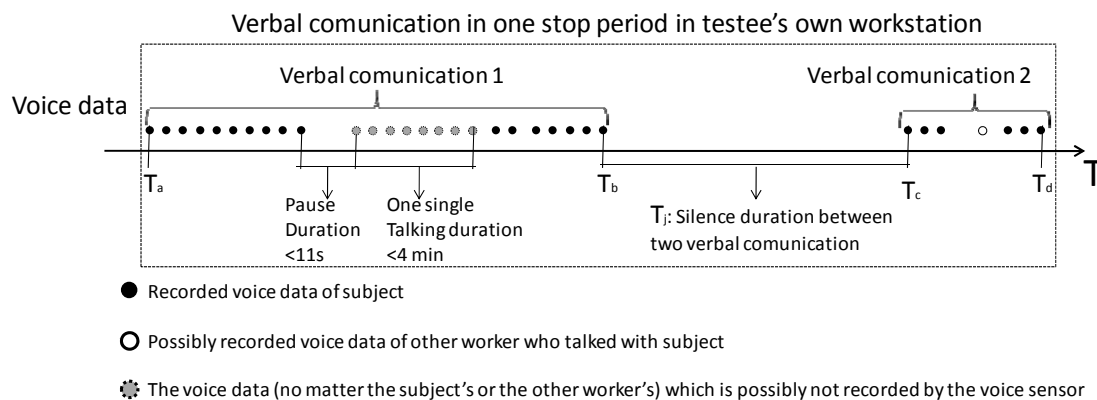


Figure 2-23 Sample of subject's verbal communications in own workstation in one stop period

Additionally, although the subject could not conduct the first and the last talking in every verbal communication, which might make T_a T_b or T_c T_d is not the beginning or ending moment of communication. Since the verbal communication always starts and ends with giving prior notice which costing subtle time, the influence of above situation could be ignored. Moreover, the subject's communication by telephone is also defined as verbal communication in this dissertation.

2) The definition of verbal communication duration in other places

In the investigated big open plan workplace, the meeting space is set up for meeting or discussion and used publicly, thus, workers go there for communication purposely and rarely operate two times of communicated in one staying time. Therefore, if the voice sensor detects the utterance of subject when subject stays at the meeting space, his/her whole staying duration is defined as verbal communication duration.

When subject stays at the relaxation space, the smoking corner or the stair & elevator hall, the communication duration is calculated as defined in Fig. 2-21.

2.6 Conclusion

In this chapter, the author established the investigation methods for this research, of which devices are mainly composed of UWB sensor and acceleration sensor, as well as the voice sensor. By the experiments, the author identified the worker's acceleration threshold values on clarifying the move from staying, which is helpful to revise the location data collected by UWB sensor network. Following, the author made the method to define the location zone according to the accuracy of location data and layout distribution of investigated workplace, and defined the space use behavior (staying behavior mainly) based on the data. In addition, in the experiment with using voice sensor, the author identified and determined an optimized wearing position, and clarifies the influence from other workers' talking on the subject's voice data. Furthermore, the definition of verbal communication based on the characteristic of data was made.

By the verification of subject's staying and move moment and duration detected by acceleration sensor, as well as the revised location data and the calculation of verbal communication, the database (Table 2-12) is created with StaMgr2 ^{*7} in the process as Fig. 2-24 showed.

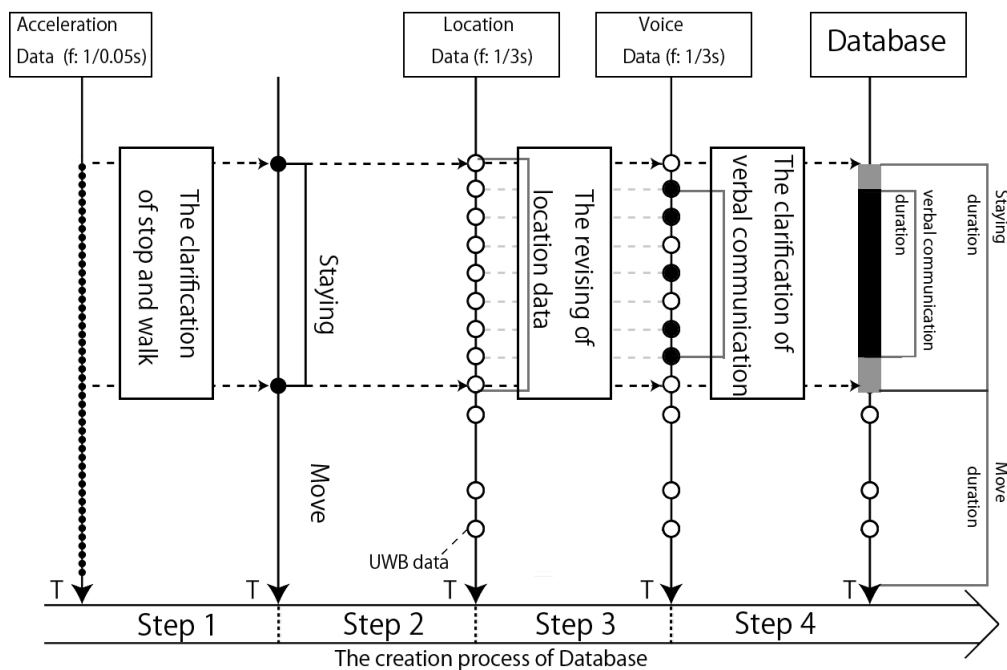


Figure 2-24 The creation process of Database ^{*8}

Table 2-12 The sample of database (big open plan workplace)

Data ID	Date	Subject attributes			Time attributes			Staying or Move	Location	Verbal Communication	
		Subject ID	Post	Specialty	Start time	End time	Lasted duration [second]			Frequency	Duration Sum [second]
1	12/14/2009	1	RS	EDS	9:23:48	9:24:42	54	Staying	Own-Seat Nearby	1	36
2	12/14/2009	1	RS	EDS	9:24:42	9:24:54	12	Move	-	0	0
3	12/14/2009	1	RS	EDS	9:24:54	9:29:57	303	Staying	Relaxation Space	1	303
4	12/14/2009	1	RS	EDS	9:29:57	9:30:09	12	Move	-	0	0
5	12/14/2009	1	RS	EDS	9:30:09	9:31:12	63	Staying	Own-Seat Nearby	0	0
6	12/14/2009	1	RS	EDS	9:31:12	9:31:27	15	Move	-	1	5
7	12/14/2009	1	RS	EDS	9:31:27	9:32:57	90	Staying	Smoking Corner	1	90
8	12/14/2009	1	RS	EDS	9:32:57	9:33:36	39	Move	-	0	0
9	12/14/2009	1	RS	EDS	9:33:36	9:40:30	831	Staying	Own-Seat Nearby	2	0
10300	12/18/2009	33	PL	ADS	11:21:04	11:32:00	1194	Staying	Relaxation Space	0	35
10301	12/18/2009	33	PL	ADS	11:32:00	11:54:57	183	Move	-	1	90
10302	12/18/2009	33	PL	ADS	11:54:57	12:08:15	798	Staying	Own-Seat Nearby	0	0

PL: Project leader; RS: Regular staff; TS: Temporary staff. ADS: Architecture design staff; EDS: Equipment design staff; SDS: Structure design staff.

Finally, by grasping the workers' space use behavior on the basis of workplace layouts, it is found that in terms of staying duration per once, 10~20% of workers' staying in workplaces was within one minute per time. Around 30% of workers' staying was within 5 minute and over 1 minute. 15~25% of staying was within 10 minutes and over 5 minute. The frequency proportion, whose staying duration is within 30 minute and over 10 minute, was around 20%. 9~16% of workers' staying was over 30 minute. This result showed that space use behavior of knowledge workers, such as architects and engineers, is composed of quite a lot of short time staying, which might not be able to grasp by the former investigation methods, such like interval observation record. Additionally, this finding also mentioned that the design or the renovation of workplace layout should be fully considered on how to respond to or support this characteristic of workers space use.

Table 2-13 The frequency and the proportion in terms of staying duration per time on the basis of workplace layout

Staying duration per time: t [min]	Territorial workplace		Non-territorial workplace		Big-open-plan workplace without partition walls		Big-open-plan workplace with partition walls		Sum
t≤1	1286	(16)	1721	(19)	482	(13)	333	(10)	3822 (16)
1<t≤5	2330	(29)	2429	(27)	1295	(35)	1062	(33)	7116 (30)
5<t≤10	1911	(24)	2254	(25)	552	(15)	534	(17)	5251 (22)
10<t≤30	1672	(21)	1847	(21)	848	(23)	752	(24)	5119 (22)
30<t	713	(9)	709	(8)	495	(13)	501	(16)	2418 (10)
Sum	7912	(100)	8960	(100)	3672	(100)	3182	(100)	23726 (100)

Number in blanket: Proportion of frequency in given staying duration per time [%].

Note

- *1. The voice sensor is only used in the investigation on workers' space use and verbal communication behavior in big open plan workplace with and without partition wall (Chapter 5).
- *2. The specification of sensors is created on the information of Hitachi Company's presentation in seminar organized by research team named 行動・環境モニタリングによるワークプレイスの省エネルギーと知的活動の活性化技術開発 and financially supported by 国土交通省、住宅・建築関連先導技術開発助成事業、2008～2009
- *3. In the investigations, the digital video camera was also used to record the workers' behavior in workplaces for checking the accuracy of data collected by sensors.
- *4. By the working theory of UWB sensor network, the accurate coordinate of subject could only be calculated in the condition that signal can be received by over 3 antennas.
- *5. The distribution of UWB sensor network antennas, the definition of staying location are presented in chapter 3, 4 and 5 according to different workplace layouts.
- *6. In the Hall's theory about personal space, the distance from 1.2m to 0.45m in the front is defined as the personal space, thus the intermediate value (0.75m) is set as the shortest test distance; meanwhile, the research by Hashimoto also showed that the most suitable distance for face to face communication is from 1.2m to 0.8m. (Hashimoto et al., A Study On The Psychological Territory Based On Experiments of Interpersonal Horizontal Distance, AIJ, Vol 485, pp.135-142, 1996)
- *7. The StaMgr2 software is developed by engineer of Hitachi Company with the request of the author, the method on revising data and the conditions about how to define behaviors is proposed by the author.
- *8. As the voice sensor is not used in the investigations on territorial and non-territorial workplace, thus only the step 1, 2 and 3 are involved in the relevant database creation processes.

Reference

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- 2) S.J. Sandra, E.K. Susan, L. Mc. Susan, A. C. Beverly and C. W. James, Predicting step time from step length and velocity, Australian Physiotherapy, Vol 38, pp.43-46, 1992
- 3) R.S. Thomä, O. Hirsch, J. Sachs and R. Zetik, UWB Sensor Networks for Position Location and

Imaging of Objects and Environments, EUCAP2007

- 4) Hall and E. T. Proxemics, *Current Anthropology* 9, 2-3, pp.83–108, 1968
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Chapter 3 Workers’ Space Use and Choosing Individual Workstation Behavior in a Non-territorial Workplace

- 3.1 Purpose
- 3.2 Outline of the investigation and investigated worksite
 - 3.2.1 Devices
 - 3.2.2 The investigated worksite
- 3.3 Patterns of workers’ space use behavior
 - 3.3.1 Classification of location zone
 - 3.3.2 Workers’ space use behavior in different territories
 - 3.3.3 Worker’s space use behavior at each typical zone in the “Work territory”
- 3.4 Behavior concerning choosing workstations
 - 3.4.1 The classifications of workstations and subjects
 - 3.4.2 Relationship between the positions of workers’ individual workstation and their post
 - 3.4.3 Consistency in workers’ choice of individual workstations
- 3.5 Patterns of worker’s space use behavior related to the selected individual workstation attribute
 - 3.5.1 Classification of location ranges and the workstation categories
 - 3.5.2 Workers’ move and space use behavior patterns on the basis of individual workstation attributes
 - 3.5.3 Workers’ move and space use behavior patterns on the basis of individual workstation attributes in terms of different posts
- 3.6 Conclusion

Note

Reference

Since 1973, there has been research on workers' behavior in non-territorial workplace by tracing the variations of workers' space use in a year-long investigation ¹⁾. Also as presented in 1.5.1, there seems to be enough studies focused on non-territorial workplace. However, as complained by Voordt ²⁾, there is still no study could reveal how workers use the space of the non-territorial workplace specifically as lack of precise data. Meanwhile, compared with other workers, the workers are allowed to select the individual workstation freely in their own specialty range. Therefore, the workers, who have different work styles and need workplaces that fit their specific work styles, could select the suitable workstation conveniently. Additionally, some work styles in a non-territorial workplace are suggested by the way workers choose their individual workstations. Although Tsunekawa et al. ³⁾ clarified the choosing individual workstation tendency and found the workers preferred to choose the individual workstation located at the top side of each table and beside corridor. However, in Tsunekawa's study, the characteristic of workers' space use behavior was not revealed in terms of their selected individual workstation' location, neither nor in terms of worker's post. Additionally, the question, whether the workers' choosing individual workstation behavior is influenced by the workers' post, is also kept as a research topic.

3.1 Purpose

In this chapter, firstly, the author focused on the workers' space use behavior in non-territorial workplace by analyzing the seamless temporal location data collected by UWB sensor network. Following, the author aimed to not only clarify quantitatively about how workers use spaces in this workplace for their daily work, but also to reveal the characteristic of workers' space use behavior in terms of post and specialty attribute.

Meanwhile, the author also focused on the relationship between worker's tendency of choosing individual workstation and worker's post attribute. Following, the author revealed the relationship between worker's workstation selecting tendency and the patterns of workers' space use behavior.

The detailed purposes of each section are showed as follows:

In section 3.3, the author aimed

- 1) To clarify the workers' space use in the work territory and the service territory in terms of workers' post and specialty attribute.
- 2) To clarify the workers' use of zones in the work territory in terms of workers' post

and specialty attribute.

In section 3.4, the author aimed

- 1) To clarify the tendency of workers' choosing individual workstations in terms of workers' post.
- 2) To ascertain the relationship between the choosing consistency and the workers' post.

In section 3.5, the author aimed

- 1) To clarify the difference of all investigated workers' move and space use according to the spatial characteristics of the selected individual workstation.
- 2) With regarding the subjects' post, to clarify the difference of workers' move and space use according to the spatial characteristics of the selected individual workstation.

3.2 Outline of the investigation and investigated worksite

3.2.1 Devices

Two types of sensors were used in the investigation, the UWB sensor network for location positioning and the acceleration sensor for data correction. The UWB sensor is a small tag (Fig. 3-1), worn by the workers and sends signals once per 3 seconds. The antenna receives the signals from the tag and transfers it to the computer server

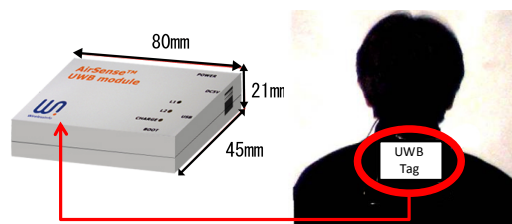


Figure 3-1 UWB sensor tag



Figure 3-2 Acceleration sensor

wirelessly. The acceleration sensor (Fig. 3-2) is worn by the worker on the waist and can detect the worker's acceleration when he or she is moving. The information on the moment and period of staying and move gathered by this method allows the author to revise the location data collected by the UWB sensor.

The investigation lasted from 9:00 to 20:00, and was conducted over 9 successive weekdays in two weeks, from the 17th to the 28th of November 2008. Twenty-seven sets of sensors, which is composed of a UWB sensor tag and an acceleration sensor, were assigned to workers randomly and evenly according to specialty range and workers' post. When a worker was assigned the sensor set, his/her name, assigned moment, post, specialty and the individual workstation he/she selected were recorded by the investigator. If the subject left work before 20:00, the sensor assigned to him/her would be reassigned to another worker. In the investigating period, 80 of 100 workers were assigned sensors 260 times (Table 3-1).

Table 3-1 Workers' Number in the non-territorial workplace [person]
[Investigated workers' number [person]]
(Investigated times of workers [person•day])

Specialty attribute	Post attribute									Sum		
	Project leader			Regular staff			Temporal staff					
ADS	13	[10]	(34)	35	[31]	(114)	17	[8]	(21)	65	[49]	(169)
SDS	2	[1]	(4)	12	[12]	(45)	1	[0]	(0)	15	[13]	(49)
EDS	2	[2]	(5)	13	[12]	(33)	5	[4]	(4)	20	[18]	(42)
Sum	17	[13]	(43)	60	[55]	(192)	23	[12]	(25)	100	[80]	(260)

ADS: Architecture design staff; SDS: Structure design staff; EDS: Equipment design staff

In the latter analysis, not only the data collected by UWB sensor net work was used to clarify the workers space use behavior, but also the record list of sensor sets' distribution was used to clarify the tendency of workers' choosing individual workstation.

3.2.2 The investigated worksite

A non-territorial workplace with 100 registered workers (Table 3-2) in an architecture construction company was chosen as the investigation subject (Fig. 3-3). The investigated non-territorial workplace is located on the north side of the 28th floor of a 54-floor high-rise building. The dimension of total investigation area is 382m².

The investigated non-territorial workplace is composed of surrounding service territory (including a meeting space which has twelve seats, copy corners, store lockers for personal belongings and shared documents), and a main work territory (Fig.3-4). Specifically, in the work territory, there are four workstation table areas with corridor between each other. Each workstation table area is composed of two big tables (each includes 8 seats, 4 of which besides vertical corridor and the other 4 besides meeting corner table) and two meeting corners (each includes 3 seats and specially used for communication). A row of store lockers separates the window workstation area from the main workstation table areas. The workplace is assigned to 3 specialty ranges: AD (Architecture Design), SD (Structure Design) and ED (Equipment Design). Although the workers are free to occupy any seat as individual workstation, most of them still chose the workstation in the range relevant to their specialty such as the Fig.3-4 showed. The workday starts with taking out one's laptop from one's individual locker and choosing a seat for work. It ends with tidying up, leaving the seat unoccupied.

Table 3-2 Workers' Number in the non-territorial workplace [person]

Specialty attribute	Post attribute			Sum
	PL	RS	TS	
ADS	13	35	17	65
SDS	2	12	1	15
EDS	2	13	5	20
Sum	17	60	23	100

ADS: Architecture design staff; PL: Project leader;

SDS: Structure design staff; RS: Regular staff;

EDS: Equipment design staff; TS: Temporal staff

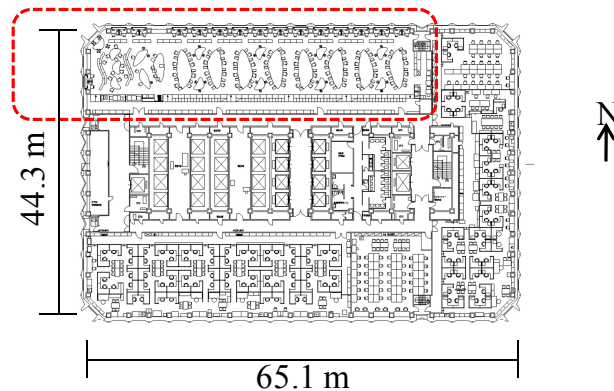
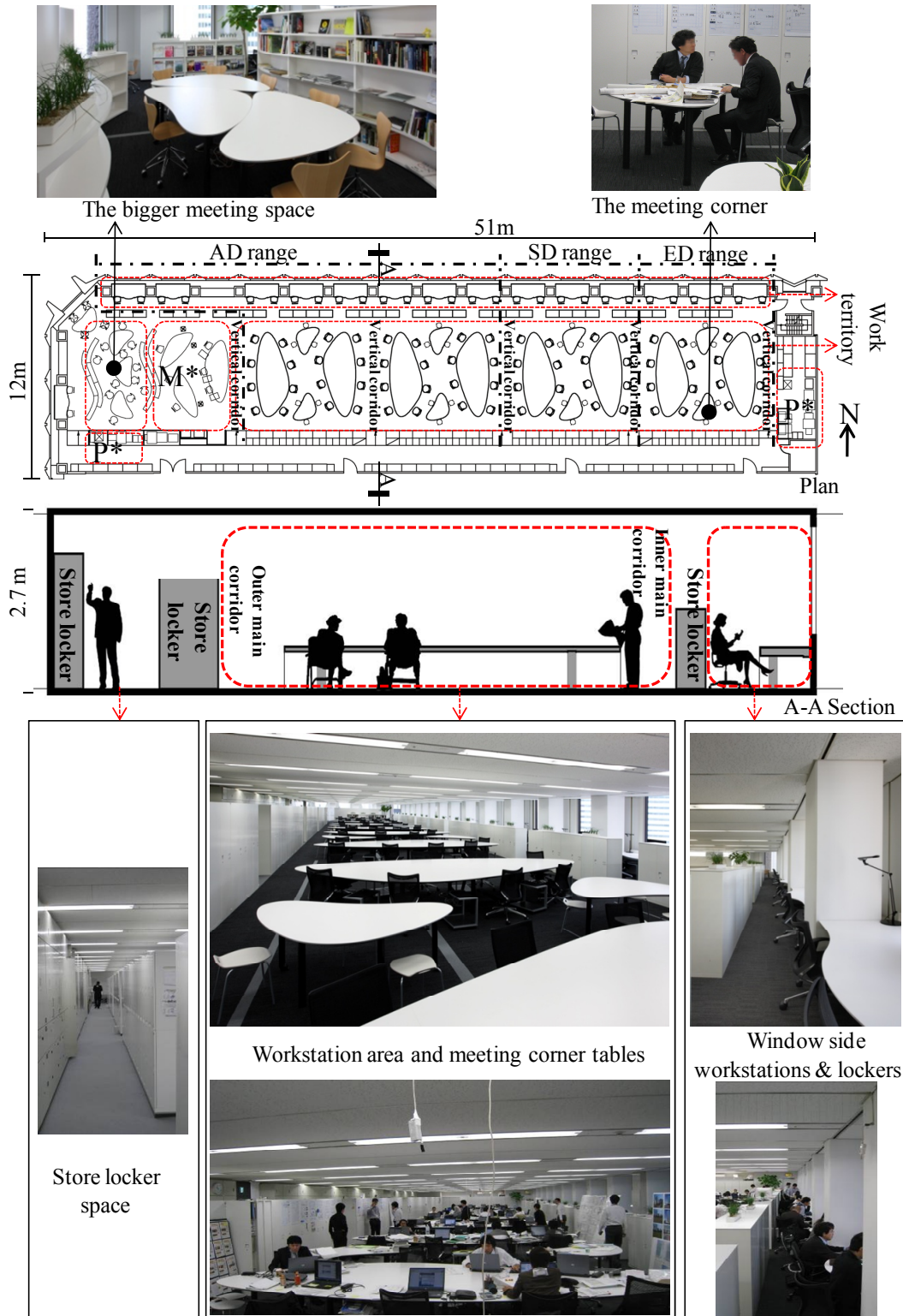


Figure 3-3 The location of investigated non-territorial workplace in high-rise



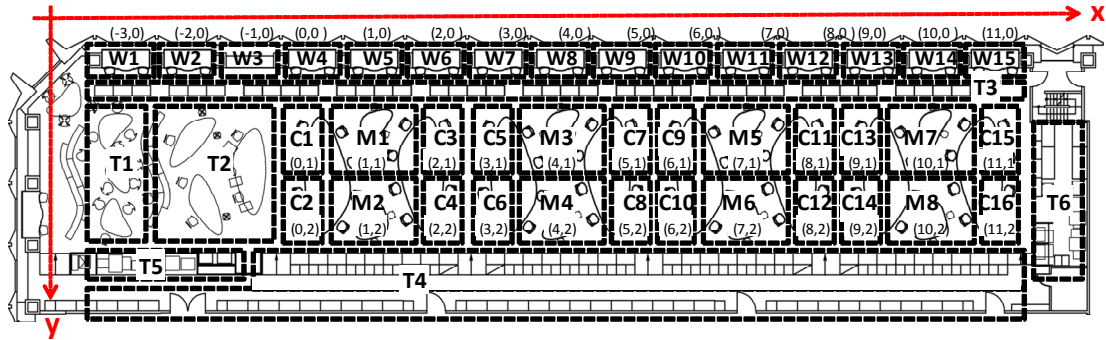
In the figure of plan, Area M*: Administration space, Areas P*: Copy corner;
AD: Architecture Design; SD: Structure Design; ED: Equipment Design

Figure 3-4 The investigated non-territorial workplace

3.3 Patterns of workers' space use behavior

3.3.1 Classification of location zone

According to the sensing accuracy of the UWB sensor network, the distribution of sensor antenna, the layout of workplace and the distance between adjacent seats, the subject's staying location in investigated workplace was classified into 35 location zones such as showed in Fig. 3-5 and Table 3-3.



The number in brackets are distribution coordinate figure of X and Y

Figure 3-5 Division of location zones

Table 3-3 Classification of location zones in the Fig. 3-5

Territory Attribute	Range Attribute	Zone Attribute	Zone ID
Work Territory	AD	Meeting corner side zone	M1-M4
		Corridor side zone	C1-C8
		Window side zone	W1-W9
	SD	Meeting corner side zone	M5-M6
		Corridor side zone	C9-C12
		Window side zone	W10-W12
	ED	Meeting corner side zone	M7-M8
		Corridor side zone	C13-C16
		Window side zone	W13-W15
Service Territory	Meeting Range	-	T1
	Administration Range	-	T2
	Store Range	-	T3-T4
	Copy Range	-	T5-T6

AD: Architecture design; SD: Structure design; ED: Equipment design

When the subject stays in this workplace, the staying moment and period could be detected and recorded by the acceleration sensor. Based on staying duration and moment, the actual coordinate figure of location for the corresponding period could be recorded by the UWB sensor and converted to location zone in the later database revising process. Especially, when subjects left the workplace for other places in the building, the antenna could not receive the signal of the UWB sensor tag, those durations were revised as “out” *¹ in the database revising process. When subjects stayed in certain zone, the author defined that staying behavior as space use behavior.

In the service territory, the zone that subject stayed at is directly defined by the range it is located in.

In the work territory, the zone which includes the workstation that the subject selected in each investigated date is defined as the “Own-Seat Nearby” zone. The other zones in the work territory, will be defined as the “Same-specialty range” *² or the “Other-specialty range” according to whether the specialty attribute of the location zone is the same as the subject’s specialty attribute or not.

Also, in the work territory, according to the attribute of space, the zones can be classified into 3 types. The 1st type is “Meeting corner side zone” that includes the Meeting corner which made the subject sitting nearby communicate with other easily. The 2nd type is “Corridor side zone” beside corridor between workstation islands, which made the subject sitting there move to other area or be visited by other subjects easily. The 3rd type is “Window side zone” located along window with locker partition behind. Meanwhile, in order to analyze the distance from subject’s “Own-Seat Nearby” relative to the work territory’s other zones that the subject visited, a distribution coordinate figure was assigned*³ (the value in brackets in Fig. 3-5).

Following, a database combining the investigated data, the attributes of location zones stayed by subjects and subjects’ attributes was built (Table 3-4).

Table 3-4 Database for space use behavior analysis (a part)

Data ID	Date	Subject attributes				Time attributes			Zone attributes of subject's staying at			
		Subject ID	Post	Specialty	Own-Seat Nearby zone ID	Start time	End time	Lastest duration [second]	Used zone ID	Territory attribute	Specialty rang attribute	Zone attribute
1	11/17/2008	1	RS	ED	C16	1:41:00 PM	1:51:15 PM	615	W15	Work	Same-specialty	Window side
2	11/17/2008	1	RS	ED	C16	1:52:12 PM	1:53:19 PM	67	M2	Work	Other-specialty	Meeting corner side
3	11/17/2008	1	RS	ED	C16	1:54:04 PM	1:54:46 PM	42	-	Out	-	-
4	11/17/2008	1	RS	ED	C16	1:55:30 PM	1:56:13 PM	43	C16	Work	Same-specialty	Own-Seat Nearby
5	11/17/2008	1	RS	ED	C16	1:57:05 PM	1:57:40 PM	36	-	Out	-	-
6	11/17/2008	1	RS	ED	C16	1:57:48 PM	2:16:52 PM	1144	C16	Work	Same-specialty	Own-Seat Nearby
7	11/17/2008	1	RS	ED	C16	2:45:12 PM	2:48:49 PM	217	-	Out	-	-
8	11/17/2008	1	RS	ED	C16	2:48:57 PM	2:49:31 PM	34	C16	Work	Same-specialty	Own-Seat Nearby
20601	11/28/2008	56	PL	AD	M2	7:32:58 PM	7:40:23 PM	379	-	Out	-	-
20602	11/28/2008	56	PL	AD	M2	7:44:13 PM	8:00:00 PM	946	M4	Work	Same-specialty	Meeting corner side

PL.: Project leader; RS: Regular staff; TS: Temporary staff.

AD: Architecture Design; SD: Structure design; ED: Equipment Design.

Zone ID: Refer to Table 3-3.

3.3.2 Workers' space use behavior in different territories

To clarify the difference of workers' staying in ranges of the work territory and the service territory, the following items are calculated and compared in the following analysis.

- ① Duration rate: the average proportion of duration that workers spend on staying at the given range or zone.
- ② Frequency per hour: the average frequency of workers' staying at the given range or zone.
- ③ Duration per time: the average duration of workers' staying at the given range or zone per time.

Moreover, to clarify the differences in workers' space use resulting from posts or specialties, the relevant items mentioned above were calculated and compared on the basis of workers' post and specialty attributes.

1) Workers' space use behavior in the "Work territory" and "Service territory"

According to Table 3-5, all investigated workers spent 13.5% of time under investigation at the out of their workplace and went outside 0.9 times/hour, with an average staying duration at 8.6 min/time.

Table 3-5 All workers' Duration rate, Frequency and Duration per time of staying in work territory and service territory

Items	Work territory			Service territory				Out
	Own-Seat Nearby	Same- specialty range	Other- specialty range	Meeting range	Administra- tion range	Store range	Copy range	
Duration rate [%]	72.5 (17.4)	8.3 (11.5)	3.5 (6.4)	1.4 (4.2)	0.4 (1.9)	0.2 (0.2)	0.2 (0.4)	13.5 (14.4)
Frequency [Times/hour]	4.2 (1.9)	1.1 (1)	0.5 (0.4)	0.1 (0.1)	0.1 (0.3)	0.3 (0.3)	0.2 (0.3)	0.9 (0.6)
Duration per time [Min/time]	10.5 (12.8)	4.6 (8)	3.9 (6.6)	15.1 (15.7)	1.8 (2.6)	0.4 (0.1)	0.6 (0.6)	8.6 (18.1)

Numbers in blanket: standard deviation

In the work territory, the total staying duration rate is summed up to 84.3%. Specifically, the workers' staying at the "Own-Seat Nearby" is the highest as judged by its having the highest duration rate (72.5%), the highest Frequency (4.2 times/hour) and the longest duration per time (10.5 min/time). In the "Same-specialty range" and the "Other-specialty range", it is found that the workers' duration rate and frequency of staying at the "Same-specialty range" was over 2.2 times higher than the relevant items on staying at "Other-specialty range" (8.3 Vs. 3.5 %; 1.1 Vs. 0.5 times/hour). Moreover, the staying duration per time at "Same-specialty range" is also slightly longer (4.6 Vs 3.9 min/time).

In the service territory, the total staying duration rate is summed up to 2.2%. Specifically, in the “Store range” and “Copy range”, although the staying duration rates and the durations per time are the lowest, these two ranges are used more frequently than the “Meeting range” and the “Administration range” in the service territory. The “Meeting range” is seldom used judged by the lowest Frequency, although its duration per time is the highest (15.1 min/time).

2) Comparison of space use behavior in the “Work territory” and the “Service territory” on the basis of workers’ post

According to Table 3-6, Project leaders went out of workplace more frequently (1.0 times/hour) and spent longer time (20.0%) out than other workers. The reason might be that they need more contact with other departments located at other workplaces in the same building.

Table 3-6 Comparison of Duration rate, Frequency and Duration per time of staying in work territory and service territory according to workers’ post

Items	Specialty attribute	Work territory			Service territory				Out
		Own-Seat Nearby	Same-specialty range	Other-specialty range	Meeting range	Administrati on range	Store range	Copy range	
Duration rate [%]	PL	L 64.4 (19.6)	7.9 (7.7)	H 4.3 (6.7)	H 2.2 (4.1)	H 0.9 (4.1)	0.2 (0.3)	0.2 (0.2)	H 20 (15.8)
	RS	72.4 (17.2)	H 8.6 (12.7)	3.6 (6.7)	1.3 (4.5)	0.4 (1.1)	0.2 (0.2)	H 0.3 (0.5)	13.2 (14.4)
	TS	H 83 (11.1)	L 6.9 (5.6)	L 1.6 (2.9)	L 0.6 (1.3)	L 0.3 (0.5)	0.2 (0.2)	0.2 (0.2)	L 7.1 (8.4)
Frequency [Times/hour]	PL	4.1 (1.3)	1.1 (0.9)	0.5 (0.5)	0.1 (0.1)	H 0.2 (0.4)	0.3 (0.4)	0.2 (0.2)	H 1 (0.5)
	RS	H 4.2 (2.1)	1.1 (1)	H 0.6 (0.8)	0.1 (0.1)	0.1 (0.3)	0.3 (0.3)	H 0.3 (0.3)	0.9 (0.6)
	TS	4.1 (1.6)	H 1.2 (0.7)	L 0.3 (0.4)	0 (0.1)	0.1 (0.2)	0.3 (0.2)	0.2 (0.2)	L 0.8 (0.6)
Duration per time [Min/time]	PL	L 9.5 (12.8)	4.3 (8)	H 5.5 (6.6)	H 16.2 (15.7)	H 2.8 (2.6)	0.4 (0.1)	0.6 (0.6)	H 12 (18.1)
	RS	10.4 (12.7)	H 4.8 (8.2)	3.7 (6)	15.7 (16.6)	1.5 (2)	0.4 (0.1)	0.6 (0.7)	8.7 (19)
	TS	H 12.2 (13.9)	L 3.5 (6.2)	L 3.2 (4.6)	L 8.3 (8.9)	1.5 (1)	0.4 (0.3)	0.6 (0.3)	L 3.9 (5.6)

H: Max value in each range or zone; **L**: Minimum value in each range or zone

Numbers in blanket: standard deviation

PL: Project leader; RS: Regular staff; TS: Temporary staff.

In the work territory, compared with other workers, Regular staffs’ duration rate at the “Same-specialty range” (8.6%), as well as frequency of staying at the “Own-Seat Nearby” (4.2 times/hour) and “Other-specialty range” (0.6 times/hour) were higher. Project leaders’ duration rate and duration per time were only higher when staying at the “Other-specialty range” (4.3% and 5.5 min/time). Temporary staffs’ duration rate and duration per time were higher when staying at the “Own-Seat Nearby” (83% and 12.2 min/time). However, the Temporary staffs’ frequency of visiting and staying at the

“Same-specialty range” was the highest (1.2times/hour). On the contrary, the Temporary staffs’ duration rate and duration per time of staying at the “Same-specialty range” were the lowest.

In the service territory, Project leaders used the “Meeting range” and “Administration range” much longer than other workers when compared by their staying duration rate, frequency and duration per time. Temporary staffs’ space use behaviors showed much less in each item. Regular staffs used the “Copy range” more in terms of staying duration rate and frequency.

3) Comparison of space use behavior in the “Work territory” and “Service territory” on the basis of workers’ specialty

According to Table 3-7, in the work territory, Architecture Design staffs used the “Own-Seat Nearby” more as judged by the highest Duration rate (73%). Meanwhile, their duration per time of staying at the same place is 11.4 min/time, also the highest of all.

Table 3-7 Comparison of Duration rate, Frequency and Duration per time of staying in work territory and service territory according to workers’ specialty

Items	Specialty attribute	Work territory			Service territory				Out
		Own-Seat Nearby	Same-specialty range	Other-specialty range	Meeting range	Administration range	Store range	Copy range	
Duration rate [%]	ADS	H 73 (18.8)	8.3 (12.5)	2.4 (4.4)	H 2.1 (5)	H 0.6 (2.3)	0.2 (0.2)	0.2 (0.5)	13.2 (15.8)
	SDS	72.7 (14.6)	8.3 (10.1)	H 7.3 (10.5)	0 (0)	0.1 (0.6)	0.2 (0.2)	0.2 (0.3)	11.2 (10.2)
	EDS	L 70.6 (14.2)	H 8.8 (8.5)	2.4 (4)	0 (0)	0.1 (0.5)	0.2 (0.2)	H 0.3 (0.2)	H 17.6 (12.3)
Frequency [Times/hour]	ADS	L 3.8 (1.7)	1.1 (1)	L 0.4 (0.5)	H 0.1 (0.2)	H 0.2 (0.3)	0.3 (0.3)	L 0.2 (0.3)	L 0.9 (0.6)
	SDS	4.4 (1.1)	L 0.8 (0.9)	H 1.1 (1.1)	0 (0)	0 (0.1)	0.3 (0.3)	0.3 (0.3)	1 (0.5)
	EDS	H 5 (2.9)	H 1.3 (1)	0.5 (0.4)	0 (0)	0 (0.1)	0.3 (0.3)	0.3 (0.2)	1 (0.5)
Duration per time [Min/time]	ADS	H 11.4 (13.6)	4.4 (7.9)	4 (5.6)	H 14.8 (15.4)	L 1.8 (2.7)	0.4 (0.2)	H 0.7 (0.8)	8.7 (17.3)
	SDS	9.9 (11.6)	H 5.8 (10)	H 4.1 (7.6)	0 (0)	1.9 (1.2)	0.4 (0.1)	0.5 (0.2)	L 6.7 (11.8)
	EDS	L 8.4 (11.2)	L 4.2 (6.4)	L 2.9 (5.8)	0 (0)	H 2 (2.4)	0.4 (0.1)	0.5 (0.3)	H 10.6 (25.8)

H: Max value in each range or zone; **L**: Minimum value in each range or zone

Numbers in blanket: standard deviation

ADS: Architecture design staff; SDS: Structure design staff; EDS: Equipment design staff.

Structure Design staffs spent 7.3% of duration under investigation on staying at the “Other-specialty range”, 3 times more than staffs in other specialties, and their frequency of staying at the “Other-specialty range” is also the highest.

Equipment Design staffs stayed and used the “Own-Seat Nearby” less as judged by their having the lowest duration rate (70.6%) and duration per time (8.4 min/time).

However, they spent 0.5% more duration on staying at the “Same-specialty range” than the other staffs.

In the service territory, only Architecture Design staffs used the “Meeting range”. The reason might be its further distance from Equipment Design Specialty and Structure Design Specialty range. Or the staffs of these two specialties did not need hold communication whose attendees are over three; on the contrary, the Architecture Design staffs might need more communication whose attendees over three that cannot be hold in meeting corner.

3.3.3 Worker’s space use behavior at each typical zone in the “Work territory” other than “Own-Seat Nearby”

In this section, in order to clarify how workers visit different zones at the “Work territory” for staying, besides the staying duration per time, the following items were calculated for clarifying more space use characteristics.

- ① Staying frequency proportion: calculated by the frequency of workers’ staying at the given type of zones divided by the whole frequency of workers’ staying at all types of zones in the same range.
- ② Used number per hour: the average used number of zones in one given type, which is stayed by worker per hour.
- ③ Staying frequency rate of zones in given type by distance series from workers’ “Own-Seat Nearby”, calculated by Formula (3.1).

$$V_{k,e,i'} = \frac{\sum_k^D \sum_d^E f_{k,d,e,i'}}{\sum_k^K \sum_d^D \sum_e^E f_{k,d,e,i'}} \times 100 \dots (3.1)$$

$V_{k,e,i'}$: Staying frequency rate of zones in given type by distance series from worker’s “Own-Seat Nearby”.

f : Staying frequency. [Time]

E : Workers’ number according to post or specialty. [Person]

D : Days of investigation [Day]

i' : Id of certain zone type in certain range of the work territory, such like “Meeting corner side zone”, “Corridor side zone” and “Window side zone” [-]

k : Distance units from visited and used zone in the work territory to Own-Seat Nearby [unit]

$$k = |x_{va} - x_s| + |y_{va} - y_s|$$

(x_{va}, y_{va}) : distribution coordinate figure of one visited and used zone in the work territory [unit]

(x_s, y_s) : distribution coordinate figure of worker’s Own-Seat Nearby in the work territory [unit]

1) Workers' space use behavior at each typical zone in the "Work territory"

According to Table 3-8 and 3-9, in both the "Same-specialty range" and "Other-specialty range", the "Meeting corner side zone" were used the most and longest as evident by their frequency proportion being the highest (62 and 53%) and the duration per time being the longest (5.3 and 5.0 min/time).

Table 3-8 Staying frequency proportion of different typical zones in each range

Items	Same-specialty range				Other-specialty range			
	Meeting corner side zone	Corridor side zone	Window side zone	Sum	Meeting corner side zone	Corridor side zone	Window side zone	Sum
Frequency [time]	1530	814	123	2468	657	533	50	1239
Frequency proportion	62%	33%	5%	100%	53%	43%	4%	100%

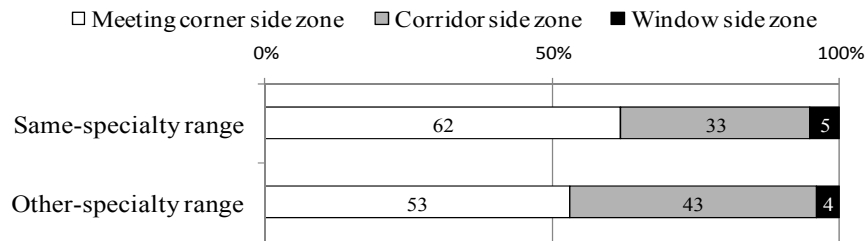


Figure 3-6 Frequency proportion of different typical zones in each range

Table 3-9 Workers' Duration per time and Used number of zones in the "Same-specialty range" and "Other-specialty range"

Items	Same-specialty range			Other-specialty range		
	Meeting corner side zone	Corridor side zone	Window side zone	Meeting corner side zone	Corridor side zone	Window side zone
Use duration per time [Min/time]	5.3 (8.3)	3.5 (7)	3.9 (6.7)	5 (7.3)	2.8 (4.4)	2.1 (1.8)
Used number of zones per hour [-]	0.3 (0.28)	0.3 (0.32)	0.1 (0.14)	0.2 (0.23)	0.2 (0.28)	0 (0.06)

Numbers in blanket: standard deviation

The used numbers of the "Corridor side zone" per hour are the same as the "Meeting corner side zone" in the "Same-specialty range" and the "Other-specialty range" (Table 3-9). However, the "Corridor side zone" was used less frequently and for less duration in the "Same-specialty range", it resulted a 29% lower frequency proportion (Fig. 3-6) and a 2 min/time shorter duration per time (Table 3-9). In the "Other-specialty range", the frequency proportion at "Corridor side zone" climbed to 43% (Fig. 3-6), only 10% lower than the same item of "Meeting corner side zone". The reason might be the location of meeting corner is in the centre of each specialty's workstation island, which made the workers visiting from other specialty sometime preferred to select the "Corridor side zone" which easily to be reached and used.

The “Window side zone” in both ranges were seldom visited or used; the reason is that its space is too narrow for visitor’s staying.

According to Table 3-10 and Fig. 3-7, in the “Same-specialty range”, the staying frequency rate of the “Meeting corner side zone” summed up to 60% within distance unit 2, and decreased regularly as the distance unit value became larger. This tendency showed that workers tended to select the nearest meeting corner and the alternate one for staying.

Table 3-10 Staying frequency rate of zones in given type by distance [%]

Ranges	Zones	Distance unit													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Same-Specialty range	Meeting corner side zone	35	26	15	13	5	3	2	1	1	0	0	0	0	0
	Corridor side zone	27	36	17	10	5	3	1	1	0	0	0	0	0	0
	Window side zone	19	23	27	14	5	7	0	0	4	0	0	1	0	0
Other-Specialty range	Meeting corner side zone	2	19	27	9	10	13	8	3	3	5	1	0	0	0
	Corridor side zone	12	18	16	16	9	7	7	6	3	3	1	1	0	0
	Window side zone	3	17	0	23	3	17	7	7	7	7	3	0	7	0

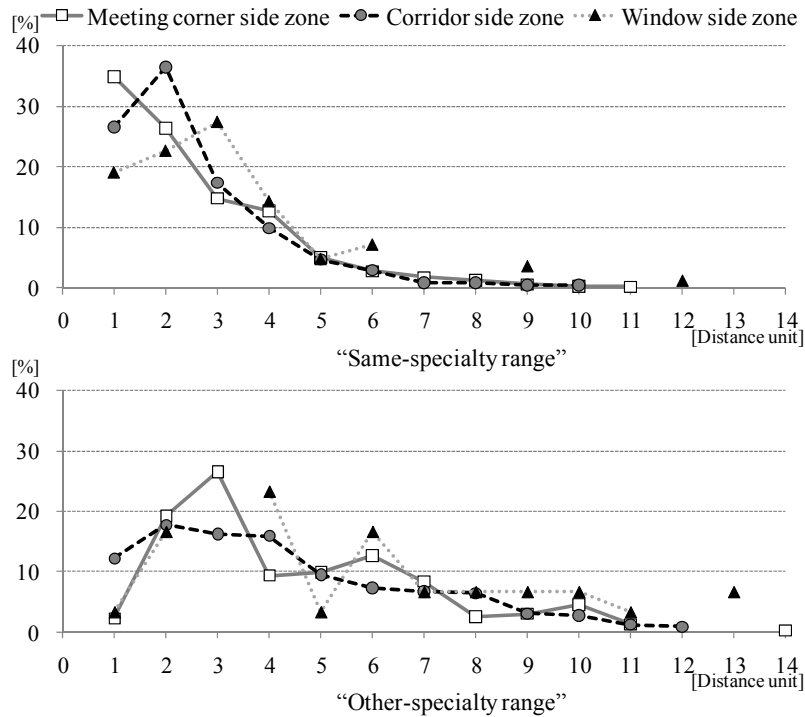


Figure 3-7 Staying frequency rate of zones in given type by distance

The frequency rate of workers' staying at the "Corridor side zone" also decreased as the distance unit increased excluding distance 1. The reason might be that, the workers could usually communicate face to face with others in adjacent zones without moving. The sharper decreasing tendency within distance unit 3 indicated that workers in the Same-specialty range who cooperate with each other closely would select neighboring seats or seats in neighboring zones as their workstations.

Compared with the regular change tendency in the "Same-specialty range", the workers' staying frequency rate in the "Other-specialty range" changed irregularly.

The analysis above showed that how workers visited and used different zones in the work territory. Meeting corner side zone was occupied the longest in each unit staying time (5 min/time). On the contrary, the window side zone was seldom used. The corridor side zone was also used frequently. Especially, corridor side zone was used more frequently when workers visited to "Other-specialty range", since it was easy to be reached by workers from other specialty ranges. Moreover, workers tended to visit the nearest and the alternate meeting corner in the Same-specialty range for staying.

2) Comparison of workers' space use at each typical zone in the "Work territory" on the basis of workers' post

According to Table 3-11, in the "Same-specialty range", Regular staffs used all zones longer than other staffs. In "Other-specialty range", Project leaders' duration per time of staying at the "Meeting corner side" zone(6.8 min/time) and the "Corridor side zone" (3.7 min/time) is longer than that of other staffs.

Table 3-11 Comparison of Duration per time, Used number of different zones in the "Same-specialty range" and "Other-specialty range" according to worker's post

Items	Post attribute	Same-specialty range			Other-specialty range		
		Meeting corner side zone	Corridor side zone	Window side zone	Meeting corner side zone	Corridor side zone	Window side zone
Duration per time [Min/time]	PL	5.1 (9.6)	3.1 (7.5)	3.1 (2.7)	H 6.8 (10.7)	H 3.7 (8)	0.3 (0)
	RS	H 5.5 (8.5)	H 3.6 (7.5)	H 4.4 (7.7)	4.8 (7.3)	L 2.6 (4.3)	1.9 (1.5)
	TS	L 4.1 (6.9)	L 2.8 (5.1)	L 1.5 (0.8)	L 3.3 (5)	2.8 (4.1)	8.1 (0)
Used number of different zones per hour	PL	H 0.38 (0.36)	H 0.32 (0.35)	L 0.05 (0.15)	H 0.22 (0.26)	0.15 (0.2)	L 0.01 (0.04)
	RS	0.27 (0.27)	0.26 (0.32)	0.06 (0.14)	0.19 (0.24)	H 0.19 (0.3)	0.02 (0.06)
	TS	L 0.14 (0.12)	L 0.19 (0.26)	0.06 (0.13)	L 0.11 (0.16)	L 0.11 (0.19)	0.02 (0.08)

H: Max value in each range or zone; **L:** Minimum value in each range or zone

Numbers in blanket: standard deviation

PL: Project leader; RS: Regular staff; TS: Temporary staff.

Also, Table 3-11 shows that, in the "Same-specialty range", Project leaders visited to and stayed at more numbers of "Meeting corner side zone" and "Corridor side zone" per hour than other staffs. In the "Other-specialty range", Project leaders only visited to and stayed at "Meeting corner side zone" more. The number of "Window side zone"

they visited to and stayed at was the fewest of all in each range. The number of “Meeting corner side zone” and “Corridor side zone” per hour in both ranges that Temporary staffs used is much fewer than other staffs. The analysis above showed that Project leaders would use more zones than other workers, which indicates they have contact with more number of workers.

Table 3-12 shows that all workers’ frequency proportion for typical zones in the “Same-specialty range” were almost the same, while the “Meeting corner side zone” was used more frequently, judging by its proportion is over 60%. Project leaders’ and Temporary staffs’ frequency proportion were also the same as in both the “Same-specialty range” and “Other-specialty range”. Only Regular staffs’ frequency proportions of staying at different zones in two ranges were obviously different.

Table 3-12 Comparison of Staying frequency proportion of different typical zones in each range according to worker’s post

Post attribute	Items	Same-specialty range				Other-specialty range			
		Meeting corner side zone	Corridor side zone	Window side zone	Sum	Meeting corner side zone	Corridor side zone	Window side zone	Sum
PL	Frequency [time]	208	115	24	348	94	57	2	153
	Frequency proportion	60%	33%	7%	100%	62%	37%	1%	100%
RS	Frequency [time]	1122	597	100	1820	509	454	46	1009
	Frequency proportion	62%	33%	6%	100%	50%	45%	5%	100%
TS	Frequency [time]	188	99	13	300	48	27	2	77
	Frequency proportion	63%	33%	4%	100%	63%	35%	2%	100%

PL: Project leader; RS: Regular staff; TS: Temporary staff.

According to Table 3-13 and Fig. 3-8, in the “Same-specialty range”, the Regular staffs’ staying frequency rate in relation to the “Meeting corner side zone” summed up to 70% within distance unit 2 with decreasing tendency. This result means they used adjacent and alternate meeting corners most frequently. Project leaders’ decreasing tendency was much weaker than Regular staffs’ within distance unit 4. The reason might be that, Project leaders need to have contact with more staffs including those whose workstations were not closed to Project leaders’. Temporary staffs’ staying frequency rate changed irregularly, perhaps because they seldom select the meeting corner on their own initiative but was asked to join the communication. The Regular staffs’ and Temporary staffs’ decreasing tendency of staying frequency at the “Corridor side zone” was almost the same, while that of Project leaders was much weaker.

Table 3-13 Comparison of Staying frequency rate of zones in the “Same-specialty range” by distance according to worker’s post [%]

Zones	Post	Distance unit													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Meeting corner side zone	PL	23	20	20	18	5	5	2	4	0	2	1	0	0	0
	RS	39	30	11	11	5	2	1	1	0	0	0	0	0	0
	TS	24	14	28	19	3	5	5	0	3	0	0	0	0	0
Corridor side zone	PL	18	28	24	14	6	4	4	3	0	0	0	0	0	0
	RS	28	38	17	10	3	2	0	0	1	0	0	0	0	0
	TS	26	35	11	15	5	3	2	0	0	3	0	0	0	0

PL: Project leader; RS: Regular staff; TS: Temporary staff.

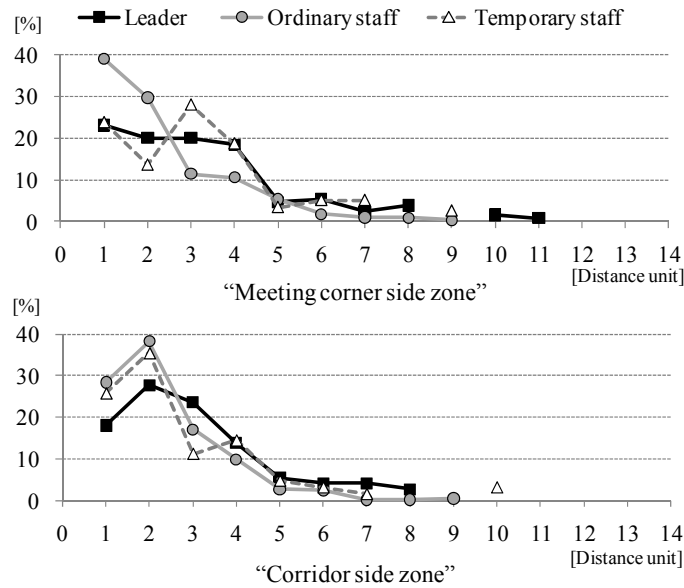


Figure 3-8 Comparison of Staying frequency rate of zones in the “Same-specialty range” by distance according to worker’s post

With regarding workers’ post, the different space use characteristic not only revealed their difference need for space, but also reflected their different work style. The main differences are described as following:

Compared with workers in other posts, Project leaders visited and used a more number of zones to contact with more workers in the same specialty. Additionally their space use behavior is less influenced by their individual workstation’s location.

Regular staffs spent more time in the “Meeting corner side zone” and “Corridor side zone” in the same specialty. Their space use behavior on visiting and using zones was most strongly influenced by the distance from the visited zones to their individual workstation.

Temporary staffs spent the least amount of time in either the meeting corner or at others’ workstation. They had contact with less number of workers than did other workers.

3) Comparison of space use behavior at each typical zone in the “Work territory” on the basis of workers’ specialty

According to Table 3-14, in the “Same-specialty range”, Structure Design staffs’ duration per time in the “Meeting corner side zone” and the “Corridor side zone” was the highest (5.9 and 5.4 min/time). In the “Other-specialty range”, Structure Design staffs’ duration per time in the “Meeting corner side zone” and “Window side zone” was the highest.

Table 3-14 Comprising space using items of same type in “Self-specialty range” and “Other-specialty range” on the basis of worker’s specialty

Items	Specialty attribute	Same-specialty range			Other-specialty range		
		Meeting corner side zone	Corridor side zone	Window side zone	Meeting corner side zone	Corridor side zone	Window side zone
Duration per time [Min/time]	ADS	5.4 (8.7)	L 2.9 (6.3)	L 2.3 (2.5)	4.7 (5.7)	H 3.2 (5.5)	2.1 (2.4)
	SDS	H 5.9 (9.6)	H 5.4 (11.3)	6.3 (7)	H 5.7 (9.5)	L 2.4 (4.3)	H 2.2 (1.9)
	EDS	L 4.1 (5.7)	3.7 (5.9)	H 11.3 (14.9)	L 3.4 (7.2)	2.6 (4.2)	L 1.7 (0.9)
Used number of different zones per hour	ADS	H 0.31 (0.31)	H 0.29 (0.36)	H 0.07 (0.17)	L 0.14 (0.21)	0.15 (0.28)	0.01 (0.06)
	SDS	L 0.18 (0.16)	L 0.16 (0.17)	0.04 (0.08)	H 0.32 (0.25)	H 0.32 (0.3)	H 0.05 (0.09)
	EDS	0.25 (0.25)	0.25 (0.25)	L 0.03 (0.06)	0.22 (0.24)	L 0.14 (0.15)	0.01 (0.04)

H: Max value in each range or zone; **L:** Minimum value in each range or zone

Numbers in blanket: standard deviation

ADS: Architecture design staff; SDS: Structure design staff; EDS: Equipment design staff.

Table 3-14 also reveals that in the “Same-specialty range”, Architecture Design staffs used more number of “Meeting corner side zone” and “Corridor side zone” per hour than other staffs, which means they visited more workers in the same specialty.

In the “Other-specialty range”, the used number of zone per hour of Structure Design staffs was higher than other staffs in all three types, but much lower in the “Same-specialty range”. This showed they visited more workers in other specialties than with those in the same specialty.

Table 3-15 Comparison of Staying frequency proportion of different typical zones in each range according to worker’s specialty

Specialty attribute	Items	Same-specialty range				Other-specialty range			
		Meeting corner side zone	Corridor side zone	Window side zone	Sum	Meeting corner side zone	Corridor side zone	Window side zone	Sum
ADS	Frequency [time]	943	500	99	1542	290	221	17	528
	Frequency proportion	61%	32%	6%	100%	55%	42%	3%	100%
SDS	Frequency [time]	370	248	22	640	162	156	15	332
	Frequency proportion	58%	39%	3%	100%	49%	47%	4%	100%
EDS	Frequency [time]	323	136	22	481	95	81	8	184
	Frequency proportion	67%	28%	5%	100%	52%	44%	5%	100%

ADS: Architecture design staff; SDS: Structure design staff; EDS: Equipment design staff.

As presented in Table 3-15, it showed that the frequency proportion of workers' use at the "Corridor side zone" in the "Other-specialty range" is higher than they used "Corridor side zone" in the "Same-specialty range". Especially, Structure Design staffs' staying frequency proportion at "Corridor side zone" is much higher than other staffs'.

According to Table 3-16 and Fig. 3-9, the decreasing tendency of Architecture Design staffs' staying frequency rate for two zones is much weaker than other workers'. The less frequency might be caused by two reasons. The 1st reason is that the Architecture Design staffs have more choice on selecting meeting corner, as their range being twice as big as other ranges. The 2nd reason is that the work of Architecture Design staff needs more coworkers in the same specialty.

Table 3-16 Comparison of Staying frequency rate of zones in the "Same-specialty range" by distance according to worker's specialty [%]

Zones	Specialty	Distance unit													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Meeting corner side zone	ADS	23	22	19	17	8	4	3	2	1	0	0	0	0	0
	SDS	48	39	5	9	0	0	0	0	0	0	0	0	0	0
	EDS	63	30	8	0	0	0	0	0	0	0	0	0	0	0
Corridor side zone	ADS	24	31	16	13	7	4	1	0	0	0	0	0	0	0
	SDS	32	41	21	7	0	0	0	0	0	0	0	0	0	0
	EDS	30	50	19	2	0	0	0	0	0	0	0	0	0	0

ADS: Architecture design staff; SDS: Structure design staff; EDS: Equipment design staff.

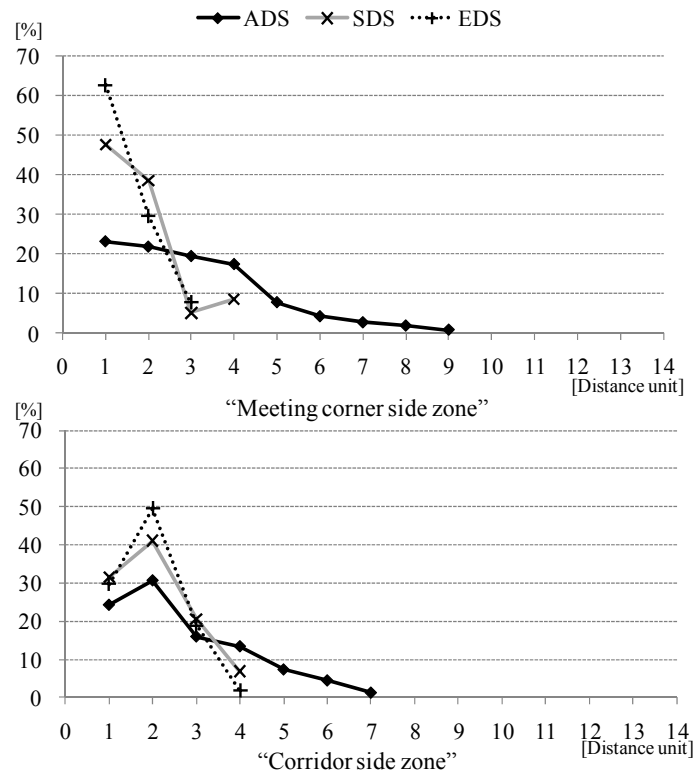


Figure 3-9 Comparison of Staying frequency rate of zones in the "Same-specialty range" by distance according to worker's specialty

In both the “Meeting corner side zone” and “Corridor side zone” of the “Same-specialty range”, the decreasing tendencies of staying frequency rate by the Structure Design and Equipment Design staffs were approximate.

With regarding workers’ specialty, the different space use characteristic not only revealed their difference need for space, but also reflected their different work style.

Compared with staffs in other specialties, Architecture Design staffs used more number of “Meeting corner side zone” in the “Same-specialty range”, which indicates they had contact with a more number of other workers in the Same-specialty. Although some of them were not seated closely. When they used the space in the “Other-specialty range”, their staying frequency proportion at the “Meeting corner side zone” is higher than the other workers.

Structure Design staffs not only spent more duration on using the “Meeting corner side zone” and the “Corridor side zone” at the “Other-specialty range”, but also had contact with a greater number of workers in other specialties.

Equipment Design staffs spent less duration on using the “Meeting corner side zone” of both the “Same-specialty range” and the “Other-specialty range”.

By the findings showed in section 3.3.3, one advantage of this non-territorial workplace is able to be verified by the sharper decreasing tendency of use frequency rate according to changing of distance unit. Specifically, workers who cooperate with each other closely could select workstations close to each other as personal workstation, which could make them communicate each other easily. Also, the finding is helpful to improve the distribution of zones in order to increase the occupancy rates of space or enhance communication. For instance, half number of meeting corner could be located at corridor side between different specialties, in order to make them easily be reached and shared by workers from different specialties.

3.4 Behavior concerning choosing individual workstations

The workers' behavior of choosing individual workstation is focused on in this section. As mentioned in section 3.2.1, on distributing the sensor sets to workers, their names and the individual workstations they chose were recorded. Following, the record list of the UWB sensor sets' distribution is used to analyze the workers' choosing individual workstation tendency in this section.

Although the investigation did not cover all workers, as the workers in the non-territorial workplace were assigned sensor sets randomly and evenly according to the specialty ranges and post. The result could also reflect the workers' choosing individual workstation patterns.

3.4.1 The classifications of workstations and subjects

1) The classifications of workstations

The workstations in the investigated area were classified according to their location attributes. Vertically, the workstations were divided into two groups, one was next to the north-south corridor (Corridor Side) and the other was next to the meeting corners (Meeting Corner Side). Horizontally, the workstations were divided into four rows (Window Row, Inner Row, Middle Row 1, Middle Row 2 and Outer Row). The Window Area was divided into five sub-areas (W1~W5) and the Table Area into eight sub-areas according to the tables (T1~T8) (Fig. 3-10).

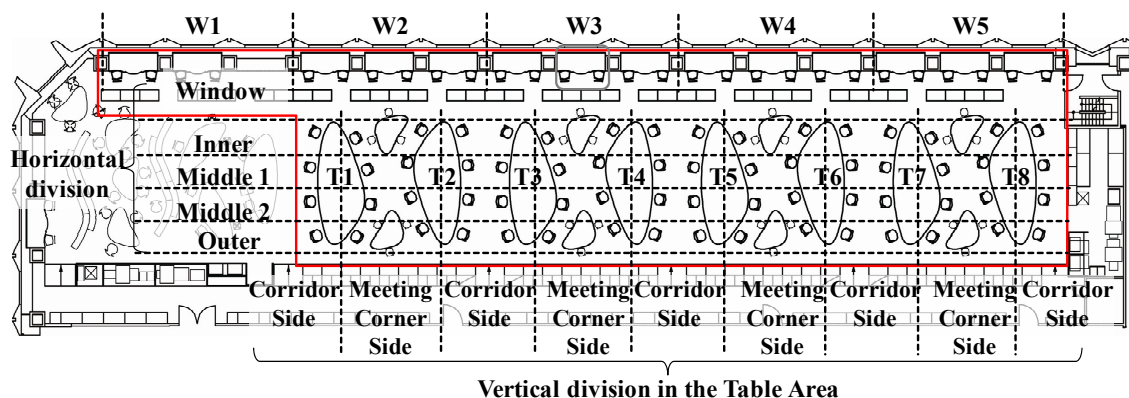


Figure 3-10 Classification of workstation in investigated workplace

2) The classifications of subjects

Subjects were classified into three types by the post: Project leader, Regular Staff and Temporary Staff.

Although the subjects could also be classified into 2 types according to the specialty attribute (such like architect, and engineer of structure or equipment design). Since the workstations are evenly distributed into the specialty ranges, the workers in different specialties have the same proportion of choosing workstation when they full filled the ranges. Therefore the subjects are only classified by their post attribute in this section.

Combining the workers post, IDs and the spatial attribute of the individual workstations selected by workers, a database was built and analyzed, as shown in Table 3-17.

Table 3-17 Database

Data ID	Date	Workstation's information				Occupant's information	
		Workstation ID	Area	Vertical division	Horizontal division	Subject ID	Post attribute
1	11/17/2008	9	T2	Meeting corner side	Inner	1	Regular staff
2	11/17/2008	1	T1	Corridor side	Inner	5	Regular staff
3	11/17/2008	36	T5	Corridor side	Outer	7	Regular staff
4	11/17/2008	57	T8	Meeting corner side	Inner	2	Project leader
5	11/17/2008	28	T4	Corridor side	Outer	18	Regular staff
6	11/17/2008	49	T7	Meeting corner side	Inner	33	Regular staff
7	11/17/2008	76	W3	-	Window	19	Temporary staff
258	11/28/2008	43	T6	Meeting corner side	Middle 2	56	Regular staff
259	11/28/2008	72	W2	-	Window	19	Temporary staff
260	11/28/2008	26	T4	Meeting corner side	Middle 1	23	Project leader

3.4.2 Relationship between the locations of workers' individual workstation and their post

According to the Fig. 3-11, Project leaders were found to be inclined to choose individual workstations in the Table Area. Regular staffs distributed themselves more evenly in the Table Area and Window Area. Temporary staffs selected the individual workstation located at the Window Area more frequently.

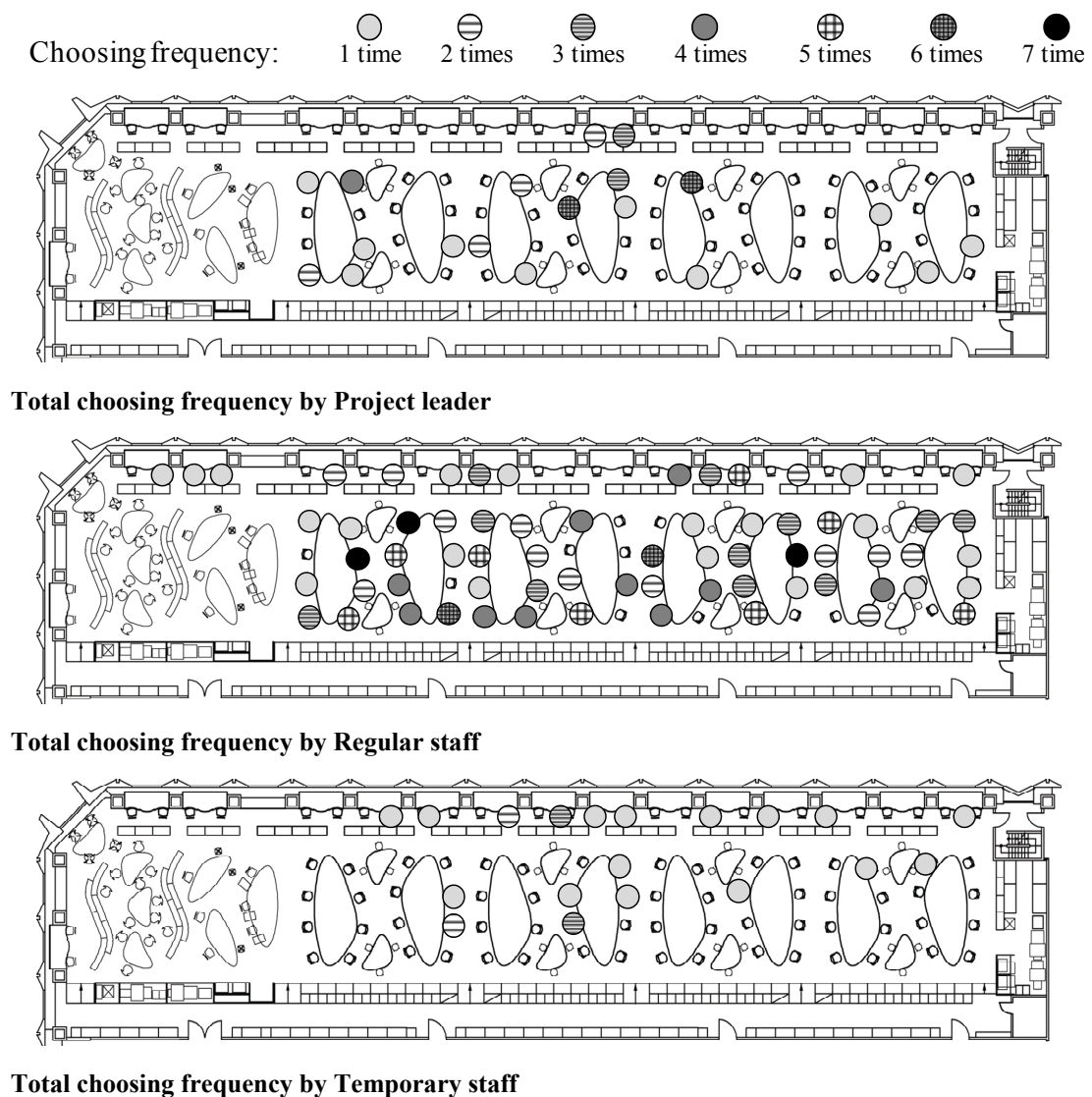


Figure 3-11 Total choosing frequency by workers on the basis of posts

1) Choices counted by horizontal division of workstations

For all the investigated workers, there were overall more occupancy in the Inner and Outer rows. This might have been because the shape of the tables became narrow toward the ends, thereby shortening the distance between workstations on opposite sides, and making it easier for face-to-face communication to take place. Moreover, the Inner and Outer rows are next to the main corridors, which make it convenient for workers to go to other tables from there. (Table 3-18, Fig. 3-12)

The preferences of Regular staffs were found to be in the following order: Outer Row, Middle Row 1, Middle Row 2, Inner Row and Window Row. This showed that Regular staffs preferred choosing individual workstations that were near the entrance more than those that were further in. (Table 3-18, Fig. 3-13)

The Project leaders occupied the Inner Row much more often than any of the other rows. This might because the Inner Row is located between the Window Area and the Table Area, next to the main corridor in the middle, which makes it the ideal position to communicate with workers in either direction. (Table 3-18, Fig. 3-14)

Temporary staffs chose workstations in the Window Row more than the other rows. (Table 3-18, Fig. 3-15)

Table 3-18 Frequency of workers' choosing individual workstation by horizontal division

Position of Row	Choosing frequency [time]			
	All workers	Regular staffs	Project leaders	Temporary staffs
Window	43	28	5	10
Inner	59	36	16	3
Middle 1	50	42	8	4
Middle 2	48	38	7	5
Outer	60	48	7	3
Sum	260	192	43	25

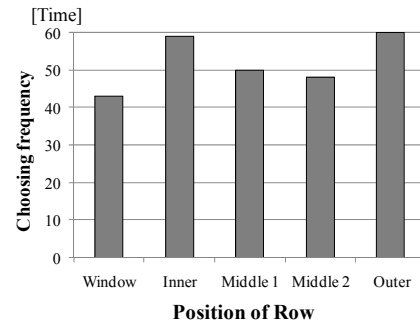


Figure 3-12 Frequency of workers' choosing individual workstation by horizontal division

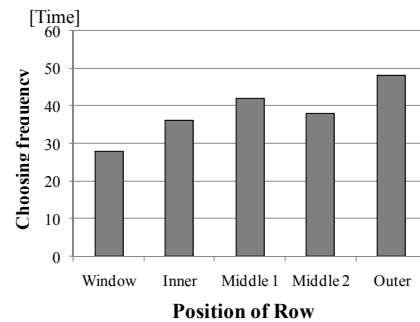


Figure 3-13 Frequency of Regular staffs' choosing individual workstation by horizontal division



Figure 3-14 Frequency of Project leaders' choosing individual workstation by horizontal division

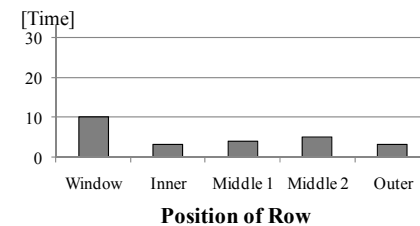


Figure 3-15 Frequency of Temporary staffs' choosing individual workstation by horizontal division

2) Choices counted based on vertical division of workstations

For all the investigated workers, there were more occupancies of the Meeting Corner Side than the Corridor Side. (Table 3-19, Fig. 3-16)

Regular staffs and Project leaders preferred choosing individual workstations located at the Meeting Corner Side; on the contrary, Temporary staffs chose the individual workstation at the corridor side more. (Table 3-19 Fig. 3-17, 18 & 19)

Table 3-19 Frequency of workers' choosing individual workstation by horizontal division

Position of Row	Choosing frequency [time]			
	All workers	Regular staffs	Project leaders	Temporary staffs
Meeting Corner Side	123	90	26	7
Corridor Side	94	74	12	8
Sum	217	164	38	15

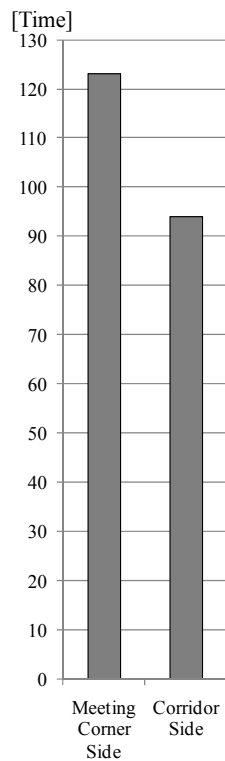


Figure 3-16 Frequency of workers' choosing individual workstation by vertical division

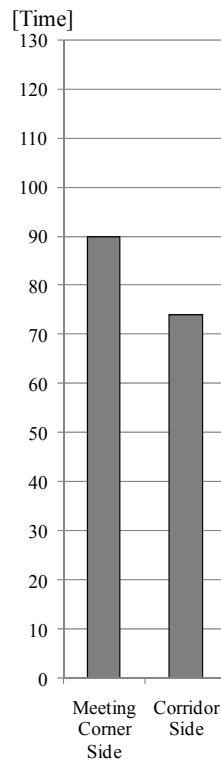


Figure 3-17 Frequency of Regular staffs' choosing individual workstation by vertical division

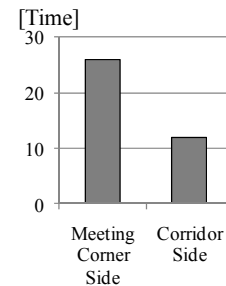


Figure 3-18 Frequency of Project leaders' choosing individual workstation by vertical division

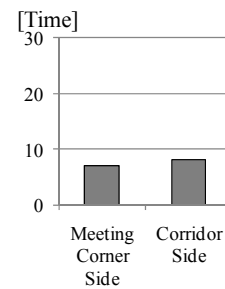


Figure 3-19 Frequency of Temporary staffs' choosing individual workstation by vertical division

3) Workers' choosing ration according to the workstation attribute

In order to identify the workers' characteristics and tendency of choosing individual workstations, with combining the workstation' vertical and horizon attribute, the workers' choosing ration (Table 3-20) was calculated by Formula (3.2):

$$r_{pi} = \frac{f_{pi} / (n_i \times d)}{S_p / (N \times d)} \dots (3.2)$$

r_{pi} : choosing ration of given post on the basis of given individual workstation
 f_{pi} : choosing frequency of given post on the basis of given individual workstation
 S_p : summation of workers on the basis of given post
 i : given workstation on the basis of categories
 p : worker in given post
 d : investigation duration (9 days)
 n_i : number of workstation on the basis of given type
 N : summation of workstation

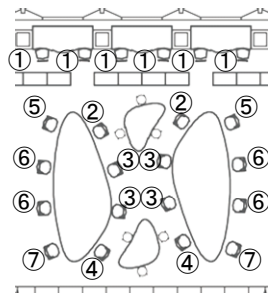


Figure 3-20 Classification of workstations

Table 3-20 Choosing ration on each workstation

Individual workstation attribute (i)	Post (p)	Choosing frequency (f_{pi})	Seat number (n_i)	Choosing ration (r_{pi})
① Window side	PL	5	26	0.40
	RS	28		0.50
	TS	10		1.38
② Inner-Meeting corner side	PL	9	8	2.35
	RS	20		1.17
	TS	2		0.90
③ Middle-Meeting corner side	PL	8	16	1.05
	RS	45		1.32
	TS	5		1.13
④ Outer-Meeting corner side	PL	4	8	1.05
	RS	25		1.46
	TS	0		0.00
⑤ Inner-Corridor side	PL	7	8	1.83
	RS	15		0.88
	TS	1		0.45
⑥ Middle-Corridor side	PL	7	16	0.92
	RS	36		1.05
	TS	4		0.90
⑦ Outer-Corridor side	PL	3	8	0.78
	RS	23		1.35
	TS	3		1.35
Mean	PL	43	90	
	RS	192		
	TS	25		

PL: Project leader; RS: Regular staff; TS: Temporary staff.

As showed in Table 3-20, Project leaders tended to select the individual workstation located at the “Inner-Meeting corner side” most frequently. In order of choosing ration, they next chose the “Inner-Corridor side”, the “Middle-Meeting corner side”, and the “Outer-Meeting corner side”; in contrast, the “Window side” was seldom selected by them.

Regular staffs tended to select the individual workstation located at the “Outer Meeting corner side” most frequently, next came the “Outer-Corridor side”, the “Middle-Meeting corner side”, the “Inner-Meeting corner side”, and the “Middle-Corridor side”.

Temporary staffs tended to select an individual workstation located at the “Window side” most frequently; next came the “Outer-Corridor side” and the “Middle-Meeting corner side”.

3.4.3 Consistency in workers' choice of individual workstations

1) Classification of consistency in workers' choice of individual workstations

Though workers may choose the individual workstation located anywhere in the investigated non-territorial workplace, some of them have been observed to consistently choose a certain workstation or workstations in a certain area. In order to understand such behavior, workers who were investigated more than three times were selected as subjects, and a Consistency Ratio (CR) was calculated according to the following Formula (3.3):

$$CR = \text{Number of times a certain worker has chosen the same workstation} \div \text{Total number of times this worker has been investigated} \dots\dots(3.3)$$

Four classifications are shown below in choices of workstations, based on CR values:

- ① Same Workstation: $CR = 1$; the worker always chooses the same workstation.
- ② Same Workstation Mainly (Adjacent): $0.5 < CR < 1$; the worker is inclined to choose the same workstation every time, and all chosen workstations are adjacent.
- ③ Same Workstation Mainly (Non-adjacent): $0.5 < CR < 1$; the worker is inclined to choose the same workstation every time, but not all chosen workstations are adjacent.
- ④ Multi-Workstation: $CR < 0.5$, the worker is less inclined to repeat his choice of workstations.

Furthermore, the distribution of the chosen workstations is classified into 3 types as shown below:

Same Area: the chosen individual workstations are located in the same table area. (Area division is shown in Fig. 3-10)

Multi-area (Adjacent): the chosen individual workstations are in adjacent multiple table areas. (For instance, the chosen workstations are in T6 and W4, refer to Fig. 3-10)

Multi-area (Non-adjacent): the chosen individual workstations are in non-adjacent multiple table areas.

2) Consistency of all the investigated workers

According to Table 3-21 and Fig. 3-21, 37% of all the workers always choose the same workstation. 36% of the workers mainly choose the same workstation, and even if they choose a different workstation, half of them choose workstations adjacent to the one they often choose.

Furthermore, 63% of the workers chose individual workstations in the same area, and 90% of the workers located themselves in the same or adjacent areas. Only 10% of the workers chose individual workstations in distant areas. (Table 3-22 and Fig. 3-22)

Table 3-21 Frequency and ration of choosing type

Choosing type	Choosing Workstation	
	Frequency [time]	Ration [%]
Same Workstation	79	37
Same Workstation Mainly (Adjacent)	38	18
Same Workstation Mainly (Non-adjacent)	38	18
Multi-Workstation	58	27
Sum	213	100

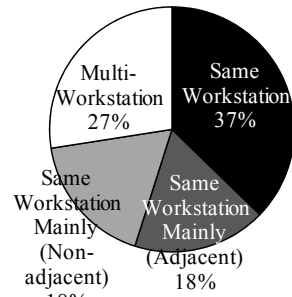


Figure 3-21 Ration of choosing type

Table 3-22 Frequency and ration of choosing area

Choosing type	Choosing	
	Frequency [time]	Ration [%]
Same Area	134	63
Same Area Mainly (Adjacent)	58	27
Multi-Area (Non-adjacent)	21	10
Sum	213	100

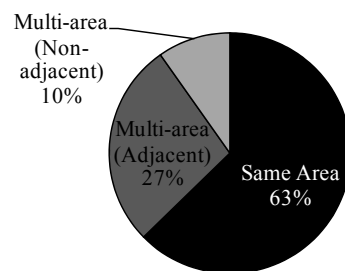


Figure 3-22 Distribution of workstations

3) Consistency analysis by post held

A similar percentage of Project leaders and Regular staffs always chose the same workstations (40% —Project leaders, 41% — Regular staff). Project leaders and Regular staffs also had similar distributions of chosen workstations. Project leaders, however, were markedly more inclined to choose the same workstation on most occasions. And when Project leaders chose different workstations, these were not necessarily adjacent to their usual ones. Regular staffs were more likely to change their workstation often (Table 3-23, Fig. 3-23).

Table 3-23 Frequency and ration of choosing type according to post

Choosing type	Project leaders		Regular staffs		Temporary staffs	
	f [time]	r [%]	f [time]	r [%]	f [time]	r [%]
Same Workstation	14	40	64	40	-	-
Same Workstation Mainly (Adjacent)	4	10	23	14	8	50
Same Workstation Mainly (Non-adjacent)	14	40	23	14	4	25
Multi-Workstation	4	10	52	32	4	25
Sum	36	100	161	100	16	100

f: Frequency; r: Ration

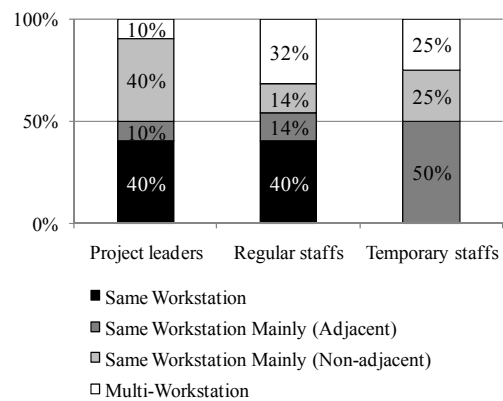


Figure 3-23 Ration of choosing type according to different post

None of Temporary staffs chose the same workstations regularly, but half of them worked centered on certain workstations and most of them chose workstations in the same area (75%). None of them chose workstations in non-adjacent areas (Table 3-24, Fig. 3-24).

Table 3-24 Frequency and ration of choosing area according to post

Choosing type	Project leaders		Regular staffs		Temporary staffs	
	f [time]	r [%]	f [time]	r [%]	f [time]	r [%]
Same Area	22	60	100	62	12	75
Same Area Mainly (Adjacent)	11	30	43	27	4	25
Multi-Area (Non-adjacent)	4	10	18	11	-	-
Sum	36	100	161	100	16	100

f: Frequency; r: Ration

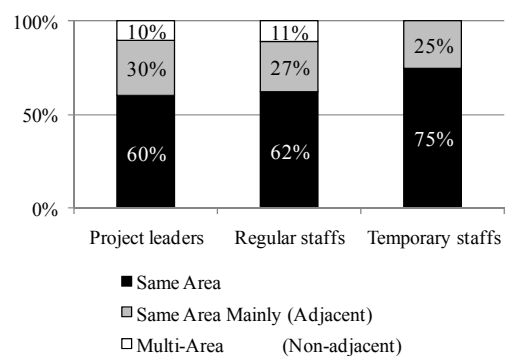


Figure 3-24 Ration of choosing area according to post

3.5 Patterns of worker's space use behavior related to the selected individual workstation attribute

In section 3.4, by analyzing the frequency of workers' choosing individual workstation, the author clarified workers' choosing tendency related to workstation's spatial attribute. Herein, the author focused on workers' space use behaviors related to individual workstation attribute by using a UWB sensor network, in order to clarify the characteristic of workers space use when they located at different individual workstations.

Additionally, different from the section 3.3, not only the workers' staying, but also the frequency of workers' move inside the workplace and the "Own-Seat Nearby" zone are analyzed ^{*4}, in order to reveal workers' space use characteristic across individual workstation attribute.

3.5.1 Classification of location ranges and the workstation categories

1) Classification of location ranges

As analyzed in the section 3.4, it is found that, most workers always choose the same individual workstation located in the same range (the same workstation table area), by which the author assumes workers' space use behavior could be mainly held there. Additionally, the space use behavior related to distance, which was analyzed in the section 3.3, also revealed that workers tended to select the adjacent or alternate workstation or meeting corner for staying. Therefore, in this section, instead of the specialty range classified in section 3.3.1, the author reclassified two workstation table areas (including 2 tables with 16 seats and 2 meeting corner tables) and window side workstations closed to them as one range (Table 3-25). The other classifications kept the same as presented in section 3.3.1. With the same division of location zones presented by Fig. 3-5, the reclassification of location ranges is showed as following table.

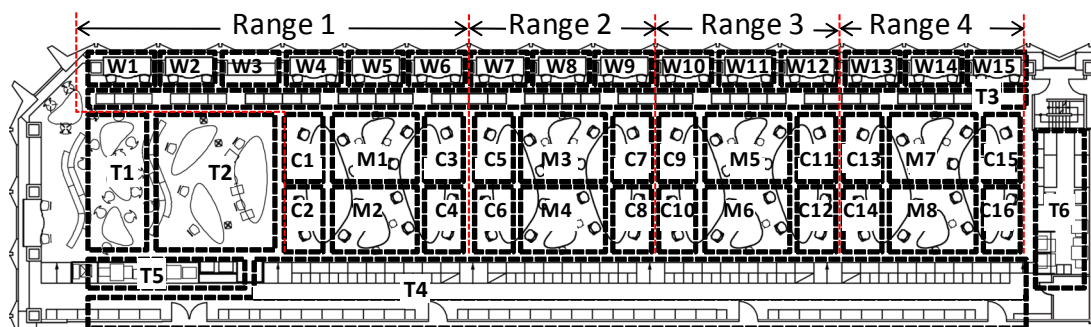


Figure 3-5 Division of zones

Table 3-25 Classification of location zones in the Fig. 3-5

Territory Attribute	Range Attribute	Zone Attribute	Zone ID
Work Territory	Range 1	Meeting corner side zone	M1-M2
		Corridor side zone	C1-C4
		Window side zone	W1-W6
	Range 2	Meeting corner side zone	M3-M4
		Corridor side zone	C5-C8
		Window side zone	W7-W9
	Range 3	Meeting corner side zone	M5-M6
		Corridor side zone	C9-C12
		Window side zone	W10-W12
	Range 4	Meeting corner side zone	M7-M8
		Corridor side zone	C13-C14
		Window side zone	W13-W15
Service Territory	Meeting Range	-	T1
	Administration Range	-	T2
	Store Range	-	T3-T4
	Copy Range	-	T5-T6

2) Classification of workstations

On the basis of workstations' spatial attributes classified in section 3.4.2-3), the workstations are classified into seven categories (Fig. 3-25).

- ① Window side: beside the window with storage locker blocked behind.
- ② Inner-Meeting corner side: next to the inner horizontal main corridor and beside the meeting corner.
- ③ Middle-Meeting corner side: between two meeting corners.
- ④ Outer-Meeting corner side: next to the outer main corridor and beside the meeting corner.
- ⑤ Inner-Corridor side: next to the vertical corridor and inner main horizontal corridor.
- ⑥ Middle-Corridor side: next to the vertical corridor.
- ⑦ Outer-Corridor side: next to the vertical corridor and outer main horizontal corridor.

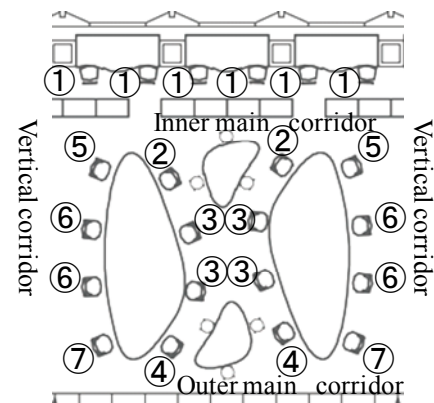


Figure 3-25 Classification of workstations

Finally, the database was combined with collected data with regarding the classification of location zones, workers' post attributes and selected individual workstation attribute, were then created (Table 3-26).

Table 3-26 Database

Data ID	Date	Subject attributes			Time attributes			Behavior	Zone attributes of subject's staying at			
		Subject ID	Post	Own-Seat Nearby zone ID	Start time	End time	Lastest duration [second]		Used zone ID	Territory attribute	Range attribute	Zone attribute
1	11/17/2008	1	RS	C16	13:41:00	13:51:15	615	Staying	W15	Work	Same-range	Window side
2	11/17/2008	1	RS	C16	13:51:18	13:52:09	51	Move	-	-	-	-
3	11/17/2008	1	RS	C16	13:52:12	13:53:19	67	Staying	M2	Work	Other-range	Meeting corner side
4	11/17/2008	1	RS	C16	13:53:22	13:54:02	39	Move	-	-	-	-
5	11/17/2008	1	RS	C16	13:54:04	13:54:46	42	Staying	-	Out	-	-
6	11/17/2008	1	RS	C16	13:54:49	13:55:27	36	Move	-	-	-	-
7	11/17/2008	1	RS	C16	13:55:30	13:56:13	43	Staying	C16	Work	Same-range	Own-Seat Nearby
8	11/17/2008	1	RS	C16	13:56:16	13:57:01	45	Move	-	-	-	-
9	11/17/2008	1	RS	C16	13:57:05	13:57:40	36	Staying	-	Out	-	-
10	11/17/2008	1	RS	C16	13:57:43	13:57:46	3	Move	-	-	-	-
11	11/17/2008	1	RS	C16	13:57:49	14:16:52	1143	Staying	C16	Work	Same-range	Own-Seat Nearby
12	11/17/2008	1	RS	C16	14:16:55	14:45:09	1694	Move	-	-	-	-
13	11/17/2008	1	RS	C16	14:45:12	14:48:49	217	Staying	-	Out	-	-
14	11/17/2008	1	RS	C16	14:48:52	14:48:55	3	Move	-	-	-	-
15	11/17/2008	1	RS	C16	14:48:58	14:49:31	33	Staying	C16	Work	Same-range	Own-Seat Nearby
40220	11/28/2008	56	PL	M2	19:32:58	19:33:38	40	Move	-	-	-	-
40221	11/28/2008	56	PL	M2	19:33:41	19:34:01	21	Move	-	-	-	-
40222	11/28/2008	56	PL	M2	19:34:04	19:40:23	379	Staying	-	Out	-	-
40223	11/28/2008	56	PL	M2	19:40:26	19:44:10	225	Move	-	-	-	-
40224	11/28/2008	56	PL	M2	19:44:13	20:00:00	946	Staying	M4	Work	Same-range	Meeting corner side

PL: Project leader; RS: Regular staff; TS: Temporary staff.

Zone ID: Refer to Fig. 3-5.

As analyzed in section 3.3, most of workers' space use behavior occurred in the work territory, the following analysis is only focused on workers' staying in the work territory, as well as workers' move.

3.5.2 Workers' move and space use behavior patterns on the basis of individual workstation attributes

As presented in Tables 3-27 and 3-28, compared with the means of all investigated workers, when workers selected individual workstation located at the “Window side”, their move frequency inside the workplace is 7.8 times/hour, significantly higher. Meanwhile, their staying frequency at the same range is 1.02 times/hour, also significantly higher, which mainly caused by the significantly higher staying frequency at both the “Meeting corner side zone” and the “Corridor side zone”.

Once choosing the individual workstation located at the “Inner-Meeting corner side”, workers' duration rate of move inside the workplace (7.7%) and staying at “Out” (21.2%) are significantly higher. However, their duration rate of staying at the “Own-Seat Nearby” zone (58.1%) and the “Meeting corner side zone” (2.3%) in the same range are significantly less. Additionally, in the same range, workers' staying frequency is significantly lower at the “Meeting corner side zone” (0.3 times/hour), but significantly higher at the “Corridor side zone” (0.44 times/hour).

Once choosing the individual workstation located at the “Middle-Meeting corner side”, workers' move duration rate inside the workplace is 4.9%, significantly lower. Whereas their staying duration rate at the “Own-Seat Nearby” zone is 72.4%, significantly higher. However, their staying duration rate at the “Meeting corner side zone” in the same range and the zones of the other ranges are significantly lower, the same state is seen by comparing the move and use frequency. Moreover, their frequency of move inside the “Own-Seat Nearby” zone (1.99 times/hour) and staying frequency outside the workplace (0.85 times/hour) are significantly lower.

Table 3-27 Workers' move and space use duration rate related to individual workstation type [%]

Individual workstation attribute	Stay inside workplace							Move		Out
	Own-Seat Nearby	Same range			Other range			Inside Own-Seat Nearby	Inside workplace	
		Meeting corner side zone	Corridor side zone	Sum	Meeting corner side zone	Corridor side zone	Sum			
Window side	66 (15)	4.5 (7)	1.9 (3)	7 (8)	3.5 (7)	1.5 (2)	5.1 (8)	- (-)	6.7 (4)	13.2 (12)
Inner-Meeting corner side	** 58.1 (18)	* 2.3 (4)	2.2 (5)	4.5 (6)	4.5 (7)	1.9 (4)	6.7 (1)	- (-)	* 7.7 (4)	** 21.2 (17)
Middle-Meeting corner side	* 72.4 (17)	** 1.5 (4)	1.3 (2)	** 2.9 (5)	* 2.8 (7)	** 1 (2)	* 3.9 (8)	- (-)	** 4.9 (2)	12.6 (15)
Outer-Meeting corner side	* 72.6 (12)	3.6 (8)	1.9 (5)	5.5 (9)	5.2 (9)	2.3 (6)	7.6 (1)	- (-)	6.1 (4)	** 7.1 (9)
Inner-Corridor side	66.4 (18)	3.9 (5)	1.5 (3)	5.8 (8)	5.2 (1)	1.6 (3)	6.9 (1)	- (-)	6.4 (2)	13.9 (12)
Middle-Corridor side	65.5 (16)	5.6 (10)	** 0.5 (1)	6.9 (11)	5.4 (13)	1.2 (2)	6.7 (14)	- (-)	6.5 (3)	12.5 (13)
Outer-Corridor side	65.7 (16)	6.2 (10)	** 0.3 (1)	6.6 (11)	6.9 (13)	1.4 (2)	8.4 (14)	- (-)	6.5 (3)	10.5 (13)
Mean	67.1	3.8	1.4	5.4	4.5	1.5	6.1	-	6.3	13

Numbers in blanket: standard deviation.

* $p < 0.05$

** $p < 0.01$

Once choosing the individual workstation at the “Outer-Meeting corner side”, the frequency of workers’ move inside the “Own-Seat Nearby” zone is significantly higher (3.38 times/hour). At the same time, the frequency of their staying at the same range is significantly lower (0.36 times/hour). This is mainly caused by the significant lower frequency of staying at the “Meeting corner side zone” (0.08 times/hour). Additionally, the frequency of their staying outside the workplace is also significantly lower (0.58 times/hour).

Once choosing the individual workstation located at the “Middle-Corridor side”, although workers’ duration rate (0.5%) and frequency (0.15 times/hour) of staying at the “Corridor side zone” in the same range are significantly lower. The significantly higher frequency of staying at the “Meeting corner side zone” (0.76 times/hour) leads to a significantly higher frequency’s summation of staying at the same range (0.97 times/hour). Meanwhile, summation of workers’ frequency on staying at other ranges is also significantly higher (1.12 times/hour).

Once choosing the individual workstation located at the “Outer-Corridor side zone”, the frequency of workers’ staying at the “Corridor side zone” in the same range (0.06 times/hour), and the duration rate at outside of the workplace are significantly lower. However, their frequency of staying at the “Meeting corner side zone” (0.82 times/hour) of other ranges is significantly higher and led to a significantly higher staying frequency at other range (1.2 times/hour). The workers’ use duration rate at the “Corridor side zone” (0.3 times/hour) is significantly lower.

Table 3-28 Workers’ move and staying frequency related to individual workstation type [time/hour]

Individual workstation attribute	Stay inside workplace							Move		Out
	Own-Seat Nearby	Same range			Other range			Inside Own-Seat Nearby	Inside workplace	
		Meeting corner side zone	Corridor side zone	Sum	Meeting corner side zone	Corridor side zone	Sum			
Window side	4.11 (2.41)	* 0.56 (0.5)	** 0.40 (0.42)	* 1.02 (0.86)	0.56 (0.6)	0.31 (0.3)	0.91 (0.78)	1.94 (1.87)	* 7.80 (2.5)	1.22 (0.75)
Inner-Meeting corner side	4.18 (1.9)	** 0.30 (0.28)	* 0.44 (0.62)	0.76 (0.64)	0.50 (0.57)	0.42 (0.46)	0.98 (1.02)	2.29 (1.37)	7.77 (3.36)	1.05 (0.5)
Middle-Meeting corner side	** 3.58 (1.04)	** 0.18 (0.37)	0.23 (0.29)	** 0.43 (0.56)	** 0.31 (0.43)	** 0.22 (0.21)	** 0.57 (0.61)	* 1.99 (1)	** 5.86 (1.59)	* 0.85 (0.57)
Outer-Meeting corner side	4.85 (2.39)	** 0.08 (0.16)	0.23 (0.27)	** 0.36 (0.29)	0.47 (0.59)	0.48 (0.7)	0.99 (0.77)	** 3.38 (1.88)	6.99 (3.07)	** 0.58 (0.49)
Inner-Corridor side	4.18 (1.47)	0.48 (0.59)	0.18 (0.31)	0.70 (0.83)	0.53 (0.87)	0.33 (0.49)	0.89 (1.27)	2.37 (1.3)	7.00 (2.63)	0.91 (0.56)
Middle-Corridor side	3.95 (1.41)	* 0.76 (0.94)	* 0.15 (0.2)	* 0.97 (1)	0.63 (0.5)	0.45 (0.46)	* 1.12 (0.86)	2.03 (1.22)	7.68 (2.63)	0.97 (0.39)
Outer-Corridor side	4.73 (2.84)	0.70 (1.12)	** 0.06 (0.16)	0.77 (1.15)	* 0.82 (0.92)	0.34 (0.39)	* 1.20 (1.15)	2.69 (2.5)	8.09 (3.8)	* 0.86 (0.52)
Mean	4.13	0.43	0.23	0.71	0.52	0.35	0.91	2.28	7.15	1.04

Numbers in blanket: standard deviation. *: $p < 0.05$ **: $p < 0.01$

The aforementioned results not only reveal how workers' move and space use patterns differed related to the individual workstations' attributes, it also indicated the advantages of each different workstation.

The "Window side", which is seldom visited and stayed at by other workers, enabled the workers located there to concentrate more easily on solo work. However, they moved more frequently and longer for visiting and staying at the table range to engage in communication.

The "Inner-Meeting corner side", which located in the center of each range and beside the Meeting corner, allowed the workers located there to use the closest meeting corner for communication conveniently and made move to other places easier.

The "Middle-Meeting corner", which is surrounded by other workstations and meeting corners, enabled the workers located there to use the closest meeting corner more conveniently but made it inconvenient to visit other places.

The "Outer-Meeting corner", which is beside the outer horizontal corridor and meeting corner, acted almost as same as the "Inner-Meeting corner side". However, as it is located on one side of the workplace, the distance to some places lengthened and the workers could not move to other places efficiently. This is the reason why the move duration rate of workers, whose individual workstation located there, is lower and the duration rate of staying at the "Own-Seat Nearby" zone is higher.

The workstations located at the "Inner-Corridor side", the "Middle-Corridor side" and the "Outer-Corridor side" acted almost the same. They made it convenient for workers located there to move to other places.

3.5.3 Characteristic of workers' move and space use behavior on the basis of individual workstation attributes in terms of posts

As showed by Table 3-20 and analyzed in section 3.4.2-3), the workers' choosing individual workstation patterns are different on the basis of their post; therefore, in order to clarify the influence of workstation's attribute on workers' space use behavior. In the latter analysis, with regarding the choosing ration of given workstation, whose value is within the highest three in the given post (Table 3-29), the move and staying of workers is focused on.

Table 3-29 Choosing ration on each workstation

Individual workstation attribute (<i>i</i>)	Post (<i>p</i>)	Choosing frequency (<i>f_{pi}</i>)	Seat number (<i>n_i</i>)	Choosing ration (<i>r_{pi}</i>)
① Window side	PL	5	26	0.40
	RS	28		0.50
	TS	10		1.38 *
② Inner-Meeting corner side	PL	9	8	2.35 *
	RS	20		1.17
	TS	2		0.90
③ Middle-Meeting corner side	PL	8	16	1.05 *
	RS	45		1.32 *
	TS	5		1.13 *
④ Outer-Meeting corner side	PL	4	8	1.05 *
	RS	25		1.46 *
	TS	0		0.00
⑤ Inner-Corridor side	PL	7	8	1.83 *
	RS	15		0.88
	TS	1		0.45
⑥ Middle-Corridor side	PL	7	16	0.92
	RS	36		1.05
	TS	4		0.90
⑦ Outer-Corridor side	PL	3	8	0.78
	RS	23		1.35 *
	TS	3		1.35 *
Mean	PL	43	90	
	RS	192		
	TS	25		

PL: Project leader; RS: Regular staff; TS: Temporary staff.

*: Choosing ration of given post is within highest three.

1) Project leaders

According to Table 3-29, Project leaders tended to select the individual workstation at the “Inner-Meeting corner side” most frequently (r_{pi} : 2.35). In order of choosing ration, Project leaders next chose the “Inner-Corridor side” (r_{pi} : 1.83), the “Middle-Meeting corner side” (r_{pi} : 1.05), the “Outer-Meeting corner side” (r_{pi} : 1.05).

According to Tables 3-30 and 3-31, compared with the means of all investigated Project leaders, once choosing the individual workstation located at the “Inner-Meeting corner side”, Project leaders’ move duration rate inside the workplace is 10.1%, significantly higher. However, their duration rate of staying at the “Own-Seat Nearby” zone (48.4%) is significantly lower. Additionally, their frequency of staying at other ranges (1.69 times/hour) is significantly higher, which is mainly caused by the significantly higher staying frequency at the “Meeting corner side zone” in that range.

Once choosing the individual workstation located at the “Inner-Corridor side”, Project leaders’ frequency of staying at the same range (0.32 times/hour) is significantly lower. This result is caused by the significantly lower staying frequency at the “Meeting corner side zone” (0.17 times/hour) and the “Corridor side zone” (0.07 times/hour). Their frequency of staying at other ranges is also significantly lower (0.44 times/hour), which is mainly caused by the significantly lower staying frequency at the “Corridor side zone” (0.07 times/hour).

When choosing the individual workstation located at the “Middle-Meeting corner side”, Project leaders’ move duration rate inside the workplace is significantly lower (4.7%). Their duration rate of staying at the same range (1.6%) and other ranges (1.7%) is significantly lower, which is caused by the significantly lower staying duration rate in the “Meeting corner side zone” of both ranges. The same state is showed by comparing the move and staying frequency. Moreover, Project leaders’ move frequency inside the “Own-Seat Nearby” zone (1.52 times/hour) is significantly lower.

When choosing the individual workstation located at the “Outer-Meeting corner side”, Project leaders’ staying duration rate at the “Corridor side zone” in the other ranges is significantly lower. Moreover, Project leaders’ move frequency inside the workplace (4.79 times/hour) is significantly lower but significantly higher inside the “Own-Seat Nearby” zone (2.77 times/hour). Additionally, Project leaders’ frequency of staying at the same range and other ranges is significantly lower, which is mainly caused by the significantly lower staying frequency at the “Meeting corner side zone” in both ranges. Their staying frequency outside of the workplace is also significantly lower (0.44 times/hour).

Table 3-31 Project leaders' move and staying duration rate related to individual workstation type [%]

Individual workstation attribute	Stay inside workplace							Move		Out
	Own-Seat Nearby	Same range			Other range			Inside Own-Seat Nearby	Inside workplace	
		Meeting corner side zone	Corridor side zone	Sum	Meeting corner side zone	Corridor side zone	Sum			
Window side	61.8 (14)	7.7 (9)	1.2 (1)	9 (9)	6 (7)	1.1 (1)	7.4 (7)	- -	7 (3)	12 (11)
Inner-Meeting corner side	* 48.4 (16)	2.9 (4)	1.2 (2)	4.1 (4)	* 9.5 (6)	2.3 (2)	* 12.1 (8)	- -	* 10.1 (4)	21.3 (15)
Middle-Meeting corner side	68.3 (20)	** 0.7 (2)	0.9 (2)	** 1.6 (2)	* 0.2 (0)	1.4 (3)	** 1.7 (3)	- -	** 4.7 (1)	18.4 (20)
Outer-Meeting corner side	70 (10)	12 (14)	0.4 (1)	12.4 (13)	2.9 (5)	** 0.5 (0)	3.4 (5)	- -	4.2 (2)	9.7 (13)
Inner-Corridor side	69.8 (17)	2.8 (5)	2.1 (5)	5.6 (9)	2.9 (4)	0.7 (2)	3.6 (5)	- -	7.1 (2)	13.2 (8)
Middle-Corridor side	62.2 (11)	2.3 (3)	0.7 (1)	2.9 (3)	5 (6)	* 0.8 (1)	5.8 (7)	- -	7 (2)	18.5 (8)
Outer-Corridor side	58.6 (15)	** 0.5 (1)	0 (0)	** 0.5 (1)	2.3 (3)	1.4 (2)	3.7 (5)	- -	6.3 (2)	30.3 (22)
Mean	62.1	3.6	1	4.8	4.8	1.3	5.8	-	6.9	17.5

Numbers in blanket: standard deviation. * $p < 0.05$ ** $p < 0.01$

Table 3-30 Project leaders' move and staying frequency related to individual workstation type [time/hour]

Individual workstation attribute	Stay inside workplace							Move		Out
	Own-Seat Nearby	Same range			Other range			Inside Own-Seat Nearby	Inside workplace	
		Meeting corner side zone	Corridor side zone	Sum	Meeting corner side zone	Corridor side zone	Sum			
Window side	3.64 (0.36)	0.86 (1.02)	0.23 (0.22)	1.15 (0.95)	0.87 (0.69)	0.44 (0.23)	1.40 (0.79)	* 1.37 (0.61)	7.79 (2.21)	1.26 (0.67)
Inner-Meeting corner side	4.24 (1.35)	0.30 (0.29)	0.37 (0.55)	0.67 (0.48)	* 0.91 (0.5)	* 0.72 (0.5)	* 1.69 (1.08)	2.17 (0.99)	8.94 (3.48)	1.03 (0.63)
Middle-Meeting corner side	3.34 (0.99)	** 0.09 (0.1)	0.15 (0.27)	** 0.25 (0.23)	* 0.18 (0.35)	0.23 (0.24)	** 0.45 (0.34)	* 1.52 (0.68)	* 5.60 (1.62)	1.02 (0.42)
Outer-Meeting corner side	3.7 (0.42)	* 0.14 (0.14)	0.08 (0.13)	** 0.21 (0.12)	** 0.18 (0.12)	0.29 (0.23)	* 0.47 (0.33)	** 2.77 (0.24)	** 4.79 (0.86)	* 0.44 (0.31)
Inner-Corridor side	4.27 (1.18)	* 0.17 (0.17)	* 0.07 (0.12)	* 0.32 (0.25)	0.33 (0.3)	** 0.07 (0.09)	** 0.44 (0.38)	2.48 (0.94)	6.15 (1.1)	0.95 (0.28)
Middle-Corridor side	4.5 (1.92)	0.47 (0.42)	0.11 (0.15)	0.60 (0.49)	0.50 (0.27)	0.25 (0.25)	0.76 (0.43)	3.08 (2.02)	7.29 (2.27)	0.94 (0.2)
Outer-Corridor side	* 3.03 (0.54)	0.32 (0.31)	0.00 (0)	0.32 (0.31)	1.04 (0.88)	* 0.08 (0.12)	1.13 (0.99)	** 0.91 (0.21)	5.60 (1.54)	0.88 (0.46)
Mean	3.92	0.32	0.17	0.51	0.55	0.33	0.93	2.12	6.84	0.99

Numbers in blanket: standard deviation. * $p < 0.05$ ** $p < 0.01$

The aforementioned results may be due to the needs of Project leaders' work style and their different daily work. That is, as Project leaders' work request more communication with other staff. Therefore, they selected the individual workstation located beside both the meeting corner and the corridor more frequently. The location enable them to visit other ranges more conveniently and also allows them to conveniently utilize the closest meeting corner to communicate with the workers who visit them. In contrast, when their daily work composed of more personal work which made them visit workers less frequently, they would select an individual workstation located at the "Outer Meeting corner side" or the "Middle Meeting corner side". Once choosing an individual workstation located at the "Inner Corridor side", Project leaders visit the zones of the same or the other ranges less frequently.

2) Regular staffs

According to Table 3-29, Regular staff tended to select the Individual workstation located at the “Outer Meeting corner side” most frequently (r_{pi} : 1.46), next came the “Outer-Corridor side” (r_{pi} : 1.35) and the “Middle-Meeting corner side” (r_{pi} : 1.32).

As displayed in Tables 3-32 and 3-33, compared with the means of all investigated Regular staffs, when choosing the individual workstation located at the “Outer-Meeting corner side”, Regular staffs’ duration rate of staying at the “Own-Seat Nearby” zone is 73%, significantly higher. However, their duration rate of staying at the outside workplace is significantly lower (6.7%). Moreover, frequency of Regular staffs’ move inside the “Own-Seat Nearby” zone is significantly higher (3.48 times/hour). Meanwhile, their frequency of staying at the “Meeting corner side zone” in the same range is significantly lower (0.08 times/hour), which leads to the lower staying frequency at the same range (0.38 times/hour). Their staying frequency at outside the workplace is also lower (0.6 times/hour).

Once choosing the individual workstation located at the “Outer-Corridor side”, Regular staffs’ move frequency inside the workplace is significantly higher (8.78 times/hour). Their frequency and duration rate of staying at the “Corridor side zone” in the same range is significantly lower.

When choosing the individual workstation located at the “Middle-Meeting corner side”, Regular staffs’ move duration rate inside the workplace is significantly lower (5.2%). Their staying duration rate at the “Own-Seat Nearby” zone is significantly higher (71.7%), but significantly lower at the “Meeting corner side zone” (1.7%) in the same range and the “Corridor side zone” (0.9%) of the other range. The same state is showed by comparing the move and staying frequency. Moreover, their move frequency inside the “Own-Seat Nearby” zone (2.07 times/hour) and staying frequency at outside the workplace is significantly lower (0.82 times/hour).

The results above reveal that when Regular staffs’ daily work is composed of more solo personal work and less visiting to workers located in other ranges, they would select an individual workstation located at the “Middle Meeting corner side”. Its location enables them to conveniently use the closest meeting corner without moving and results in more continual staying at their individual workstation and nearby. The same situation took place at the individual workstation located at the “Outer Meeting corner side”. In contrast, if the Regular staffs’ daily work is composed of more visiting to workers located in other ranges, they would select an individual workstation located

at the “Outer Corridor side”. The inter range location and the corridor beside it enable them to visit other ranges more easily.

Table 3-32 Regular staff s’ move and staying duration rate related to individual workstation type [%]

Individual workstation attribute	Stay inside workplace							Move		Out
	Own-Seat Nearby	Same range			Other range			Inside Own-Seat Nearby	Inside workplace	
		Meeting corner side zone	Corridor side zone	Sum	Meeting corner side zone	Corridor side zone	Sum			
Window side	64.5 (16)	5 (8)	2.3 (4)	8 (9)	3.4 (8)	1.5 (2)	5 (9)	- -	7.1 (4)	13.5 (13)
Inner-Meeting corner side	* 59.9 (16)	* 2.2 (5)	1.8 (5)	4.1 (6)	2.8 (6)	1.9 (4)	4.9 (8)	- -	6.9 (3)	** 23.2 (17)
Middle-Meeting corner side	* 71.7 (17)	** 1.7 (5)	1.6 (3)	** 3.4 (6)	3 (7)	** 0.9 (1)	* 4.2 (9)	- -	** 5.2 (2)	12.2 (14)
Outer-Meeting corner side	* 73 (13)	2.2 (6)	2.1 (5)	4.4 (7)	5.5 (10)	2.6 (7)	8.3 (11)	- -	6.4 (4)	** 6.7 (8)
Inner-Corridor side	63.9 (17)	4.4 (6)	1.3 (2)	6.2 (7)	5.9 (11)	2.1 (3)	8.1 (12)	- -	6.4 (2)	15 (14)
Middle-Corridor side	64.5 (16)	6.1 (11)	** 0.5 (1)	7.6 (11)	5.8 (7)	1.4 (2)	7.4 (7)	- -	6.5 (3)	12.5 (13)
Outer-Corridor side	64.1 (16)	7.5 (11)	** 0.3 (1)	7.9 (11)	7.9 (15)	1.5 (2)	9.5 (15)	- -	7 (3)	* 8.6 (9)
Mean	66.7	4	1.4	5.8	4.6	1.6	6.5	-	6.3	12.7

Numbers in blanket: standard deviation. * $p < 0.05$ ** $p < 0.01$

Table 3-33 Regular staffs’ move and staying frequency related to individual workstation type [time/hour]

Individual workstation attribute	Stay inside workplace							Move		Out
	Own-Seat Nearby	Same range			Other range			Inside Own-Seat Nearby	Inside workplace	
		Meeting corner side zone	Corridor side zone	Sum	Meeting corner side zone	Corridor side zone	Sum			
Window side	4.14 (2.81)	0.60 (0.57)	* 0.42 (0.42)	* 1.08 (0.86)	0.45 (0.55)	0.31 (0.33)	0.79 (0.78)	2.06 (2.13)	7.68 (3.95)	1.13 (0.79)
Inner-Meeting corner side	4.05 (1.86)	** 0.27 (0.28)	0.34 (0.59)	0.66 (0.64)	0.35 (0.46)	0.31 (0.38)	0.70 (0.83)	2.11 (1.22)	6.88 (2.95)	1.05 (0.39)
Middle-Meeting corner side	3.67 (1.06)	** 0.21 (0.41)	0.26 (0.31)	** 0.50 (0.62)	** 0.32 (0.46)	** 0.22 (0.21)	** 0.59 (0.67)	* 2.07 (1.06)	** 6.00 (1.63)	* 0.82 (0.62)
Outer-Meeting corner side	** 5.03 (2.53)	** 0.08 (0.16)	0.26 (0.27)	** 0.38 (0.3)	0.52 (0.62)	0.50 (0.74)	1.07 (0.78)	** 3.48 (2)	7.34 (3.15)	** 0.60 (0.51)
Inner-Corridor side	4.19 (1.59)	0.61 (0.67)	0.23 (0.36)	0.86 (0.94)	0.57 (1)	0.45 (0.55)	1.05 (1.47)	2.31 (1.44)	7.48 (2.92)	0.95 (0.61)
Middle-Corridor side	* 3.85 (1.29)	* 0.77 (1.02)	** 0.13 (0.2)	0.96 (1.05)	* 0.68 (0.54)	0.51 (0.49)	* 1.24 (0.91)	** 1.74 (0.86)	7.52 (2.81)	0.96 (0.43)
Outer-Corridor side	* 5.15 (3.01)	0.83 (1.22)	** 0.07 (0.18)	0.91 (1.24)	0.80 (0.97)	0.40 (0.41)	1.25 (1.22)	3.07 (2.67)	* 8.78 (3.86)	0.86 (0)
Mean	4.21	0.46	0.24	0.75	0.51	0.37	0.92	2.36	7.28	0.91

Numbers in blanket: standard deviation. * $p < 0.05$ ** $p < 0.01$

3) Temporary staffs

According to ration showed in Table 3-29, Temporary staffs tended to select an individual workstation located at the “Window side” most frequently (r_{pi} : 1.38), next came the “Outer-Corridor side” (r_{pi} : 1.35) and the “Middle-Meeting corner side” (r_{pi} : 1.13).

As presented in Tables 3-34 and 3-35, compared with the means of all investigated Temporary staffs, once choosing the workstations located at the “Window side” as an individual workstation, Temporary staffs’ move duration rate (5.6%) and frequency (8.14 times/hour) inside workplace is significantly higher. Meanwhile, compared with other workers that selected the same type of workstation, Temporary staffs’ staying duration rate is much lower at each zone of the same range or other ranges. This result indicates that they need less communication than other workers.

Once choosing the individual workstation located at the “Outer-Corridor side”, the Temporary staffs’ duration rate of staying at the “Corridor side zone” (0.1%) in other ranges and frequency of staying at outside of the workplace (4.9%) is significantly lower. Their use frequency of staying at the “Meeting corner side zone” in the same range is also significantly lower (0.08 times/hour).

When choosing the individual workstation located at the “Middle-Meeting corner side”, Temporary staffs’ move duration rate and frequency inside the workplace are significantly lower. Their staying duration rate is significantly higher at the “Own-Seat Nearby” zone (84.5%). However, their staying frequency is significantly lower at both the “Meeting corner side zone” (0.04 times/hour) and the “Corridor side zone” (0.05 times/hour) in the same range. The same state is showed by comparing the move and staying frequency. Their staying frequency at outside of the workplace is also significantly lower (0.69 times/hour).

The aforementioned results reveal that because the “Window side” is seldom visited by other workers, thus, Temporary staffs who located their individual workstations there were less disturbed from their solo work, although they would spent more time for move and stay at other places.

Table 3-34 Temporary staff s' move and staying duration rate related to individual workstation type [%]

Individual workstation attribute	Stay inside workplace							Move		Out
	Own-Seat Nearby	Same range			Other range			Inside Own-Seat Nearby	Inside workplace	
		Meeting corner side zone	Corridor side zone	Sum	Meeting corner side zone	Corridor side zone	Sum			
Window side	72.3 (14)	1.4 (3)	1.2 (1)	3.2 (4)	2.5 (3)	1.8 (3)	4.4 (3)	- -	* 5.6 (2)	* 12.7 (9)
Inner-Meeting corner side	83 (11)	0.7 (0)	10 (6)	10.7 (6)	0 (0)	0 (0)	0 (0)	- -	4.7 (3)	1.6 (2)
Middle-Meeting corner side	* 84.5 (4)	** 0.1 (0)	** 0.2 (0)	** 0.3 (0)	4.8 (3)	0.7 (1)	5.5 (3)	- -	** 3.1 (0)	6.1 (4)
Outer-Meeting corner side	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- -	- (-)	- (-)
Inner-Corridor side	87.3 (0)	0.9 (0)	0 (0)	0.9 (0)	9.6 (0)	0 (0)	9.6 (0)	- -	2.2 (0)	0 (0)
Middle-Corridor side	79.2 (4)	7.5 (7)	0.7 (1)	8.5 (7)	2.8 (4)	** 0.2 (0)	2.9 (4)	- -	5 (1)	** 2.5 (1)
Outer-Corridor side	85 (5)	1.6 (2)	0 (0)	1.9 (2)	4.2 (3)	** 0.1 (0)	4.4 (4)	- -	3.5 (2)	* 4.9 (1)
Mean	78.9	2.1	1.4	3.8	3.3	0.9	4.2	-	4.5	7.4

Numbers in blanket: standard deviation. * $p < 0.05$ ** $p < 0.01$

Table 3-35 Temporary staffs' move and staying frequency related to individual workstation type [time/hour]

Individual workstation attribute	Stay inside workplace							Move		Out	
	Own-Seat Nearby	Same range			Other range			Inside Own-Seat Nearby	Inside workplace		
		Meeting corner side zone	Corridor side zone	Sum	Meeting corner side zone	Corridor side zone	Sum				
Window side	4.27 (1.67)	0.32 (0.59)	0.4 (0.46)	0.77 (0.75)	0.7 (0.59)	0.26 (0.23)	1 (0.65)	1.88 (1.4)	* 8.14 (1.5)	* 1.27 (0.59)	
Inner-Meeting corner side	5.24 (3.5)	0.38 (0.2)	1.44 (0.28)	* 1.81 (0.07)	0 (0)	0 (0)	0 (0)	3.46 (2.88)	7.44 (4.54)	0.58 (0.68)	
Middle-Meeting corner side	* 3.23 (0.63)	** 0.04 (0.07)	** 0.05 (0.06)	** 0.16 (0.12)	0.46 (0.2)	0.2 (0.16)	0.66 (0.23)	1.95 (0.62)	** 4.98 (0.61)	* 0.69 (0.15)	
Outer-Meeting corner side	- -	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Inner-Corridor side	3.48 (0)	0.39 (0)	0 (0)	0.39 (0)	1.16 (0)	0 (0)	1.16 (0)	2.71 (0)	4.25 (0)	0 (0)	
Middle-Corridor side	4.12 (0.96)	0.97 (0.81)	0.32 (0.17)	1.43 (1.01)	0.27 (0.31)	0.17 (0.17)	0.45 (0.42)	2.13 (0.76)	7.77 (1.45)	0.75 (0)	
Outer-Corridor side	3.17 (1.13)	** 0.08 (0.05)	0 (0)	* 0.16 (0.15)	0.73 (0.45)	0.15 (0.04)	0.88 (0.46)	1.58 (0.41)	5.32 (2.43)	0.7 (0.37)	
Mean	3.95	0.35	0.27	0.75	0.53	0.19	0.75	2.06	6.9	0.9	

Numbers in blanket: standard deviation. * $p < 0.05$ ** $p < 0.01$

3.6 Conclusion

In this chapter, the author clarified the characteristic of workers' space use, choosing individual workstation and the space use behavior related to the spatial attribute of the selected individual workstation in a non-territorial workplace at an architecture construction company. This examination of workers' behavior characteristics, which are held only in the non-territorial workplace, would provide information that may be of value in terms of workplace layout design. The specific findings in each section are showed as following.

The analysis on workers' space use behaviors in section 3.3 showed that all workers spent 84.3% of time on staying at the "Work territory", where the "Own-Seat Nearby" is used for staying the most. On leaving the "Own-Seat Nearby" for staying at other place in the work territory, in order of the staying frequency, the "Meeting corner side zone" is used more, next came the "Corridor side zone". In addition, on selecting the "Meeting corner side zone" and the "Corridor side zone" to use, the workers tended to select the nearest and the alternate ones for use (70% of frequency). Furthermore, the "Meeting corner side zone" was used most frequently for staying by workers, whose individual workstation located in the same specialty range. However, the staying frequency proportion at "Corridor side zone" is 10% higher by workers' whose individual workstation located in the different specialty range. The reason is that the "Meeting corner side zone" located at the inner of each specialty workstation area, which made the visitor reached not so conveniently compared with the "Corridor side zone".

The workers' space use appeared differently according to post or specialty; the detailed findings of this study are listed below:

- 1) Compared with staffs in other posts, Project leaders spent the least amount of time in the "Own-Seat Nearby". However, they spent an aggregate 14.4% of time on staying at the other area of the workplace and used the maximum number of different areas per hour for staying, which indicate they had extensive contact with more staffs. Regular staffs spent 72.4% of time on staying at the "Own-Seat Nearby"; in the "Same-specialty range", they tended to use the adjacent and alternate "Meeting corner side zone" or "Corridor side zone". Temporary staffs stayed at "Own-Seat Nearby" for 83% of time, the most steadily.

- 2) Compared with the staffs in other specialties, Architecture Design staffs spent 73% of their time at the "Own-Seat Nearby"—more than other workers. The "Meeting

range” (bigger meeting space located at the west side) was used only by them. In the “Same-specialty range”, they used more number of zones (0.67) per hour, which indicate their work needs more cooperators in the same specialty. Structure Design staffs spent much more time in the “Other-specialty range”. Equipment Design staffs spent 8.8% of time on staying at the “Same-specialty range”, 0.5% higher than other staffs, and used it most frequently.

On analyzing the workers’ behavior of choosing workstations in section 3.4, it showed that:

1) Although the workers were free to locate anywhere they wished, more than 70% of them always chose the same workstation or chose the same workstation on most occasions. In total, 90% of the workers located themselves in the same or adjacent areas. Only 10% of the workers chose workstations that were dispersed over the workplace.

2) Project leaders tended to select the individual workstation at the “Inner-Meeting corner side” most frequently. In order of choosing ration, they next chose the “Inner-Corridor side”, the “Middle-Meeting corner side”, and the “Outer-Meeting corner side”. In contrast, the “Window side” was seldom selected by them. Regular staffs tended to select the Individual workstation located at the “Outer Meeting corner side” most frequently, next came the “Outer-Corridor side”, the “Middle-Meeting corner side”. Temporary staffs tended to select an individual workstation located at the “Window side” most frequently, next came the “Outer-Corridor side” and the “Middle-Meeting corner side”.

Moreover, in section 3.5, the analysis on workers’ move and space use behavior related to the selected individual workstation attribute revealed that:

1) The “Middle-Meeting corner side” and the “Outer-Meeting corner side” enabled the worker that located there to use the meeting corner more conveniently and shorten the time spent visiting and staying at other places in the same area. The “Outer corridor side” and “Middle corridor side” enabled the worker who located there to move to other places more easily. The “Inner-Meeting corner side” enabled the worker located there to conveniently use the closest Meeting corner for communication and made moving to other places easier. Worker with workstations at the “Window side”, which is seldom visited and stayed at by other worker, enabled them to be less often disturbed.

2) With regarding post, workers’ tendency to select different types of workstations is a result of their different needs. That is, leaders tended to select a

workstation at the “Inner Meeting corner side” most frequently, as they had to visit more and stay in other areas. In contrast, when they select a workstation at the “Outer Meeting corner side” or the “Middle Meeting corner side”, they visited and staying at the other zones of the work territory less. Regular staffs selected individual workstations at the “Middle Meeting corner side” more frequently, and made their visiting and staying at the other zones less. Meanwhile, they tended to select an individual workstation at the “Middle Corridor side” or the “Outer Meeting corner side” more frequently. Since being next to the corridor and the inter-area location of “Middle Corridor side” made visiting other areas easier. Temporary staffs’ staying at other places and being visited by other staffs are much fewer. Therefore, they tended to locate their individual workstations most frequently at the “Window side”, which is seldom visited and stayed at by other worker, and they would be disturbed from their solo work less often.

In this chapter, by analyzing the workers’ space use and the choosing workstation, it is found that: With regarding the workers’ post, workers tended to select the workstation with certain spatial attribute, and their space use behavior would perform differently when located at different type of individual workstation. Since most workers selected the workstation located in the same or adjacent location, and visited to the adjacent and the alternated workstations zones for staying the most frequently. It indicated the non-territorial workplace is helpful to forming self-organization system and made the workers who cooperate with each other closely would select neighboring seats as their workstation.

Moreover, the finding of this study will be helpful to improve current workplace layout. For instance: 1) As the bigger meeting space is used seldom, it should be removed from the workplace. 2) Half of the meeting corners should be located at corridor side to make it be shared more easily by different specialty staffs. 3) By the clarification of workers choosing individual workstation and their space use behavior related to the workstation attribute, the layout distribution or the furniture design could be improved. For instance, the frequently selected workstation by Project leaders (such like the “Inner-Meeting corner side” type and the “Inner-Corridor side”) could be especially reserved for Project leaders with responding to the selectors’ number and the choosing rate according to post and specialty.

Note

*1 The “out” defined here refers to subject’s staying inside the building but outside the investigated worksite. When subject leave the workplace for other place, such like construction site, the sensor set distributed to him/her would be turned off, and turned on after his/her coming back.

*2 In the investigated non-territorial workplace, although workers in different specialties can select workstations freely, our research showed that most of the time (over 87.5%) they were occupied by staffs in same specialty. Therefore, although some time the Architecture Design staffs might choose the individual workstation located in the structure design range, the architecture design range that hold the most staffs with same specialty would also be defined as his/her “Same-specialty range”.

*3 The setting of distribution coordinate figure is not equals to setting of actual coordinate figure of UWB sensor network; it is assigned for revealing relative position relationship of spatial zones based on their distribution.

*4 As the subject’s move duration inside the “Own-Seat Nearby” zone is too short to show the significant difference, thus, only the frequency is calculated and compared.

Reference

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- 3) K. Tsunekawa, A study of activity on free-address office with various spaces, *Summaries of technical papers of AIJ.*, E-1, Architectural planning and design I, 1997, pp.219-22, 1997

Chapter 4 Comparison of Workers' Space Use Behavior in Territorial and Non-territorial Workplaces

- 4.1 Purpose
- 4.2 Outline of the investigations and investigated workplaces
 - 4.2.1 Devices
 - 4.2.2 The investigated worksites
- 4.3 Comparison of space using way between non-territorial and territorial workplaces by observation record
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 - 4.3.2 Comparison of the using-way of individual workstation between non-territorial and territorial workplace
 - 4.3.3 Comparison of communication between non-territorial and territorial workplace
- 4.4 Comparison of workers' move and space use in territorial and non-territorial workplace by using a UWB sensor network
 - 4.4.1 Classification of location zone
 - 4.4.2 Comparison of T and N-T workers' space use and move
 - 4.4.3 Comparison of space use and move according to workers' attribute
 - 4.4.4 Estimation and comparison of occupancy rates in different workplaces
- 4.5 Conclusion

Note

Reference

In chapter 3, the characteristics of the workers' space use and space use correlated to the spatial attribute of individual workstation selected in non-territorial workplace were clarified. But a question was raised as to how workers use the territorial and non-territorial workplace differently, or in other words, whether the non-territorial workplace could perform better than territorial workplace for workers' space use.

4.1 Purpose

As mentioned in section 3.1.1, compared with territorial workplace, the main renovation motivations of non-territorial workplace are to respond to workers' low attendance in workplace and enhance the communication between workers. Therefore, its renovation purpose is to make the space used more effectively and to offer greater potential for information sharing ¹⁾. However, there are few studies focused on comparison of workers' precise space use behavior in territorial and non-territorial workplace. The existed studies correlated to space use behavior are mostly operated by questionnaire or interval observation record, which made the findings contributed by workers' general space use frequency seemed to not be so accurate.

In this chapter, the author aimed to identify whether the investigated non-territorial workplace is occupied more frequently and more flexibly than territorial workplace. Therefore, the author compared the characteristics of workers' space use in territorial and non-territorial workplace by workers' precise temporal location data with using a UWB sensor network. Meanwhile, as the number of sensor sets could not cover all workers existed in the investigated workplaces, either it could not record the exact space using way of workers. Therefore, the observation record is also used for comparing how the workstations and meeting corners are occupied by workers for different using ways, such like work with PC, work with document or communication.

The detailed purposes of each section are showed as follows:

In section 4.3, by interval observation record once per 30min, the author aimed to

- 1) To clarify the difference of occupancy frequency at workstation in non-territorial and territorial workplace, with regarding the using ways, such as Working with PC or other using ways like working with document etc.
- 2) To clarify the difference of frequency of communication occurred in meeting corner in non-territorial and territorial workplace

In section 4.4, the author aimed

- 1) To clarify the workers' space use in each territory, range, and zone at non-territorial and territorial workplace.
- 2) To clarify the workers' staying and move characteristics in each workplace with regarding post and specialty.
- 3) To estimate and clarify the occupancy rates at the workstations and meeting corners in non-territorial and territorial workplace.

4.2 Outline of the investigations and investigated worksites

4.2.1 Devices

The investigation by using the UWB sensor network was conducted with two sensors, the UWB sensor tag for location positioning and an acceleration sensor for data correction.

Two typical architecture design workplaces in one architecture construction company were selected for investigation. The investigation in the non-territorial workplace lasted from 9:00 to 20:00, and was conducted over 9 successive weekdays in two weeks, from the 17th to the 28th of November 2008. In the territorial workplace, the investigation lasted for 10 successive weekdays from 1st to 12th December 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 and evenly according to the distribution of specialty ranges and workers' post. When a worker was assigned a sensor set, his/her name, the time of assignment, post, specialty, and his/her individual workstation was recorded by the investigator. If the subject left work before the investigation was over, the sensor assigned to him/her were reassigned to another worker.

While conducting the investigation with sensor sets, the investigation with observation record was also conducted in successive 5 weekdays, from 9th to 15th Dec. 2008. The using way of every workstation and communication frequency was recorded once per 30 minutes from 9:00 to 19:30 in both workplaces. The investigator walked around the investigation area and recorded the using way of workstation and the communication occurred at the meeting corners.

4.2.2 The investigated worksites

As mentioned above, two workplaces for architecture and engineering design specialties in an architecture construction company were chosen as the workplace for

investigation. They were located on the north and south sides, respectively, of the 28th floor of a 54-floor high-rise building (Fig. 4-1). The two workplaces had the same territorial layout until one of them was transformed to non-territorial layout in 2007. Each workplace was used by one department, and their daily work and composition were almost the same. Both workplaces were used by architects and structural and equipment engineers.

The territorial workplace with 60 registered workers (Table 4-1) was a traditional workplace with fixed individual workstations that were surrounded by partitions and document storage shelves. In the work territory, 5 large meeting corners were located in the centre of the general-type workstation group (Fig. 4-2 ①), and 4 small meeting corners were located beside each Project leader's window-side workstation (Fig. 4-2 ②). 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 (Fig. 4-2 ④).

Table 4-1 Workers' Number in investigated territorial and non-territorial workplace [person]

Workplace attribute	Specialty attribute	Designing work	Post attribute			Sum
			Project leader	Regular staff	Temporal staff	
Territorial workplace	Architect	Architecture design	8	22	10	40
	Engineer*1	Structure design	0	2	0	2
		Equipment design	2	13	1	16
		Technology design	0	2	0	2
		Sum	2	17	1	20
	Sum		10	39	11	60
Non-territorial workplace	Architect	Architecture design	13	35	17	65
	Engineer	Structure design	2	12	1	15
		Equipment design	2	13	5	20
		Sum	4	25	6	35
	Sum		17	60	23	100

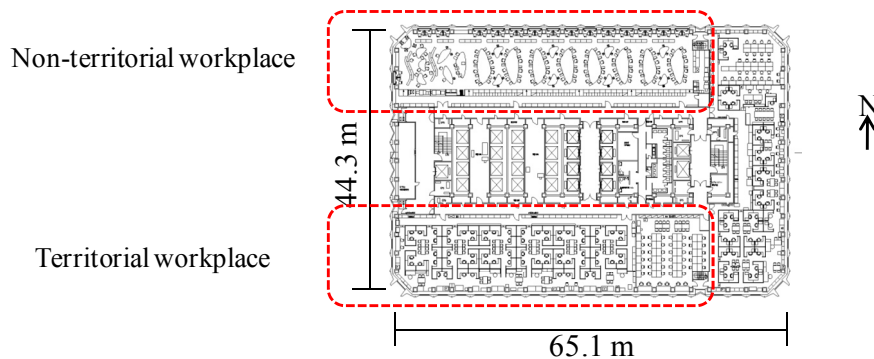


Figure 4-1 The location of investigated territorial and non-territorial workplaces

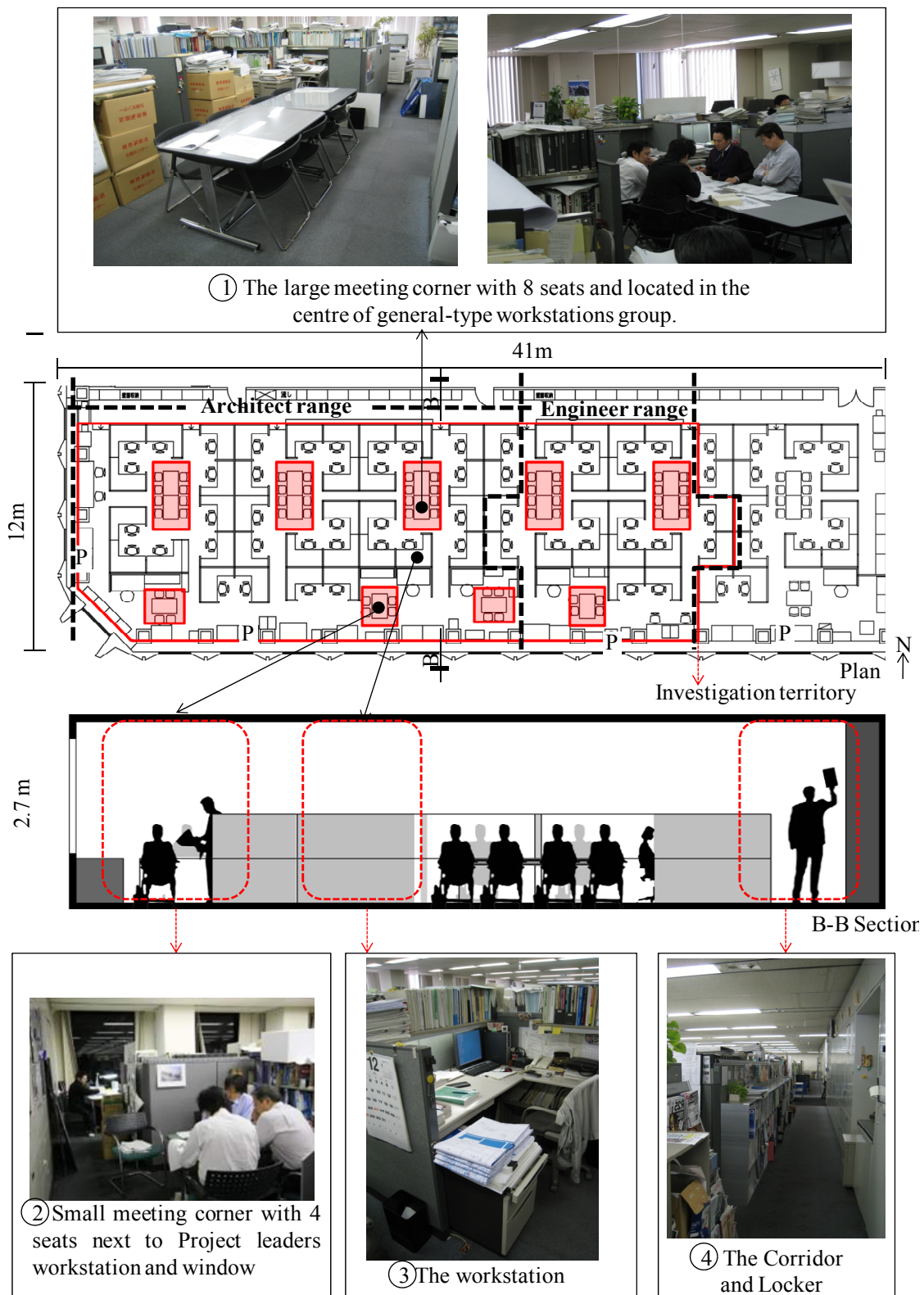
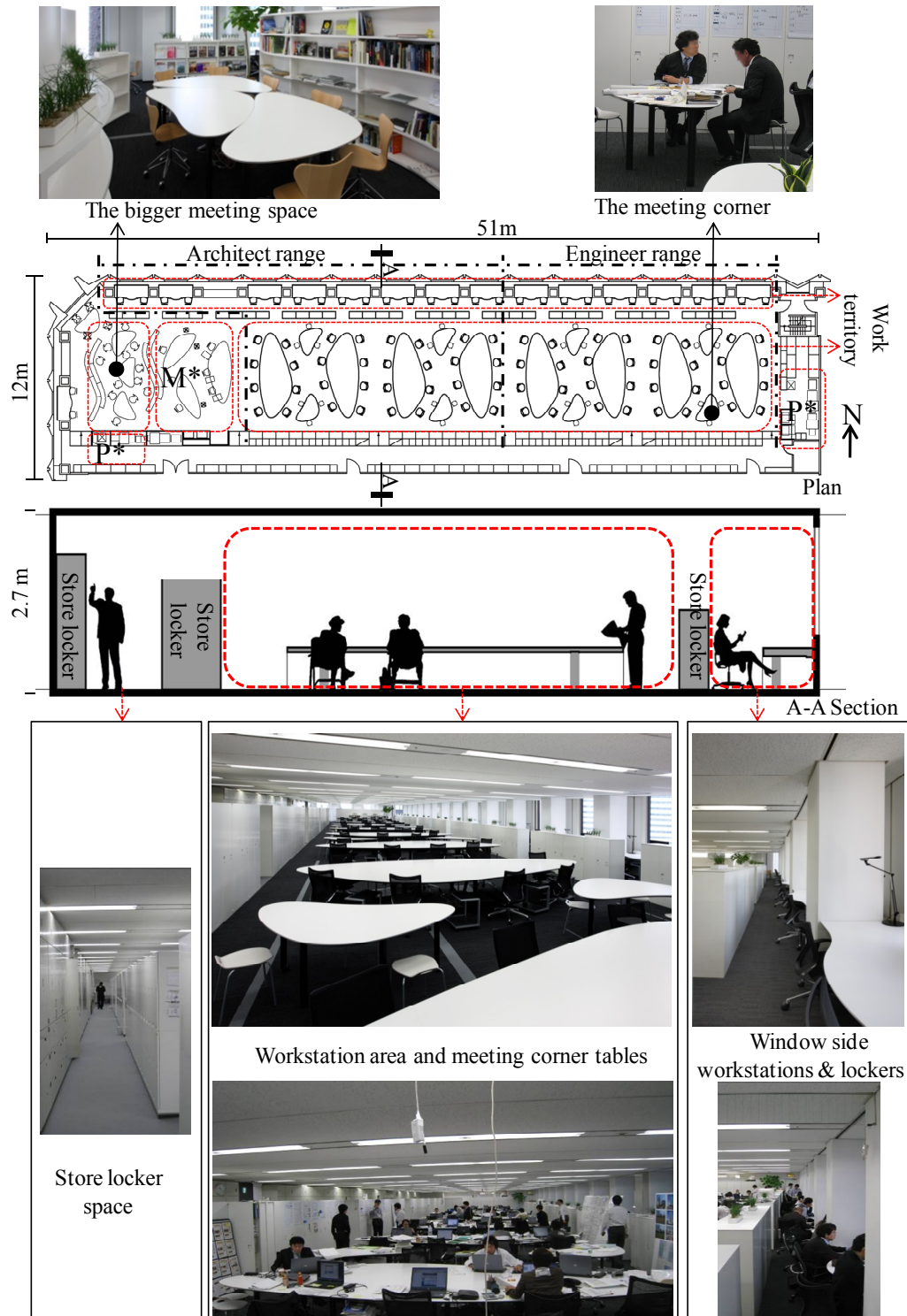


Figure 4-2 The investigated territorial workplace

A non-territorial workplace with 100 registered workers (Table 4-1) in an architecture construction company was chosen as the investigation subject (Fig. 4-1); it is also located on the north side of the 28th floor of a 54-floor high-rise building.

It is composed of surrounding service (including a meeting space which has twelve seats, copy corners, store lockers for personal belongings and shared documents), and a main work territory (Fig.4-3). Specifically, in the work territory, there are four workstation table areas with corridor between each other. Each workstation table area is composed of two big tables (each includes 8 seats) and two meeting corners (each includes 3 seats and specially used for communication). A row of document lockers separates the window seat area from the islands area, which is assigned to 2 specialty ranges in this chapter: Architect range, Engineer range. Although the workers are free to select any seat as a workstation, most of them still chose the seat in the range relevant to their specialty attribute such as the Fig.4-3 showed. The workday starts with taking out one's laptop from one's personal locker and choosing a seat for work; it ends with tidying up, leaving the seat unoccupied.



In the figure of plan, Area M*: Administration space, Areas P*: Copy corner;

Figure 4-3 The investigated non-territorial workplace

4.3 Comparison of space using way between non-territorial and territorial workplaces by observation record

4.3.1 Classification of space using way

The investigation on the workers' space using way is conducted by the interval observation record. The investigator walked around the investigation area and recorded the workers' using way of workstation and meeting corner (Fig. 4-4).

The using way of workstation in 4 types as below:

- A: Non-use: workstation is vacant, without PC on or occupied by other things.
- B: Working with PC: workstation is occupied by worker on working with PC.
- C: Only PC: worker goes out for a while, leaving the computer turned on.
- D: Others: workstations may be occupied by work only with document, model, or workers seated temporarily to have a short discussion with others or read document on the table*¹.

The communication was recorded in two types as follows:

- I: Communication in Meeting Corner. In this type, the location, number and attribute of attendee (architect, engineer, or both architect and engineer) were recorded.
- II: Communication in workstation. In this type, only location was recorded.

The workers of 4 specialties are classified into 2 types, Architecture Design as

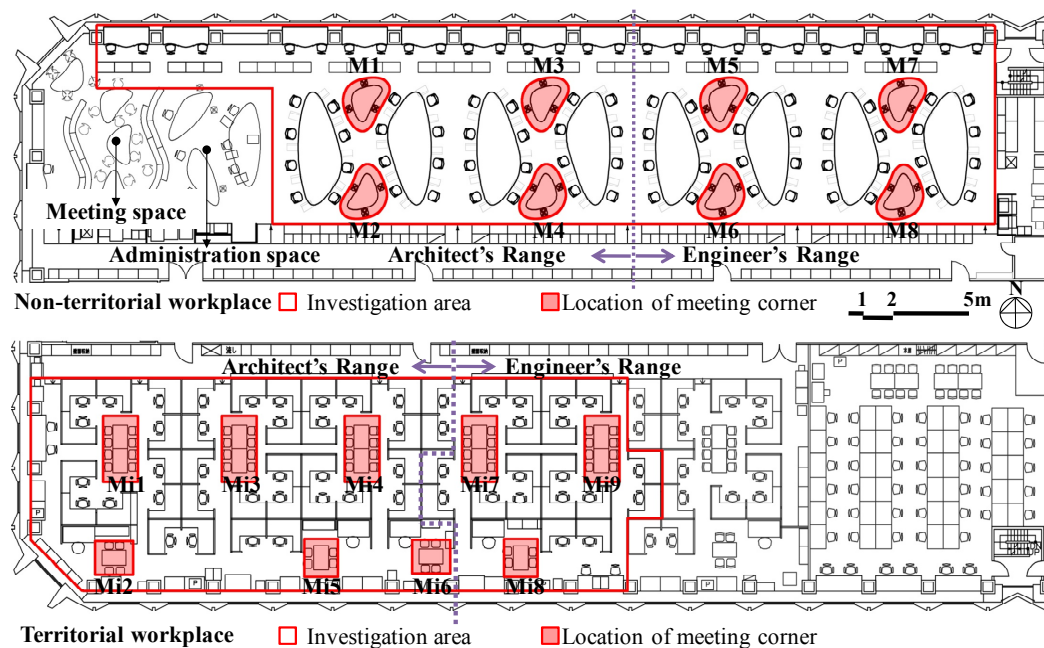


Figure 4-4 The investigated workplaces' layouts

Architects; Structure, Equipment, and Technology Design as Engineers in the two workplaces*². According to the actual distribution of workers, the investigated area in each workplace is divided into Architect's Range and Engineer's Range*³. (Fig. 4-3)

The investigation time is divided into 4 sections:

- ① Morning: 9:00-12:00
- ② Noon Rest: 12:00-13:00
- ③ Afternoon: 13:00-17:30
- ④ Overtime: 17:30-20:00

Following, databases combining the investigated data and type attribute for each workplace was built (Table 4-2) and analyzed in the following.

Table 4-2 Sample of database in Non-territorial workspace (a part)

Date	Period	Using way of workstation					Worker's number in meeting corner				Communication frequency in meeting corner area		Communication frequency in workstations	
		Seat 1	Seat 2	Seat 3	Seat 4	... Seat 92	M1	M2	...	M8	Architect's Area	Engineer's Area	Architect's Area	Engineer's Area
12/9/2008 9:00	①	A	D	B	D	... C	0	0	...	0	0	1	2	2
12/9/2008 9:30	①	A	D	B	A	... B	0	0	...	0	0	1	0	0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12/9/2008 12:00	②	...	...	...	...	...	...	...	...	...	...	...	...	...
12/9/2008 13:00	③	B	B	B	B	... C	3	0	...	2	1	1	2	2
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12/15/2008 19:30	④	A	A	A	A	... A	0	0	...	0	0	0	0	3

Using ways of workstations: A- Non-use; B- Working with PC; C-Only PC; D- Others
Period:① - Morning; ② - Noon Rest; ③ - Afternoon; ④ - Overtime.

4.3.2 Comparison of the using-way of individual workstation between non-territorial and territorial workplace

1) Comparison of use rate in the whole investigation period

With the total frequencies of certain using way in the same section, the rate of each using way was calculated (Table 4-3).

Either worker worked with PC in the workstation or went out of workplace leaving his computer on, the workstation was occupied. The occupancy rate was calculated by adding up use rate of Working with PC and use rate of Only PC.

Table 4-3 Use rate in non-territorial workplace and territorial workplace [%]

Date	Non-use		Total occupancy rate						Others	
			Working with PC		Only PC left in workstation		Sum			
	NT	T	NT	T	NT	T	NT	T	NT	T
12/9/2008	18.4	35.3	38.1	43.8	38.1	20.9	76.2	64.7	5.4	-
12/10/2008	24.9	36.4	42.2	36.2	29.3	27.4	71.6	63.6	3.6	-
12/11/2008	21.5	36.5	40.5	36.1	34.5	27.4	75	63.5	3.5	-
12/12/2008	30.9	37.2	36.5	35.9	28.9	26.9	65.3	62.8	3.8	-
12/15/2008	18.6	24.7	41.5	41.7	36.5	33.6	78	75.3	3.4	-
Mean	22.8	34	39.8	38.7	33.5	27.3	73.2	66	3.9	-

NT: Non-territorial workplace T: Territorial workplace

According to Table 4-3 and Fig. 4-5, in either workplace, the means of use rate of Working with PC was the highest of all, and in the non-territorial workplace, next came the rate of Only PC (33.5%), Non-use (22.8%) and Others(3.9%). Whereas in the territorial workplace, the rate of Non-use (34.0%) was higher than Only PC (27.3%). Comparing the two workplaces, the rate of Working with PC in Workstation in non-territorial workplace's (39.8%) was a little higher than territorial workplace's (38.7%). However, the rate of Only PC in the non-territorial workplace was 6.2% higher than territorial workplace, thereby resulting in the 7.2% higher occupancy rate in the non-territorial workplace. Moreover, workstation of non-territorial workplace was used in other ways for 3.9%, thus, rate of Non-use in non-territorial workplace was more than 10% lower than the territorial workplace.

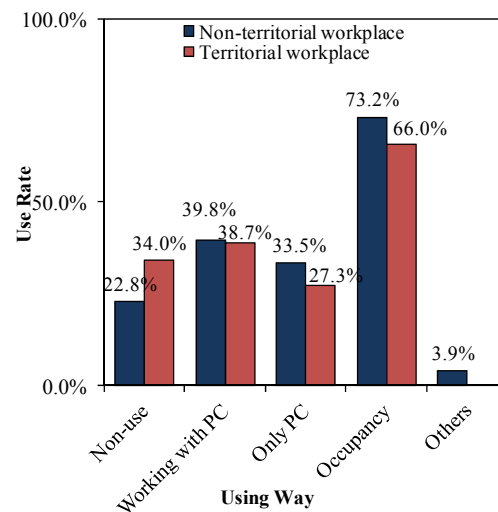


Figure 4-5 Comprising the means of use rate

According to Fig. 4-6 and Fig. 4-7, in the non-territorial workplace the Occupancy rates at Architect's range and Engineer's range from 10:00 to 18:00 were 10% to 20% higher and steadier than territorial workplace. In the territorial workplace, the occupancy rates at Architect's Range decreased persistently and obviously from 80% to 70% after 13:00, while in the non-territorial workplace it only decreased from 85% to 82%.

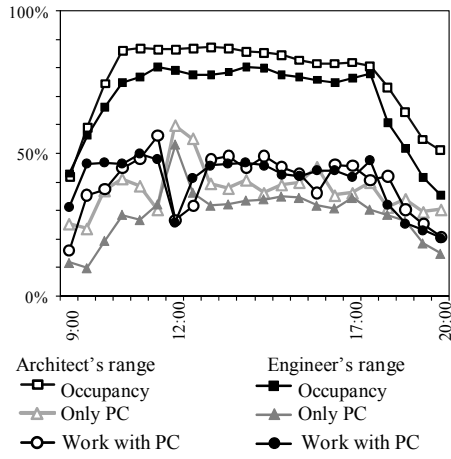


Figure 4-6 Workstations' use rate of Architect's Area and Engineer's Area in the non-territorial workplace on the basis of time

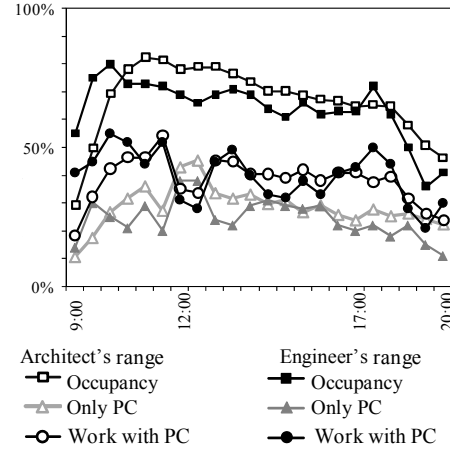


Figure 4-7 Workstations' use rate of Architect's Area and Engineer's Area in the territorial workplace on the basis of time

The analysis above showed that, compared with territorial workplace the workstation of non-territorial workplace was not only occupied more by worker's working with PC there but also was occupied and used in other ways.

2) Comparison on use rate by time section and area

In order to show the discrepancy of use rate in non-territorial workplace compared to territorial workplace in Architect's Range and Engineer's Range respectively, the discrepancy rate was calculate by Formula (4.1) as below:

$$\Delta U_{NP} = \frac{U_{NPn} - U_{NPt}}{U_{NPt}} \times 100[\%] \dots (4.1)$$

($N = \{\text{workers using way of workstations, A,B,C,D}\}$, $P = \{\text{Architect's range, Engineer's range}\}$)

ΔU_{NP} : Discrepancy rate of certain use rate in Architect's Range or Engineer's Range of non-territorial workplace compared with that of territorial workplace

U_{NPn} : Use rate of certain using way in certain area of non-territorial workplace

U_{NPt} : Use rate of certain using way in certain area of territorial workplace

According to Table 4-4, the rate of Working with PC in the non-territorial workplace was a little bit lower (within 2%) than territorial workplace except for in the Afternoon, when the rate was higher (4.2%) in contrast. By Table 4-4 and Table 4-5, compared with territorial workplace, the lower rate of Working with PC in non-territorial workplace in the Morning resulted from the simultaneous negative discrepancy rate in both Architect's Range and Engineer's Range. The same way, the higher rate in the Afternoon also resulted from the simultaneous positive discrepancy rate in both ranges. It shows that comparing with territorial workplace; workers in the non-territorial workplace were inclined to occupy the workstation more in the Afternoon rather than Morning.

Also by Table 4-4, the rate of Only PC and Occupancy in non-territorial workplace was higher than territorial workplace in each time section. Meanwhile, it was significantly higher in the average rate of Only PC (6.2% higher) and in the Occupancy rate in the Afternoon (12.1% higher).

Presented by Table 4-5, in non-territorial workplace, the discrepancy rates of both Only PC and Occupancy in the Architect's Range and Engineer's Range were reversed changed in the Morning. However compared to territorial workplace, except in Morning, the discrepancy rates of Only PC and Occupancy were positive in both ranges. It showed the workstations of non-territorial workplace were occupied more by Only PC and Working with PC after the Noon Rest, especially in the Afternoon.

Table 4-4 Comparison of use rate in each time section and T-test result [%]

Using way	Morning			Noon rest			Afternoon			Overtime			Average		
	NT	T	p	NT	T	p	NT	T	p	NT	T	p	NT	T	p
Working with PC	42.2	42.7	-	31.3	32.8	-	44.9	40.7	-	30.9	32.7	-	39.8	38.7	-
Only PC	27.4	24.4	-	51.5	42.1	-	36.2	28.3	-	28.7	22.8	-	33.5	27.3	*
Occupancy	69.6	67.1	-	82.8	74.9	-	81.1	69	-	59.6	55.5	-	73.2	66	*

NT: Non-territorial workplace T: Territorial workplace *p<0.05

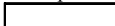
 Non-territorial<Territorial  Non-territorial>Territorial

Table 4-5 Discrepancy rate of use rate in each time section in Architect's Area and engineer's area

	Morning		Noon rest		Afternoon		Overtime		Average	
	ΔArchi.	ΔEng.	ΔArchi.	ΔEng.	ΔArchi.	ΔEng.	ΔArchi.	ΔEng.	ΔArchi.	ΔEng.
Working with PC	-0.5	-6.9	-15.2	14	9.6	13	0.4	-13.8	2.9	1.2
Only PC	30.9	-7.1	30.7	17.8	32.2	27.6	30.9	35.3	31.4	18.5
Occupancy	11.6	-7	10.6	16.2	19	18.8	13.9	2.8	15.1	7.8

Δ: Discrepancy rate of Non-territorial workplace compared to Territorial workplace

 Homodromous change*

ΔArchi.: Discrepancy rate in the Architect's range ΔEng.: Discrepancy rate in the Engineer's range

 Reversed change*

* Homodromous change means the discrepancy rate of Archi and Eng were both negative or both positive.

Reversed change means the discrepancy rate of one was negative while another was positive.

4.3.3 Comparison of communication between non-territorial and territorial workplace

1) Using frequency in each meeting corner

In either workplace, there were meeting corners that were used more and ones that were used less. In non-territorial workplace, the meeting corner of M1 and M2 that were at one side of Architect's Range were used less than other meeting corners (M3~8). It might be because workers could easily use the Meeting space^{*4} closed to M1 and M2. (Table 4-6, Fig. 4-8)

In the territorial workplace, 4 small meeting corners (Mi2, Mi5, Mi6 and Mi8) were located beside group leaders' workstation. It might be convenient for leaders, but actually, the using frequency of these meeting corners was much lower than other meeting corners (Table 4-6, Fig. 4-9).

Though the layout of meeting corners in non-territorial workplace were distributed more evenly, it did not have the using difference caused by diversified location, such like near group leaders' workstation, as in territorial workplace.

Table 4-6 Using frequency of meeting corners in territorial workplace

Meeting corner of Territorial workplace									
[times/ day]	Mi1	Mi2	Mi3	Mi4	Mi5	Mi6	Mi7	Mi8	Mi9
	10.6	2.4	9.4	11.6	2.8	3.4	7.8	4.6	11.4
Meeting corner of Non-territorial workplace									
[times/ day]	M1	M2	M3	M4	M5	M6	M7	M8	-
	3.6	4.4	9.4	6.8	7.8	7.2	6.2	8	-

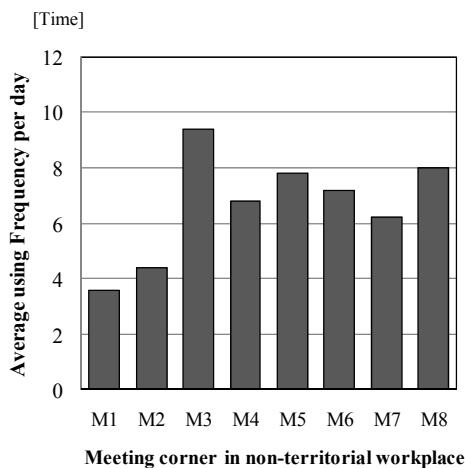


Figure 4-9 Average using frequency of meeting corners in non-territorial workplace

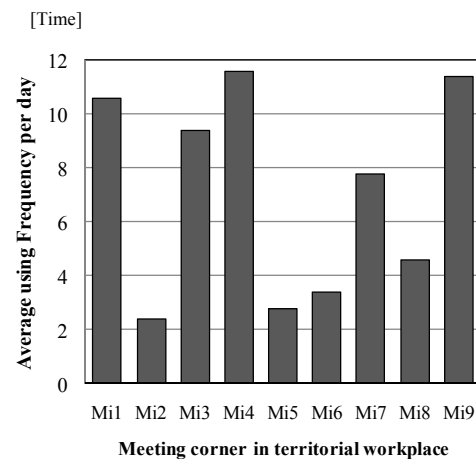


Figure 4-8 Average using frequency of meeting corners in territorial workplace

2) Attendee's attribute in meeting

The communication in meeting corners can be divided into 3 types according to the attribute of users:

- I. Communication between architects;
- II. Communication between architect and engineer;
- III. Communication between engineers.

In the territorial workplace, though the meeting corner in Engineer's Range (Mi7, in Engineer's Range but close to Architect's Range) was sometimes used for only architect's meeting, architects and engineers were inclined to have their own meeting in each own range in most times. The meetings including both architects and engineers were held in all the meeting corners except for Mi6 and Mi8. In the non-territorial workplace, the percentage of architect's meeting decreased from M1 to M6, but still covered more than 50% in M5 and 30% in M6, which are in Engineer's Range and close to Architect's Range. Moreover, there were also engineers having their own meeting in M4, which is in Architect's Range, but close to Engineer's Range. The meetings including both architects and engineers concentrated more in Engineer's Range. (Table 4-7 & 8, Fig. 4-10)

Table 4-7 Meeting attendee's attribute and frequency in each meeting corner of territorial workplace

Type	Communication frequency at the Meeting corner in Territorial workplace [times]								
	Architect's Range						Engineer's Range		
	Mi1	Mi2	Mi3	Mi4	Mi5	Mi6	Mi7	Mi8	Mi9
Architect	43 (82.7)	11 (91.7)	40 (85.1)	52 (94.5)	13 (92.9)	17 (100)	6 (18.8)	0 (0)	0 (0)
Architect & Engineer	9 (17.3)	1 (8.3)	7 (14.9)	3 (5.5)	1 (7.1)	0 (0)	3 (9.4)	0 (0)	9 (16.4)
Engineer	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	23 (71.9)	21 (100)	46 (83.6)
Sum	52 (100)	12 (100)	47 (100)	55 (100)	14 (100)	17 (100)	32 (100)	21 (100)	55 (100)

Number in bracket: proportion of using frequency [%]

Table 4-8 Meeting attendee's attribute and frequency in each meeting corner of non-territorial workplace

Type	Communication frequency at the Meeting corner in Non-territorial workplace [times]							
	Architect's Range				Engineer's Range			
	M1	M2	M3	M4	M5	M6	M7	M8
Architect	9 (100)	19 (100)	27 (93.1)	25 (96.2)	18 (54.5)	9 (32.1)	0 (0)	0 (0)
Architect & Engineer	0 (0)	0 (0)	2 (6.9)	0 (0)	4 (12.1)	0 (0)	4 (18.2)	4 (11.1)
Engineer	0 (0)	0 (0)	0 (0)	1 (3.8)	11 (33.3)	19 (67.9)	18 (81.8)	32 (88.9)
Sum	9 (100)	19 (100)	29 (100)	26 (100)	33 (100)	28 (100)	22 (100)	36 (100)

Number in bracket: proportion of using frequency [%]

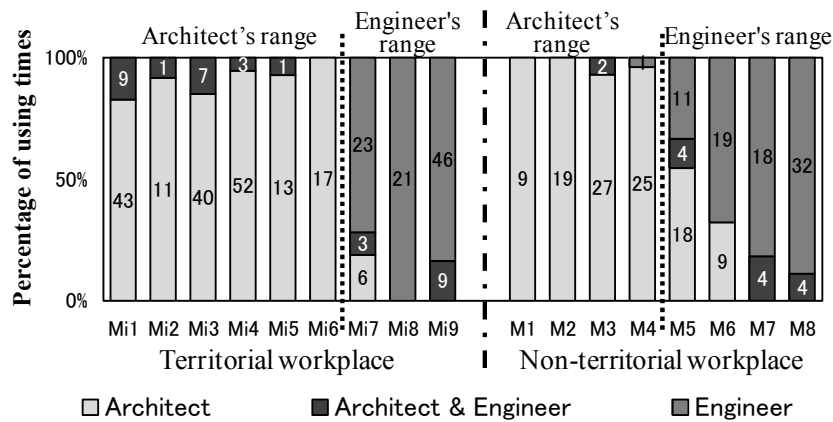


Figure 4-10 Meeting attendee's attribute and meeting frequency in each meeting corner

According to Table 4-9 and Fig. 4-11, comparing with territorial workplace, in non-territorial workplace, there was higher proportion that architects used meeting corners in Engineer's Range for their own meetings. Engineers also had their own meetings in Architect's Range although as low as 1%. It shows meeting corners in non-territorial workplace were shared more by both kinds of workers. Moreover, meetings including both architects and engineers were held more in Architect's Range in the territorial workplace. Whereas in non-territorial workplace, they were held more in Engineer's Range. The author may just speculate it resulted from architects moved more in non-territorial workplace.

Table 4-9 Comparison on distribution of different attendee's meeting in two workplaces

Attendee's attribute	Non-territorial workplace			Territorial workplace		
	Architect range	Engineer range	Sum	Architect range	Engineer range	Sum
Architect	80 (75)	27 (25)	107 (100)	176 (97)	6 (3)	182 (100)
Architect & Engineer	2 (14)	12 (86)	14 (100)	21 (64)	12 (36)	33 (100)
Engineer	1 (1)	80 (99)	81 (100)	0 (0)	90 (100)	90 (100)

Number in bracket: proportion of using frequency [%]

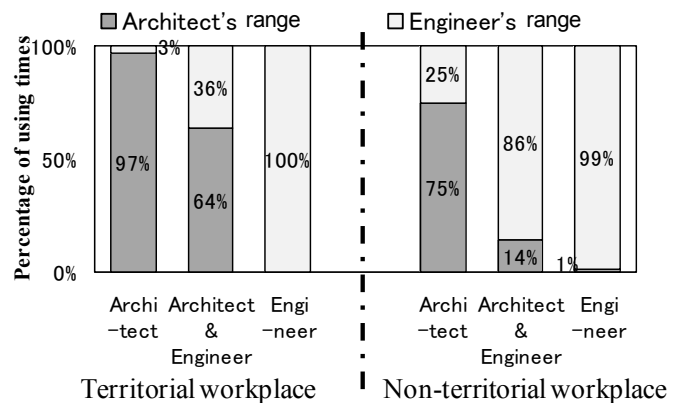


Figure 4-11 Comparison on distribution of different attendee's meeting in two workplaces

3) Attendee's number per meeting

According to Table 4-10 and 4-11, attendee's number per meeting in non-territorial workplace was significantly smaller (0.59) than territorial workplace in the Morning. The fewer attendees' number of non-territorial workplace appeared in both Architect's Range and Engineer's Range. Whereas in the Afternoon and Overtime, attendee's number per meeting in non-territorial workplace was larger than the territorial workplace and the larger attendee's number both appeared in Architect's Range and Engineer's Range. It showed that, comparing with the territorial workplace, workers in the non-territorial workplace were inclined to hold smaller meeting in the Morning and larger meeting from the Afternoon.

Table 4-10 Comparison of Attendee's number per meeting in each time section and T-test result

Attendee's number per meeting	Morning			Noon rest			Afternoon			Overtime			Average		
	NT	T	p	NT	T	p	NT	T	p	NT	T	p	NT	T	p
	2.23	2.82	**	3.43	3.33	-	2.69	2.58	-	3.06	2.46	-	2.66	2.71	-

NT: Non-territorial workplace T: Territorial workplace *p<0.05

☐ Non-territorial<Territorial ☐ Non-territorial>Territorial

Table 4-11 Discrepancy rate of Attendee's number per meeting in each time section in Architect's Area and engineer's area

Morning		Noon rest		Afternoon		Overtime		Average	
ΔArchi.	ΔEng.	ΔArchi.	ΔEng.	ΔArchi.	ΔEng.	ΔArchi.	ΔEng.	ΔArchi.	ΔEng.
-17.9%	-14.0%	-5.6%	75.0%	3.4%	8.7%	7.1%	17.9%	-2.4%	5.1%

Δ: Discrepancy rate of Non-territorial workplace compared to Territorial workplace

ΔArchi.: Discrepancy rate in the Architect's area ΔEng.:Discrepancy rate in the Engineer's area

☐ Homodromous change* ☐ Reversed change*

* Homodromous change means the discrepancy rate of Archi and Eng were both negative or both positive.

Reversed change means the discrepancy rate of one was negative while another was positive.

The analysis above showed that comparing with territorial workplace, the meeting corner of non-territorial workplace was used more evenly (except for M1 and M2) by workers. Although the attendees' number per meeting of meeting corner in non-territorial was a little bit lower only in Morning, both average numbers in two workplaces were within 3 and over 2. Meanwhile, the seats' number of meeting corner in territorial workplace were 4 seats or 6 seats much more than 3seats of non-territorial workplace's meeting corner. Therefore, it showed that more number of meeting corner's seats in territorial workplace was vacant while the space of meeting corner in non-territorial workplace was used more effectively. Also, the meeting corners of non-territorial workplace were used more flexibly as they were shared more by both architects and engineers.

4.4 Comparison of workers' move and space use in territorial and non-territorial workplace by using a UWB sensor network

In the last section, the author clarified the different space using way in territorial and non-territorial workplace by analyzing the occupancy frequency with the data collected by interval observation record. In this section, in order to ascertain the characteristics of the two workplaces, the author aim to clarify the differences between workers' precise move and space use in each workplace based on their location as revealed by using the UWB sensor network.

The investigation conducted with UWB sensor sets was lasted for 2 weeks in both territorial and non-territorial workplace. 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 245 times in the territorial workplace (Table 4-12).

Table 4-12 Workers' Number in each workplace [person]
[Investigated workers' number [person]]
(Investigated times of workers [person•day])

Workplace attribute	Specialty attribute	Post attribute									Sum		
		Project leader			Regular staff			Temporary staff					
Territorial workplace	Architect	8	[6]	(33)	22	[21]	(93)	10	[7]	(41)	40	[34]	(167)
	Engineer	2	[2]	(10)	17	[17]	(48)	1	[0]	(0)	20	[19]	(58)
	Sum	10	[8]	(45)	39	[38]	(158)	11	[7]	(42)	60	[53]	(245)
Non-territorial workplace	Architect	13	[10]	(34)	35	[31]	(114)	17	[8]	(21)	65	[49]	(169)
	Engineer	4	[3]	(9)	25	[24]	(78)	6	[4]	(4)	35	[31]	(91)
	Sum	17	[13]	(43)	60	[55]	(192)	23	[12]	(25)	100	[80]	(260)

4.4.1 Classification of location zone

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 35 zones in the non-territorial workplace and 36 zones in the territorial workplace (Fig. 4-11, Table 4-13).

When a subject was in the workplace, his/her move and staying was recorded by the acceleration sensor. Based on the actual coordinates of the location for the corresponding period could recorded by the UWB sensor, the coordinates was 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. In the work territory, the zone that includes the subject's own workstation was defined as the "Own-Seat Nearby". Other zones were defined as the "Same-specialty range" or "Other-specialty range" according to whether or not their range attributes was the same as the subject's specialty.

For example, if circle X in C6 in Fig. 4-12 is where a subject's individual selected workstation is located, when the subject stays in C6, his/her staying location is defined as the "Own-Seat Nearby". If a subject stays at M1 - M4, the staying location is defined as the "Meeting corner side zone" in the same specialty. If a subject stays at C1, his/her staying location is defined as the "general-type workstation" in the same specialty range. If a subject stays at W1-W9, the staying location is defined as the "window-side zone" in the same specialty range.

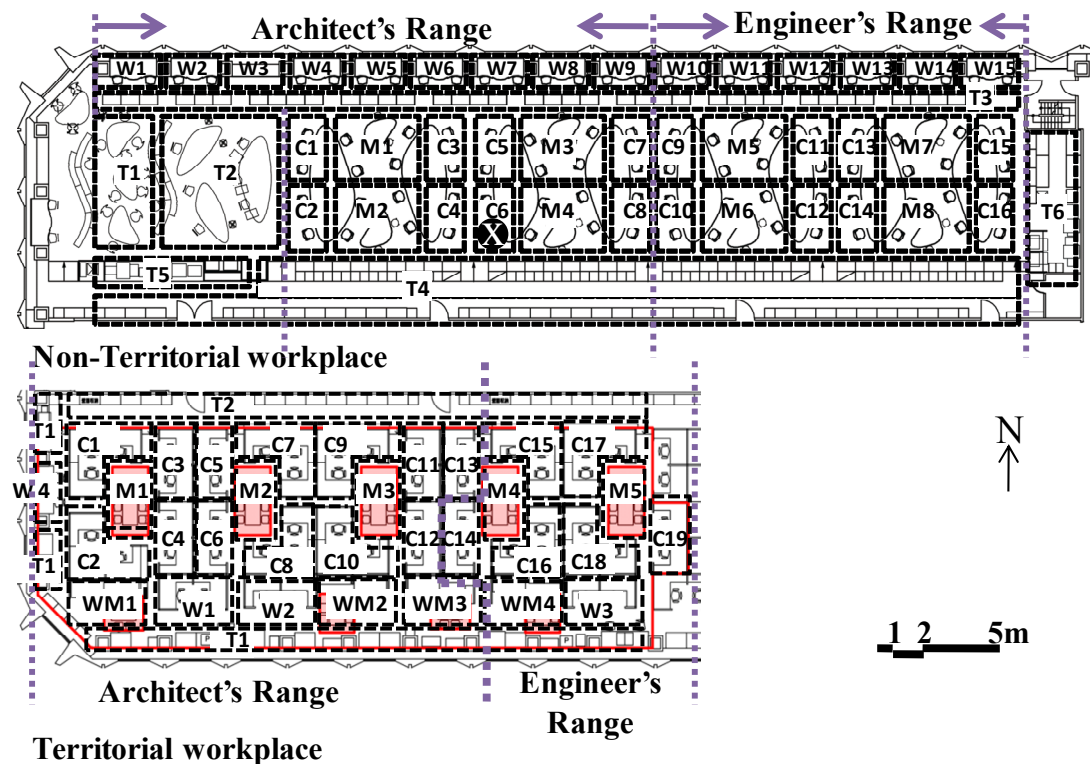


Figure 4-12 Division of location zones

Table 4-13 Classification of zones in the Fig. 4-12

Workspace Attribute	Items	Work territory						Service Territory			
	Range Attribute	Architect range			Engineer range			Meeting Space	Administration Space	Main corridor	Support Space
	Zone Attribute	*Meeting corner side	General type	Window side	Meeting corner side	General type	Window side				
Territorial	Zone ID	M1-M3 WM1-WM3	C1-C13	W1, W2, W4	M4-M5 WM4	C14-C19	W3	-	-	T2	T1
Non-Territorial	Zone ID	M1-M4	C1-C8	W1-W9	M5-M8	C9-C16	W10-W15	T1	T2	-	T3-T6

* Only the zones marked by M1~5 in territorial workplace refer to the pure meeting corner table. The other zones named by "Meeting corner side" refer to the meeting corner and the workstation around it. In territorial Workspace, the meeting corner is classified into two types: the general type and the window side type.

Based on their post, workers could be classified into 3 main categories—“PL” (Project leader), “RS” (Regular staff), and “TS” (Temporary staff)—or another 2 categories—“architect” and “engineer”—depending upon their specialties. Databases that combine the investigated data, zone attributes, and worker attribute were then constructed (Table 4-14).

Table 4-14 Database Sample- Non-Territorial workplaces

Data ID	Date	Subject attributes				Time attributes			Staying or Move	Used space attributes			
		Subject ID	Post	Specialty	Own-Seat Nearby ID	Start time	End time	Lastest duration [second]		Used zone ID	Territory attribute	Specialty range attribute	Zone attribute
1	11/17/2008	1	RS	Engineer	C16	13:41:00	13:51:15	615	Staying	W15	Working	Same-specialty	Window side
2	11/17/2008	1	RS	Engineer	C16	13:51:15	13:52:12	57	Move	-	-	-	-
3	11/17/2008	1	RS	Engineer	C16	13:52:12	13:53:19	67	Staying	M2	Working	Other-specialty	Meeting corner
4	11/17/2008	1	RS	Engineer	C16	13:53:19	13:54:04	39	Move	-	-	-	-
5	11/17/2008	1	RS	Engineer	C16	13:54:04	13:54:46	42	Staying	-	Out	-	-
6	11/17/2008	1	RS	Engineer	C16	13:54:46	13:55:30	38	Move	-	-	-	-
7	11/17/2008	1	RS	Engineer	C16	13:55:30	13:56:13	43	Staying	Z16	Working	Same-specialty	Own-Seat
8	11/17/2008	1	RS	Engineer	C16	13:56:13	13:57:05	45	Move	-	-	-	-
9	11/17/2008	1	RS	Engineer	C16	13:57:05	13:57:40	36	Staying	-	Out	-	-
10	11/17/2008	1	RS	Engineer	C16	13:57:40	13:57:51	3	Move	-	-	-	-
11	11/17/2008	1	RS	Engineer	C16	13:57:51	14:16:52	1144	Staying	Z16	Working	Same-specialty	Own-Seat
12	11/17/2008	1	RS	Engineer	C16	14:16:52	14:45:12	1700	Move	-	-	-	-
13	11/17/2008	1	RS	Engineer	C16	14:45:12	14:48:49	217	Staying	-	Out	-	-
14	11/17/2008	1	RS	Engineer	C16	14:48:49	14:48:59	3	Move	-	-	-	-
15	11/17/2008	1	RS	Engineer	C16	14:48:59	14:49:31	34	Staying	Z16	Working	Same-specialty	Own-Seat
40220	11/28/2008	56	PL	Architect	M1	19:32:38	19:34:04	26	Move	-	-	-	-
40221	11/28/2008	56	PL	Architect	M1	19:34:04	19:40:23	379	Staying	-	Out	-	-
40222	11/28/2008	56	PL	Architect	M1	19:40:23	19:44:13	230	Staying	-	-	-	-
40223	11/28/2008	56	PL	Architect	M1	19:44:13	20:00:00	946	Move	M3	Working	Same-specialty	Meeting corner

PL: Project leader; RS: Regular staff; TS: Temporary staff.

4.4.2 Comparison of T and N-T workers' space use and move

In order to differentiate workers' move and space use patterns within the T (territorial) and N-T (non-territorial) workplaces, the duration rate and frequency of their use of each range workplace were calculated. Meanwhile, the author calculated the same items of workers' move in each workplace. The following items were then tested by Z test.

- ① DR: Duration rate – average proportion of duration at each worker stayed.
- ② F: Frequency - how frequently each worker stayed on an average.
- ③ AD: Stay duration per unit time - how long each worker stayed on an average per unit time.

1) Comparison of T and N-T workers' space use and movement in ranges of workplaces

As presented in Table 4-15, 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 rate sum of their staying at the work territory was almost the same. However, the N-T workers' DR and F was significantly higher for using the "Own-Seat Nearby" zone (DR [%]: T, 58.7; N-T, 67.1), but significantly lower for using the "same specialty range" (DR [%]: T, 18.3; N-T, 8.2; F [time/hour]: T, 1.1; N-T: 1.1). In the "service territory," although, the DR of N-T workers were significantly higher, the F of N-T and T workplace was the same (0.7 time/hour). The reason is that, the N-T workers spent 1.1% of duration on staying at the "Meeting Space".

Table 4-15 Comparison of T and N-T Workers' space use in each range of workplace

Items	Workplace attribute	Staying inside Workplace									Moving inside Workplace	Out of Workplace
		Work territory				Service territory						
		Own-Seat Nearby	Same Specialty range	Other Specialty range	Sum	Support Space	Main Corridor	Administ ration	Meeting Space	Sum		
DR [%]	T	58.7 (19.9)	18.3 (17.3)	3.6 (8.9)	80.7 (11.3)	0.5 (0.7)	0.2 (0.3)	-	-	0.7 (0.8)	6.4 (3.3)	12.2 (10.8)
	N-T	** 67.1 (16.9)	** 8.2 (10.7)	3.5 (5.9)	78.7 (14.3)	0.4 (0.5)	-	0.5 (1.7)	1.1 (4)	** 2.1 (4.4)	6.3 (3.2)	12.9 (13.6)
F [time/hour]	T	3.6 (1.9)	1.9 (1.7)	0.3 (0.6)	5.8 (3)	0.6 (0.7)	0.1 (0.2)	-	-	0.7 (0.7)	7.4 (3.3)	0.9 (0.5)
	N-T	** 4.1 (2)	** 1.1 (1)	** 0.5 (0.7)		0.5 (0.4)	-	0.1 (0.3)	0.0 (0.1)	0.7 (0.6)	7.1 (3)	0.9 (0.6)

T: Territorial Workplace; N-T: Non territorial Workplace.
Number in blanket: Standard deviation

* p<0.05 **p<0.01

According to Table 4-16 and Fig. 4-13, in both T and N-T workplaces, once the worker stayed at the "Own-Seat Nearby" zone, the mean of staying duration per unit time was around 11 minutes. Moreover, around 10% of staying duration per time was

0~1 min/time, 20% was 1~5 min/time, 35% was 5~10 min/time, the frequency proportion of staying duration over 30 minute was around 10%.

In both T and N-T workplaces, when workers visited and stayed at the other place of the work territory, the staying frequency, of which duration is 1~5 min/time, is around 50%, the highest of all. When workers stayed at the “Support Space”, the staying frequency, of which duration is 0~1 min/time, is over 80%, the highest of all.

Table 4-16 Workers’ mean and frequency of staying duration per time

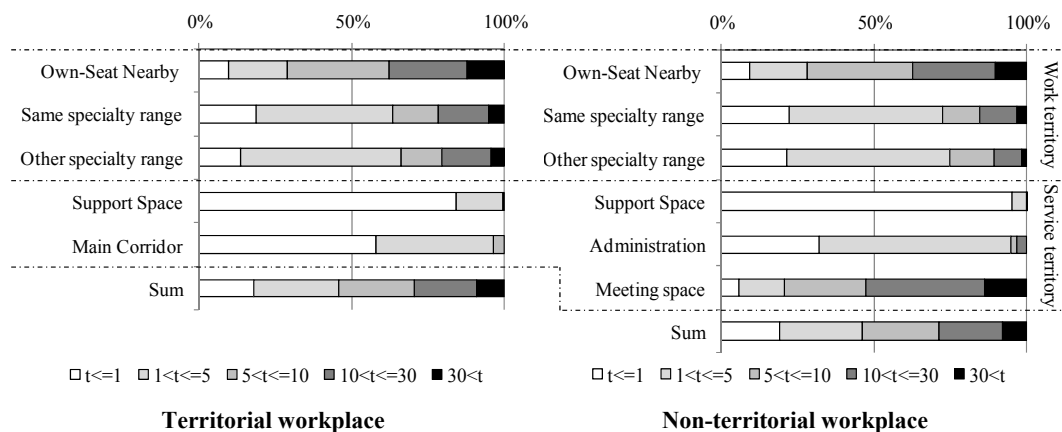
Staying duration per time: t [min]	Work territory			Service territory		Sum
	Own-Seat Nearby	Same specialty range	Other specialty range	Support Space	Main Corridor	
t≤1	406 (9.7)	371 (18.7)	42 (13.7)	352 (84.2)	80 (58)	1251 (17.8)
1<t≤5	803 (19.2)	884 (44.6)	161 (52.4)	65 (15.6)	53 (38.4)	1966 (27.9)
5<t≤10	1399 (33.4)	300 (15.1)	41 (13.4)	0 (0)	5 (3.6)	1745 (24.8)
10<t≤30	1074 (25.6)	324 (16.4)	50 (16.3)	1 (0.2)	0 (0)	1449 (20.6)
30<t	508 (12.1)	102 (5.1)	13 (4.2)	0 (0)	0 (0)	623 (8.9)
Sum	4190 (100)	1981 (100)	307 (100)	418 (100)	138 (100)	7034 (100)
Mean [min/time]	11.9	6.4	8.7	0.5	0.7	-

Number in blanket: Proportion of frequency in given staying duration per time [%].

Non-territorial workplace

Staying duration per time: t [min]	Work territory			Service territory			Sum
	Own-Seat Nearby	Same specialty range	Other specialty range	Support Space	Administration	Meeting space	
t≤1	490 (9.2)	276 (22.4)	133 (21.5)	739 (95.2)	49 (32.2)	4 (5.6)	1691 (18.9)
1<t≤5	998 (18.8)	618 (50.1)	332 (53.5)	36 (4.6)	95 (62.5)	11 (15.3)	2429 (27.1)
5<t≤10	1841 (34.7)	151 (12.2)	90 (14.5)	1 (0.1)	3 (2)	19 (26.4)	2254 (25.2)
10<t≤30	1445 (27.2)	151 (12.2)	55 (8.9)	0 (0)	5 (3.3)	28 (38.9)	1847 (20.6)
30<t	535 (10.1)	38 (3.1)	10 (1.6)	0 (0)	0 (0)	10 (13.9)	709 (7.9)
Sum	5309 (100)	1234 (100)	620 (100)	776 (100)	152 (100)	72 (100)	8960 (100)
Mean [min/time]	11.5	4.5	3.5	0.5	1.7	15.7	10

Number in blanket: Proportion of frequency in given staying duration per time [%].



2) Comparison of T and N-T workers' staying and move in zones of "work territory"

As analyzed above, in each workplace, workers spent most of their time on using the "work territory," with a significant difference in their space depending on their "same specialty range." In order to learn more details about workers' different space use patterns in each zone of the work territory in different workplaces; their use of each kind of zone in the "work territory" was compared in terms of the following items:

- ① DR: Duration rate - proportion of duration at different defined places where each worker stayed on an average.
- ② F: Frequency - how frequently each worker stayed on an average.
- ③ AD: Staying duration per unit time - how long each worker stayed on an average per unit time.

In particular, the frequency of move 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 4-17).

As shown in Table 4-17, when using the zones other than their "Own-Seat Nearby" zone in the "work territory," both T and N-T workers stayed longer and more frequently in the "Meeting corner side zone" than in the "workstation zone" in both ranges.

As compared with T workers, the N-T workers' DR for using the "Meeting corner side zone" in the same specialty range was significantly lower. However, their move frequency inside the "Own-Seat Nearby" zone and the DR of their stay in the "workstation zone" in each range were significantly high. Moreover, the DR quotient for using 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 to be used for 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 move frequency in the "Own-Seat Nearby"; they therefore spent a longer duration on using the "Own-Seat Nearby."

In the T workplace, compared with the “general-type meeting corner side” the “window-side meeting corner side” is visited less. The reason might be that the window-side meeting corner is further from the general groups, where most subjects’ own seats are located; therefore, most workers used the general-type meeting corner instead.

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.

Table 4-17 Comparison of T and N-T Workers’ space use and move in the “Working territory”

Items	Workplace attribute	Own-Seat Nearby	Same Specialty range						Other Specialty range						Move inside Own-Seat Nearby
			Meeting corner side zone			Workstation Zone			Meeting corner side zone			Workstation Zone			
			General type	Window side	Sum	General type	Window side	Sum	General type	Window side	Sum	General type	Window side	Sum	
DR	T	58.7 (19.9)	13.9 (16.2)	2.9 (7.6)	16.7 (17.2)	0.9 (1.3)	0.7 (1.6)	1.6 (2)	3 (8.7)	0.2 (1.2)	3.3 (8.8)	0.1 (0.3)	0.2 (0.9)	0.3 (1)	-
	N-T	** 67.1 (16.9)	-	-	** 5.9 (9.9)	** 1.9 (3.9)	* 0.4 (1.7)	** 2.3 (4.3)	-	-	2.5 (5.1)	** 0.9 (1.8)	** 0.1 (0.4)	** 1 (1.9)	-
F	T	3.6 (1.9)	1.1 (1.3)	0.1 (0.3)	1.2 (1.3)	0.4 (0.6)	0.2 (0.7)	0.6 (0.9)	0.2 (0.4)	0 (0.1)	0.2 (0.4)	0.1 (0.2)	0 (0.1)	0.1 (0.3)	1.4 (1.1)
	N-T	** 4.1 (2)	-	-	** 0.7 (0.8)	0.4 (0.4)	** 0.1 (0.2)	** 0.4 (0.5)	-	-	** 0.3 (0.5)	** 0.2 (0.4)	0 (0.1)	** 0.2 (0.4)	** 2.3 (1.6)
AD	T	11.9 (6.7)	8.6 (7.7)	11.3 (14.9)	9 9.2 (7.7)	1.3 (1)	2.4 (2.9)	1.6 (1.5)	13.1 (23.7)	3.6 (4)	11.4 (21.2)	1.4 (1.1)	4 (4.3)	2 (2.4)	-
	N-T	11.5 (5.4)	-	-	** 5.3 (5.4)	** 3.5 (5.8)	** 3.7 (6.4)	** 3.6 (5.3)	-	-	** 4.3 (4.8)	** 2.9 (3.7)	** 2.1 (1.8)	** 2.8 (3.5)	-
T: Territorial Workplace; DR: Duration rate [%];			N-T:Non-territorial Workplace. F: Frequency [time/hour];				Number in blanket: Standard deviation AD: Average duration per time [min/time]				* p<0.05 **p<0.01				

4.4.3 Comparison of space use and move according to workers' attribute

In this section, the workers space use and move for the different specialties and posts in each workplace were compared.

1) Comparing workers' stay and movement in each workplace by specialty

As shown in Table 4-18, in both the T and N-T workplaces, compared with engineers, architects' DR in the "Own-Seat Nearby" zone was significantly higher. Their DR in the "other specialty range", however, was significantly lower. 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, when they stayed in the "same specialty range," engineers' DR in the "workstation zone" was significantly higher than that of architects. In addition, their AD in the "workstation zone" was approximately the same as that for their AD in the "meeting corner zone". 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 engineers' significantly higher frequency of movement in the "Own-Seat Nearby" zone indicates that they may move and communicate with other engineers at adjacent seats more frequently than do architects.

Table 4-18 Comparison of workers' space use and move according to specialty attribute in each workspace

Items	Workplace attribute	Specialty attribute	Staying inside workplace															Move		Out of Workplace
			Own-Seat Nearby	Same Specialty range					Other Specialty range					SUM	Inside Own-Seat Nearby	Inside Workplace				
				Meeting corner side zone			Workstation zone		SUM	Meeting corner side zone			Workstation zone				SUM			
				General type	Window side	Sum	General type	Window side		Sum	General type	Window side	Sum							
DR	T	Architect	* 59.6 (19.5)	14.3 (16)	2.4 (6.9)	16.7 (17)	** 1 (1.4)	0.7 (1.6)	* 1.7 (2.1)	18.4 (17.3)	2.6 (7.3)	* 0.2 (0.9)	2.8 (7.3)	0.1 (0.3)	* 0.2 (0.8)	0.3 (0.9)	* 3 (7.5)	* 6.7 (3.4)	* 11.5 (10)	
		Engineer	55 (21.6)	13.6 (18.3)	4.2 (9)	17.7 (18.7)	0.6 (0.9)	0.6 (1.6)	1.2 (1.8)	19 (18.7)	4.2 (11.7)	0.5 (1.6)	4.7 (11.6)	0.2 (0.3)	0.3 (1)	0.5 (1.1)	5.2 (11.7)	-	5.8 (2.8)	
	N-T	Architect	** 68.6 (18.4)	-	-	* 6.5 (10.9)	1.7 (3.8)	0.3 (1)	* 2 (4)	8.5 (11.6)	-	-	** 1.5 (3.4)	0.7 (1.5)	0 (0.4)	0.7 (1.6)	** 2.2 (4)	-	** 5.9 (3.1)	13.3 (14.9)
		Engineer	64.3 (13.9)	-	-	4.7 (7.4)	2.3 (4)	0.6 (2.5)	2.9 (4.8)	7.6 (8.6)	-	-	3.7 (7)	1.4 (2.2)	0.1 (0.3)	1.5 (2.3)	5.1 (8)	-	6.9 (3.2)	15.3 (10.7)
F	T	Architect	3.6 (1.8)	1.1 (1.2)	* 0.1 (0.2)	1.2 (1.2)	* 0.5 (0.6)	** 0.3 (0.7)	* 0.7 (0.9)	2 (1.6)	0.2 (0.4)	0 (0.2)	0.2 (0.4)	0.1 (0.2)	0 (0.1)	0.1 (0.3)	0.3 (0.6)	1.3 (1)	7.4 (3.4)	0.8 (0.5)
		Engineer	3.5 (2)	1.1 (1.5)	0.2 (0.4)	1.3 (1.4)	0.3 (0.5)	0.1 (0.2)	0.4 (0.6)	1.7 (1.8)	0.2 (0.3)	0 (0.1)	0.2 (0.3)	0.1 (0.2)	0.1 (0.2)	0.2 (0.3)	0.4 (0.5)	1.5 (1.4)	7.3 (3.1)	0.9 (0.5)
	N-T	Architect	** 3.9 (1.7)	-	-	0.7 (0.8)	0.4 (0.5)	** 0.1 (0.2)	0.4 (0.5)	1.1 (1)	-	-	** 0.2 (0.4)	0.2 (0.3)	0 (0.1)	** 0.2 (0.3)	** 0.4 (0.5)	** 2.1 (1.4)	** 6.8 (2.7)	0.9 (0.6)
		Engineer	4.6 (2.3)	-	-	0.6 (0.8)	0.3 (0.4)	0 (0.1)	0.4 (0.5)	1 (1)	-	-	0.4 (0.6)	0.4 (0.4)	0 (0.1)	0.4 (0.8)	0.8 (1.9)	2.6 (7.9)	1 (0.5)	
AD	T	Architect	11.9 (6.3)	8.5 (7.4)	11.1 (13)	9.1 (7.5)	1.3 (1)	** 2 (2.7)	- 1.5 (1.4)	6.2 (5.5)	12.9 (25.1)	2.1 (0.8)	- 11.5 (24)	** 1.6 (1.3)	** 4.5 (3.3)	- 2.1 (1.9)	- 8.8 (21.4)	-	-	-
		Engineer	11.5 (7.6)	8.8 (8.5)	11.2 (17.9)	9.5 (8.1)	1.3 (0.9)	4.1 (3.3)	- 1.9 (1.8)	7 (4.9)	14.3 (18.9)	6.6 (5.8)	- 11.8 (11.9)	1.1 (0.8)	3.2 (4.9)	- 1.9 (3.1)	- 8.5 (11.3)	-	-	-
	N-T	Architect	* 12.1 (5.6)	-	-	5.4 (5.4)	* 2.9 (4.7)	** 2.2 (2.4)	- 2.8 (4.5)	4.3 (4.4)	-	-	4.4 (5.1)	3.1 (3.7)	2.1 (2.2)	- 2.9 (3.5)	- 3.5 (3.1)	-	-	-
		Engineer	10.3 (4.9)	-	-	5 (5.2)	4.5 (7.3)	7.1 (10.1)	- 4.7 (6.4)	4.9 (4.5)	-	-	4.2 (4.5)	2.6 (3.6)	2.1 (1.5)	- 2.6 (3.5)	- 3.5 (4)	-	-	-
T: Territorial Workplace; DR: Duration rate [%];			Number in blanket: Standard deviation AD: Average duration per time [min/time] * p<0.05 **p<0.01															The T-test is conducted by comparing the sample of Architect with the sample of Engineer		

T: Territorial Workplace; N-T: Non territorial Workplace. Number in bracket: Standard deviation
 DR: Duration rate [%]; F: Frequency [time/hour]; AD: Average duration per time [min/time]
 * p<0.05 **p<0.01 The T-test is conducted by comparing the sample of Architect with the sample of Engineer

2) Comparison of workers' stay and movement in each workplace by post

As presented in Table 4-19, 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), which might be due to PL needing to leave for other workplaces more often for inter-departmental cooperation. PLs' use of 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 side zone" in the same range (DR [%]: T, 14.9; N-T, 4.3). PLs' move 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 meeting corner located in their "Own-Seat Nearby", 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" were significantly higher (DR [%]: T, 75.8; N-T, 78.9. AD [min/time]: T, 16.6; N-T, 14.3). However, their move frequency in the "own-seat nearby" was the lowest. Meanwhile, TSs' 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 using the "Meeting corner side zone" of each range was significantly lower and their AD for the "Meeting corner side zone" was significantly shorter. These results show that TS might do more than 10% more time for work to be done individually than other staff, a work characteristic that causes them to move less within the workplace.

Table 4-19 Comparison of workers' space use and move according to post attribute in each workspace

Items	Workplace attribute	Specialty attribute	Staying inside workplace														Move			Out of Workplace
			Own-Seat Nearby	Same Specialty range					Other Specialty range					Inside Own-Seat Nearby	Inside Workplace					
				Meeting corner side zone			Workstation zone		Meeting corner side zone			Workstation zone				SUM				
				General type	Window side	Sum	General type	Window side	Sum	General type	Window side	Sum	General type				Window side	Sum		
DR	T	PL	** 54.1 (18.9)	** 13.1 (16.8)	* 1.8 (4.5)	* 14.9 (17.2)	1.1 (1.6)	* 0.4 (1.1)	1.5 (1.8)	* 16.4 (17.4)	2.9 (7.1)	0.2 (1.1)	0.1 (0.2)	3.1 (7.1)	0.2 (1.2)	0.3 (1.2)	3.4 (7.1)	6.9 (4)	** 18 (14.1)	
		RS	54.7 (19.9)	17.5 (8.1)	3.3 (18)	20.7 (18)	0.9 (1.2)	0.8 (1.7)	1.7 (2)	22.4 (18.2)	3.4 (9.7)	0.3 (1.3)	0.2 (0.3)	3.7 (9.8)	0.2 (0.8)	0.3 (0.9)	4 (9.8)	6.4 (3)	11.9 (9.9)	
		TS	** 75.8 (10.9)	** 3.7 (5.2)	2.3 (7.9)	** 6 (8.7)	0.9 (1.2)	0.6 (1.6)	1.5 (2.3)	** 7.5 (8.8)	1.9 (5.6)	* 0.1 (0.3)	* 2 (5.6)	0.2 (0.3)	0.1 (0.7)	0.3 (0.8)	* 2.3 (6)	6.1 (3.2)	** 7.7 (5.3)	
	N-T	PL	63.5 (18.7)	-	-	* 4.3 (5.6)	1.5 (2.8)	0.3 (0.9)	1.8 (2.9)	6.1 (7.1)	-	-	3.3 (5.6)	0.7 (1.8)	0 (1.8)	0.7 (1.8)	** 4 (6)	6.9 (3.2)	* 17.2 (15.1)	
		RS	66.7 (16.5)	-	-	6.4 (11)	2 (4.2)	0.4 (1.9)	2.4 (4.6)	8.9 (11.8)	-	-	2.3 (5.2)	1 (2)	0 (1.9)	1.1 (2)	1.1 (6.2)	3.4 (3.2)	12.7 (13.6)	
		TS	** 78.9 (11.2)	-	-	4.3 (4.6)	1.8 (3.4)	* 0.1 (0.3)	2 (3.3)	6.3 (5.2)	-	-	* 1.1 (2.5)	* 0.5 (1)	0.2 (1.1)	0.7 (1.6)	* 1.8 (2.8)	** 4.5 (1.9)	** 7.4 (7.6)	
F	T	PL	3.4 (1.3)	** 0.8 (1.1)	0.1 (0.3)	** 1 (1.1)	0.5 (0.7)	* 0.1 (0.2)	0.6 (0.7)	1.6 (1.6)	0.2 (0.3)	0 (0.1)	0.2 (0.3)	0.1 (0.1)	0 (0.3)	0.1 (0.3)	0.5 (0.5)	1.6 (3.3)	0.9 (0.8)	
		RS	3.7 (2.1)	1.4 (1.4)	0.2 (0.3)	1.5 (1.4)	0.4 (0.5)	0.3 (0.8)	0.7 (0.9)	2.2 (1.8)	0.2 (0.3)	0 (0.2)	0.2 (0.4)	0.1 (0.2)	0 (0.2)	0.1 (0.3)	0.3 (0.6)	1.4 (3.4)	7.7 (0.5)	
		TS	** 3.3 (1.4)	** 0.4 (0.4)	0.1 (0.3)	** 0.5 (0.5)	0.4 (0.5)	0.2 (0.2)	0.6 (0.6)	** 1.1 (0.9)	0.2 (0.5)	0 (0.1)	0.2 (0.6)	0.1 (0.2)	0 (0.7)	0.1 (0.2)	0.3 (0.7)	* 1.1 (0.9)	6.1 (2.4)	
	N-T	PL	3.9 (1.3)	-	-	0.6 (0.7)	0.4 (0.5)	0.1 (0.2)	0.4 (0.6)	1 (0.9)	-	-	0.3 (0.5)	** 0.1 (0.2)	0 (0.2)	** 0.2 (0.5)	0.4 (0.8)	2.6 (2.6)	1 (0.5)	
		RS	4.2 (2.1)	-	-	0.7 (0.9)	0.4 (0.4)	0.1 (0.2)	0.4 (0.5)	1.1 (1)	-	-	0.3 (0.5)	0.3 (0.4)	0 (0.1)	0.3 (0.4)	0.6 (0.8)	2.2 (1.7)	0.9 (3.1)	
		TS	4 (1.7)	-	-	0.7 (0.6)	0.4 (0.5)	0.1 (0.1)	0.5 (0.4)	1.2 (0.8)	-	-	0.2 (0.3)	** 0.1 (0.2)	0 (0.1)	** 0.1 (0.3)	0.3 (0.4)	2 (1.4)	6.9 (2.8)	
AD	T	PL	10.4 (4.6)	10 (8.5)	9.1 (8.9)	9.7 (7.9)	* 1.5 (1.2)	3 (4.4)	1.9 (1.7)	7.4 (7.7)	15.5 (24)	4.2 (4.4)	** 0.7 (0.8)	14.3 (23)	3.9 (1.8)	1.3 (1.6)	10.6 (20.8)	-	-	
		RS	10.9 (6.4)	8.8 (7.7)	12.5 (16.9)	9.4 (7.7)	1.3 (1)	2.3 (2.6)	1.6 (1.6)	6.6 (4.4)	6.6 (26.3)	3.7 (4.2)	1.6 (1.2)	12.2 (22.8)	3.5 (4.2)	2.2 (2.6)	9.1 (20.4)	-	-	
		TS	** 16.6 (7.4)	** 6.3 (6.1)	** 7.4 (7.6)	** 7.2 (7.1)	1.2 (0.9)	1.8 (1.7)	1.3 (0.8)	5 (5.6)	** 5.8 (5.7)	** 2.3 (0.7)	** 5.8 (1)	5.8 (5.7)	1 (0.6)	1.8 (1.8)	4.7 (5.5)	-	-	
	N-T	PL	10.4 (3.7)	-	-	6.5 (7.7)	3.1 (1.5)	** 2.3 (1.5)	3.1 (5.9)	4.3 (5)	-	-	6.7 (4.6)	3.3 (3.5)	0.3 (0)	3 (4.2)	4.4 (5.6)	-	-	
		RS	11.4 (5.4)	-	-	5.2 (4.9)	3.7 (6)	4.2 (7.1)	3.7 (5.5)	4.8 (4.5)	-	-	4 (3.6)	2.8 (3.5)	1.9 (1.4)	2.7 (3.5)	3.4 (3)	-	-	
		TS	** 14.3 (6.9)	-	-	* 4.1 (3.8)	** 2.1 (2)	** 1.5 (0.7)	2 (1.9)	3.3 (2.6)	-	-	** 2.5 (2.3)	2.6 (2.6)	8.1 (0)	2.8 (2.6)	2.9 (1.8)	-	-	

T: Territorial Workplace; N-T:Non territorial Workplace. Number in Bracket: Standard deviation
R: Duration rate [%]; F: Frequency [time/hour];

* p<0.05 **p<0.01 PL: Project leader; RS: Regular staff; TS: Temporary staff.

T: Territorial Workplace; N-T: Non territorial Workplace; Number in bracket: Standard deviation
 DR: Duration rate [%]; F: Frequency [time/hour]; AD: Average duration per time [min/time]
 * p<0.05 **p<0.01 PL: Project leader; RS: Regular staff; TS: Temporary staff.

4.4.4 Estimation and comparison of occupancy rates in different workplaces

One purpose of the renovation of the non-territorial workplace is to increase the flexible use of workspace and make it occupied more frequently for saving space. Although, the evaluations on space use efficiency could be different according to the standards, such like by judging the increasing of productivity and so on. Here, as the one of the renovation purposes of non-territorial workplace is to make the space occupied more by workers, thus, the evaluation on use efficiency discussed in this section is represented by the workers' occupancy at the space of workplace.

The analysis in section 4.4.2 revealed that the workers' daily work duration mainly consists of staying in the workstation and meeting corner of their "work territory". Hence, the occupancy rate at the workstations and meeting corners actually indicates the space use efficiency of each workplace. To compare the space occupancy of the T and N-T workplaces, the author defined three categories of occupancy. Also, since the author had 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 rate (Table 4-20) recorded once per 30 min in the same investigation period and the DR values calculated in 4.3.2-1) and 2) are included in the calculation of the estimated occupancy duration rates in Formulas (4.2), (4.3), and (4.4).

- ① R_{PRO} : Proprietary occupancy rate-when the workstation is occupied by a worker whose own seat located there (Formula 4.2).
- ② R_{FLO} : Flexible occupancy rate-when the workstation is occupied by a worker whose own seat is not located there (Formula 4.3).
- ③ R_{PUO} : Public occupancy rate-when the meeting corner is occupied by a worker (Formula 4.4).

$$R_{PRO} = \frac{\sum_e (DR_{s,e} n_e r_e) T}{T \times Z_W} \times 100 \dots (4.2)$$

$$R_{FLO} = \frac{\sum_e (DR_{w,i,e} n_e r_e) T}{T \times Z_{W,i}} \times 100 \dots (4.3)$$

$$R_{PUO} = \frac{\sum_e (DR_{M,i,e} n_e r_e) T}{T \times Z_{M,i}} \times 100 \dots (4.4)$$

DR : Duration rate of staying [%]
 S : "Own-Seat Nearby" [-]
 W : "Workstation" [-]
 M : "Meeting corner" [-]
 T : Duration of daily working [hour]
 e : Worker's attribute such like specialty and post
 n : Number of workers [person]
 i : Position attribute general type or window side type [-]
 Z : Seat number of workstation or meeting corner [seat]
 r : attendance rate [%]

Table 4-20 Workers' average daily attendance rate

Workplace attribute	Workers' attribute		Post attribute			Sum	
			Project leader	Regular staff	Temporary staff		
T	Specialty attribute	Architect	Staff number	8	22	10	40
			Attendance rate	62%	72%	100%	77%
		Engineer	Staff number	2	17	1	20
			Attendance rate	68%	75%	100%	76%
N-T	Specialty attribute	Architect	Staff number	13	35	17	65
			Attendance rate	64%	72%	93%	75%
		Engineer	Staff number	4	25	6	35
			Attendance rate	60%	70%	100%	74%

1) Comparison of workstation's occupancy

As shown in Table 4-21, compared with the T workplace, R_{PRO} in the N-T workplace is 8.5% higher, while R_{FLO} is also higher, at 2.8%. In the T workplace, R_{FLO} 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_{FLO} 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. 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

Table 4-21 Comparison of T and N-T workplaces' occupancy rate

Workplace attribute	Seat attribute	Use attribute	Occupancy rate [%]	Position attribute	Occupancy rate [%]
T	Work station	PRO	48.2	-	-
				General type	0.9
		FLO	1.5	Window side	4.8
				General type	17.1
	Meeting corner	PUO	15.7	Window side	11.2
				-	-
N-T	Work station	PRO	56.7	-	-
				General type	7.2
		FLO	4.3	Window side	1.0
				-	-
	Meeting corner	PUO	22.6	-	-
				-	-

communicate. The results also indicate that, since the N-T workplace workstation is twice as flexibly used (4.3/1.5), it could induce the workers located workstation there to communicate with visitors easily, without leaving for the meeting corner, thus, leading to the higher R_{PRO} .

2) Comparison of meeting corner occupancy

According to Table 4-21, R_{PUO} of the N-T workplace was 6.9% higher than that of the T workplace; while in the T workplace, R_{PUO} of the general-type meeting corner was 5.9% higher than it was for the window side type meeting corner.

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 number of meeting corners 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 (4 or 8 seats) than there were in the N-T workplace (3 seats). According to 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, 1 to 5 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.

4.5 Conclusion

In this chapter, the author focused on the workers' space use in a non-territorial workplace and a territorial workplace, in order to clarify differences of workers' move and space use behavior in each workplace. Meanwhile, the using way of workstation and meeting corner was also studied by interval observation record. It is found that, the workers space use is composed of quite a lot of short time staying. The total frequency proportion of the staying duration within 5 min was around 45%. Comparing with territorial workplace, the space of non-territorial workplace were used more flexibly, as its workstations were occupied more by both workers' working and other using way such as communication. Additionally, the meeting corner of non-territorial were used more evenly, as the seats' number was quite suitable for attendees' number per meeting time and shared used more by both architects and engineers for communication in both investigated workplaces. Moreover, the non-territorial workplace was occupied more frequently and flexibly than territorial workplace by comparing the estimated occupancy rates at the workstations and meeting corners.

The findings of comparing on workers' using way of workstation and meeting corner in detail are listed as below:

1) About the using ways of workstation: The rate of Working with PC in workstations of non-territorial workplace was 1.1% higher than territorial workplace and it was the 6.2% higher rate of Only PC led to the 7.2% higher Occupancy rate in the non-territorial workplace.

2) About communication: In the territorial workplace, architects and engineers used meeting corners for communication with the workers in same specialty in almost all cases. While in non-territorial workplace, architects and engineers also used meeting corners not in their range for communication with the worker in different specialty. 75% of the meeting corners in non-territorial workplace were evenly used, except for M1 and M2 which were located closed to the bigger meeting space. In territorial workplace the rate was only 56%, except for the 4 smaller meeting corners located next to leaders' workstation and further from general workstation group.

3) Taking into account of both workstation using and communication, it showed that workers in the non-territorial workplace were inclined to work in and occupy the workstation more, hold more and larger meetings in meeting corner in the Afternoon. However, the contrary tendency appeared in the Morning.

Additionally, the findings of comparing on workers' move and space use in detail are listed as below:

1) In each workplace, workers spent 80% of time on staying inside the work territory, in which the "Own-Seat Nearby" was used the longest and the most frequently. Moreover, around 30% of workers' staying at "Own-Seat Nearby" was within 5 min per time; when workers leaving the "Own-Seat Nearby" zone for other places in the work territory, over 60% of their staying was within 5 min per time. Workers only spent 0.7~0.9% of time on staying at the service territory (exclude the meeting space in the non-territorial workplace); while the frequency proportion of staying, whose duration per time within 1 min, was over 95%.

2) Compared with workers in a territorial workplace, non-territorial workplace workers' duration rate of staying at the "Own-Seat Nearby" was 8.4% higher. When leaving the "Own-Seat Nearby" zone for other places in the work territory, non-territorial workplace workers stayed 11.6% less in the "meeting corner zone", but 1.4% more in the "workstation zone".

3) A comparison of the stay and movement by workers' posts and specialty in each separate workplace showed the following same tendency. Architects stayed about 4% longer in the "Own-Seat Nearby" zone than engineers, while engineers visited the architects' specialty range more. As 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 spends over 75% of the work time staying in the "Own-Seat Nearby".

4) In terms of estimated occupancy rates, the non-territorial workplace workstation had an 8.5% higher proprietary occupancy rate than the territorial workplace. Meanwhile, its 2.8% higher flexible occupancy rate indicates that the space of the workstations in the non-territorial workplace is occupied more frequently 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.

One of the motivating aims of innovation with a non-territorial workplace which is transformed from territorial workplace is to increase the occupancy rate. In this chapter, it is verified the space of workstation and meeting corner were used more flexible than territorial workplace. Furthermore, the author revealed that how the space of the investigated non-territorial workplace is occupied more frequently and flexibly than the

territorial workplace. Meanwhile, by the analysis, the spaces of territorial workplace which are not used so evenly and are wasted were found out, with its reason well explained.

The bigger meeting space in the non-territorial workplace and the smaller meeting corner in territorial workplace were not used as same evenly as the other meeting corners, since they are both located further from the most workers' workstation. Although they made the workers next to them used conveniently, their location made them lost the characteristic of public sharing use but transformed into the exclusiveness of some specialty or post. Therefore, in order to increase the occupancy rate, the frequently used space for public sharing (such like the meeting space) should be distributed evenly in the workplace. Meanwhile, as one important reason, why the non-territorial workplace was occupied more efficiently, is that the workers' individual workstation is visited more frequently and stayed much longer by other workers. Therefore, in order to increase the occupancy rate, the workstation should be designed to be reached and stayed conveniently by other workers in order to response and support short time staying which occurs frequently in workers' space use behavior. Furthermore, the suitable seats number of the meeting corner table is quite important to increase the occupancy rate. As it is found that the average workers' number per staying at the meeting corner is around 3, that is why the occupancy rate of the bigger meeting corners (which has 8 seats) in the territorial workplace is lower. It also well explained why the workers in the investigated non-territorial workplace seldom used the bigger meeting space, as there is not so much necessary to use it for holding over 3 workers' meeting.

With the above consideration, some improvements can be suggested to the investigated territorial workplaces. For instance, the meeting corners of territorial workplace should be transformed smaller (decreasing seats' number) and arranged more evenly for all workers. 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.

Note

*1 In the investigated territorial workplace, since the workstation is always occupied by documents or project drawing no matter with workers in the work or left work. Therefore, it is impossible to clarify whether workers really worked with documents or not. Therefore, in the observation record investigation process, the workers' space using way is recorded by whether the workers worked with PC and only PC turned on.

*2 In the investigated territorial workplace, there are 4 specialties which are Architecture Design, Structure, Equipment and Technology Design; while in non-territorial workplace, there are 3 specialties which are Architecture Design, Structure and Equipment Design.

*3 In the investigated non-territorial workplace, although workers of different specialties can select workstation freely, our research on workers' workstation selecting behavior in non-territorial workplace showed that the architects and engineers mainly concentrated in their own ranges, though workstations in Engineer's Range were sometimes occupied by architects, but most of the times (87.5%) were still occupied by engineers. So the data in this range was considered to be able to reflect work style of engineers.

*4 Meeting space refers to the space located at the west side of non-territorial workplace, and different from the meeting corner defined in this dissertation.

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Chapter 5 Comparison of Workers' Space Use and Verbal Communication in Big Open Plan Workplace with and without Partition Walls

- 5.1 Purpose
- 5.2 Outline of the investigations and investigated workplaces
 - 5.2.1 Devices
 - 5.2.2 The investigated worksite
 - 5.2.3 Definition of locations
- 5.3 Comparison of space use and verbal communication in each workplace
 - 5.3.1 Workers' use of locations in each workplace
 - 5.3.2 Workers' verbal communication in places in each workplace
 - 5.3.3 Comparison of workers' space use and verbal communication in different workplaces
 - 5.3.4 Comparison of proportions of workers' verbal communication while at different locations in the two workplaces
- 5.4 Comparison of space use and verbal communication according to workers' post and specialty in each workplace
 - 5.4.1 Comparison of space use and verbal communication on the basis of post
 - 5.4.2 Comparison of space use and verbal communication on the basis of specialty
- 5.5 Conclusion
- Note
- Reference

One important motivation in workplace innovation is to increase the communication among intellectual workers¹⁾ in order to share information. It had caused the change of workplace layouts, among which the big open plan workplace has become popular in recent projects. The question has been raised, however, as to whether, and in what way, a big open plan workplace is better or increases communication among workers.

As presented in section 1.5.2, the previous studies on big open plan workplaces were mainly concerned with the interior environment such as the lighting or ventilation. However, there are few studies focused on comparing workers' precise space use behavior, especially about the verbal communication. The existed studies correlated to space use behavior are mostly operated by questionnaire or interval observation record, which made the findings contributed by workers' general space use frequency but not exact duration seemed to be not so accurate.

In this chapter, therefore, the author used location sensor and voice sensor to provide a means of monitoring the worker' space use and verbal communication behaviors objectively and continuously in a varied workplace in a building.

5.1 Purpose

The main purpose of this chapter is to clarify the differences between workers' space use and verbal communication in big open plan workplace without inter-specialty partition walls and the same one with inter-specialty partition walls.

In addition to ascertaining the characteristics of the two workplaces, valuable information about workers' different space use and verbal communication at places in workplace with and without partition walls was obtained.

The aims are as follows:

- 1) By comparing the workers' different staying and verbal communication in two workplaces, to clarify the influence of partition walls on the workers' staying and verbal communication.
- 2) By comparing the space use and verbal communication according to the workers' post and specialty in each workplace, to clarify their characteristic in this regard.

Compared with workplace with partition walls, which is considered to be better to offer workers a more quite and calm environment, one motivation of the innovation of big open plan workplace is to increase the visual contact for increasing verbal communication. It is therefore significant to clarify whether, in what way, and in which level a big open plan workplace improves the workers' verbal communication. This

understanding can help evaluate which workplace is better for workers' verbal communication.

5.2 Outline of the investigations and investigated workplaces

5.2.1 Devices

Presented by Fig. 5-1, three types of sensors were used in the investigations: a UWB sensor network with a voice sensor for recording the location and duration of staying and verbal communication, and acceleration sensors for data correction (refer to chapter 2).

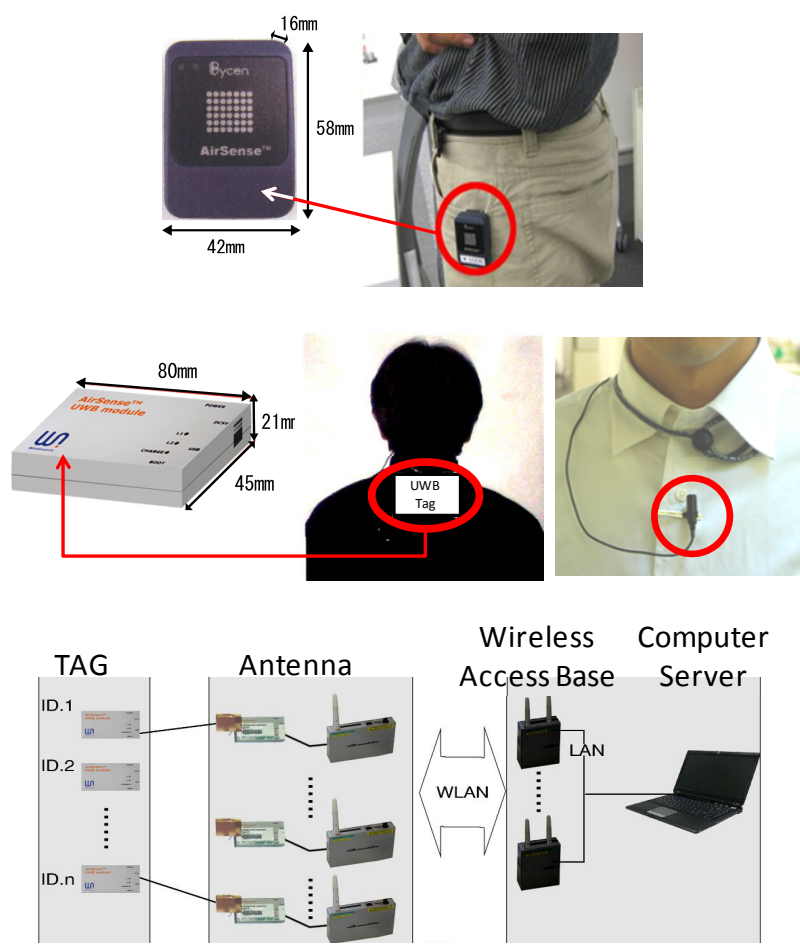


Figure 5-1 Sensor set and the UWB sensor network system

5.2.2 The investigated worksite

A workplace for architecture, equipment, and structure design specialties in an architecture construction company was chosen for research, and was investigated twice. The investigated area was originally composed of two main types of space: (1) the “Work Territory”, in which a large space was evenly divided into three ranges for three specialties in which workers had fixed individual workstations. (2) the “Public Territory”, which contains a “Meeting Space”, “Relaxation Space”, “Smoking Corner”, and the “Stair and Elevator Hall”. During the first investigation, a partition wall (Fig. 5-2.④) that was high enough to touch the ceiling, was set up between the specialty ranges in the “Work Territory”. During the second investigation, the “Work Territory” was converted back to a single large space.

The first investigation, which concerned a workplace with partition walls between specialties (WP workplace), was conducted from 8:00 to 20:00 for 5 successive weekdays from November 30th to December 4th, 2009. The second investigation, which concerned a big open plan workplace without partition walls (WOP workplace), was lasted for 5 successive weekdays from 14th to 18th, December, 2009. On each day of both investigations, 20 sets of sensors were assigned randomly and evenly to workers in the three specialties. When a worker was assigned a sensor set, his/her name, the time of assignment, post, specialty, and the workstation where he/she was located were recorded by the investigator. If a subject left work before the investigation was over, the sensor assigned to him/her was reassigned to another worker. During the period of investigation, 53 out of 55 workers were assigned sensors a total of 112 times in the WP workplace, while 54 out of 56 workers were assigned sensors a total of 118 times in the WOP workplace (Table 5-1).

Table 5-1 Workers' Number in the non-territorial workplace [person]
[Investigated workers' number [person]]
(Investigated times of workers [person•day])

Workplace attribute	Specialty attribute	Post attribute						Sum		
		Project leader			Regular staff					
WP workplace	ADS	3	[2]	(6)	15	[15]	(32)	18	[17]	(38)
	EDS	2	[2]	(10)	17	[17]	(33)	19	[19]	(43)
	SDS	2	[2]	(6)	16	[15]	(25)	18	[17]	(31)
	Sum	7	[6]	(22)	48	[47]	(90)	55	[53]	(112)
WOP workplace	ADS	3	[2]	(6)	15	[15]	(38)	18	[17]	(44)
	EDS	2	[2]	(10)	18	[17]	(34)	20	[19]	(44)
	SDS	2	[2]	(5)	16	[16]	(25)	18	[18]	(30)
	Sum	7	[6]	(21)	49	[48]	(97)	56	[54]	(118)

ADS: Architecture design staff; SDS: Structure design staff; EDS: Equipment design staff

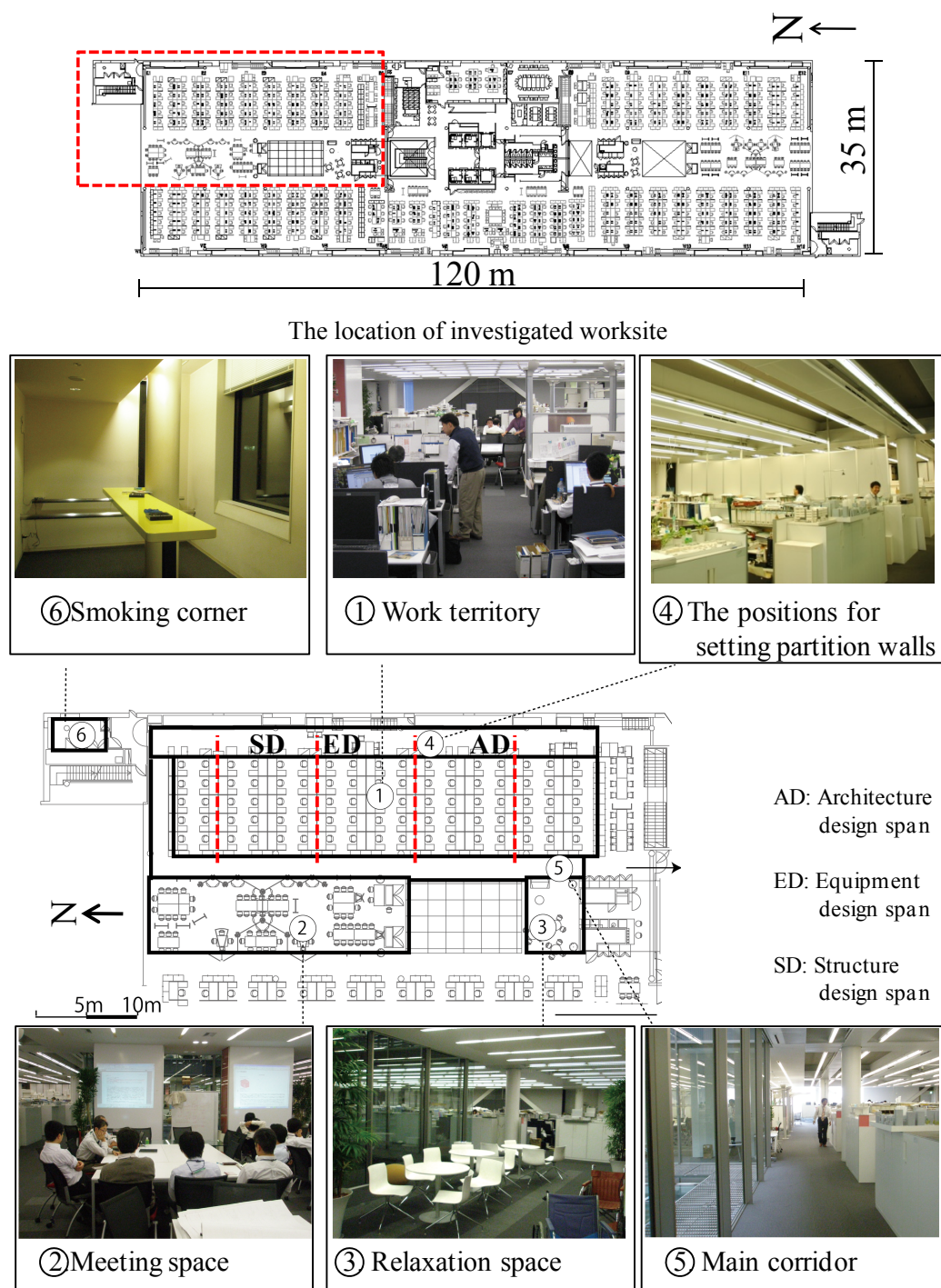


Figure 5-2 The investigated worksite

5.2.3 Definition of locations

According to the locating accuracy of the UWB sensor network, the distribution of sensor antennas, the actual division of the workplace layout, and the distance between adjacent desks, the subject's locations were defined, as shown in Fig. 5-3. When a subject was in the workplace, his/her location was recorded by the UWB sensor and converted to the defined locations in the subsequent database revision process. The antenna could not receive a signal when a subject left the investigated area to go to other places in the building. These periods were revised as being "Out of Workplace". In the "Work Territory", the place that includes a subject's own workstation was defined as being "Own-seat nearby", which is indicated by the black block with an "X" in Fig. 5-3. The other places were defined as the "Same-Group", "Other-Group" or "Other Specialty" according to whether the location attributes matched the subject's group or specialty.

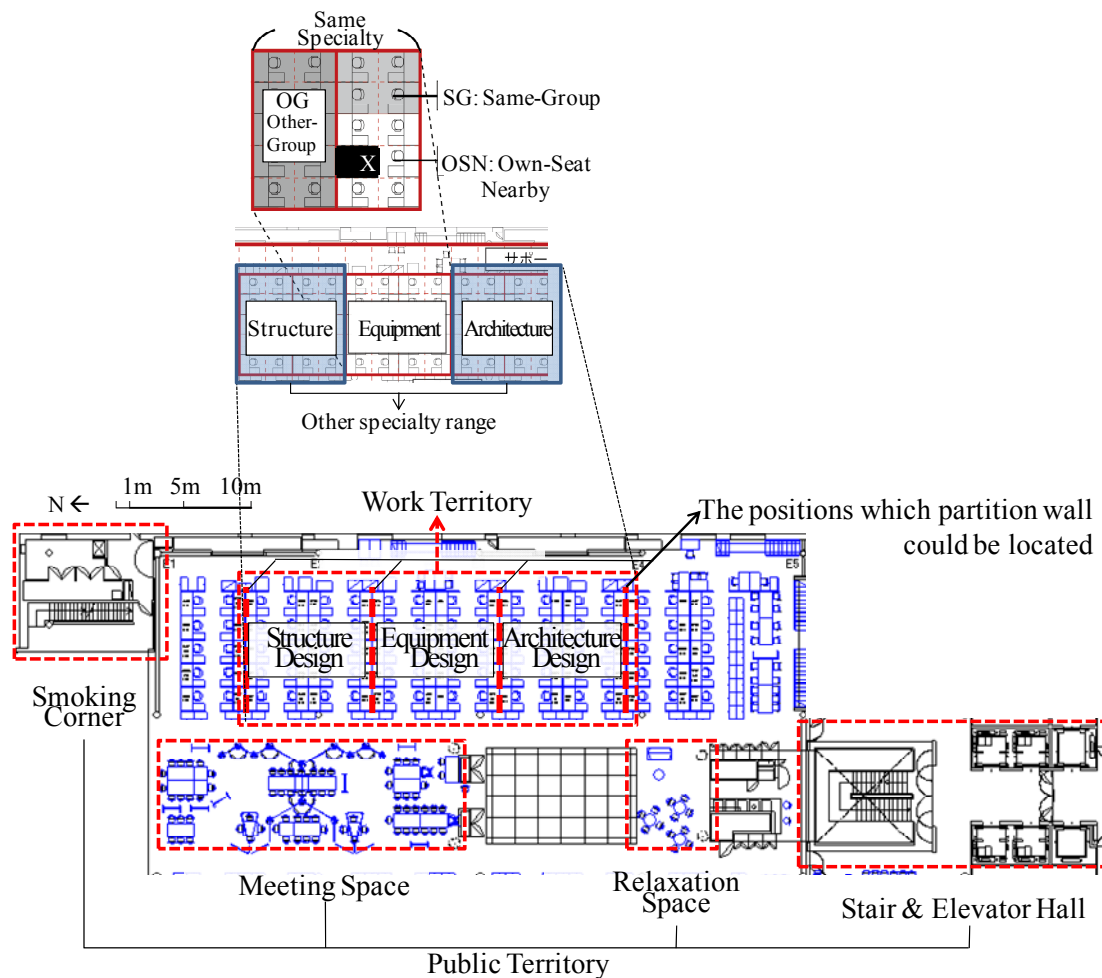


Figure 5-3 The classification of location zones

Based on post attribute, workers were classified into two main categories—“PL” (project leader) and “RS” (regular staff)—or into another three categories—“ADS” (architecture design staff), “EDS” (equipment design staff), and “SDS” (structure design staff)—depending upon which they belonged to. Databases that combine the investigated data and worker attributes were then constructed (Table 5-2).

Table 5-2 Database Sample- WOP workplace

Data ID	Date	Subject attributes			Time attributes			Staying or Move	Location	Verbal Communication	
		Subject ID	Post	Specialty	Start time	End time	Lastest duration [second]			Frequency	Duration Sum [second]
1	12/14/2009	1	RS	EDS	9:23:48	9:24:42	54	Staying	Own-Seat Nearby	1	36
2	12/14/2009	1	RS	EDS	9:24:42	9:24:54	12	Move	-	0	0
3	12/14/2009	1	RS	EDS	9:24:54	9:29:57	303	Staying	Relaxation Space	1	303
4	12/14/2009	1	RS	EDS	9:29:57	9:30:09	12	Move	-	0	0
5	12/14/2009	1	RS	EDS	9:30:09	9:31:12	63	Staying	Own-Seat Nearby	0	0
6	12/14/2009	1	RS	EDS	9:31:12	9:31:27	15	Move	-	1	5
7	12/14/2009	1	RS	EDS	9:31:27	9:32:57	90	Staying	Smoking Corner	1	90
8	12/14/2009	1	RS	EDS	9:32:57	9:33:36	39	Move	-	0	0
9	12/14/2009	1	RS	EDS	9:33:36	9:40:39	831	Staying	Own-Seat Nearby	2	1662
10300	12/18/2009	33	PL	ADS	11:21:04	11:21:04	0	Staying	Relaxation Space	0	0
10301	12/18/2009	33	PL	ADS	11:32:00	11:33:00	1194	Staying	Relaxation Space	0	0
10302	12/18/2009	33	PL	ADS	11:51:54	11:54:57	183	Move	-	1	90
10302	12/18/2009	33	PL	ADS	11:54:57	12:08:15	798	Staying	Own-Seat Nearby	0	0

PL: Project leader; RS: Regular staff; TS: Temporary staff.

ADS: Architecture design staff; EDS: Equipment design staff; SDS: Structure design staff.

5.3 Comparison of space use and verbal communication in each workplace

In order to differentiate workers' different space use and verbal-communication patterns within the WP and WOP workplaces, the following items were calculated and compared using a Z test or T test, depending upon the sample size:

- ① S-DR: staying duration rate - average proportion of durations at different defined places where each worker stayed;
- ② S-F: staying frequency - how frequently each worker stayed on average;
- ③ VC-DR: verbal communication duration rate - average proportion of durations at different defined places where each worker's verbal communication occurred;
- ④ VC-F: verbal communication frequency - how frequently each worker's verbal communication occurred on average.
- ⑤ The quotient of the duration of verbal communication divided by the staying duration in each place was also calculated, in order to clarify the probability of verbal communication when workers stayed at the places in the workplace.

Formula (5.1).

$$VC / S - DQ_{e,i} = \frac{\sum_d^D \sum_e^E Tvc_{d,e,i}}{\sum_d^D \sum_e^E Ts_{d,e,i}} \dots (5.1)$$

Ts : Duration of staying [second].

Tvc : Duration of verbal communication [second].

E : Worker's specialty and post attribute.

D : Investigation dates.

i : Location id in each workplace.

5.3.1 Workers' use of locations in each workplace

Compared in terms of S-DR and S-F, Table 5-3 shows that in both the WP and WOP workplaces, workers spent around 85% of their time within the workplace, 5% of which they spent on moving around. When workers stayed at the different specified places within each workplace, they stayed at "Own-seat nearby" over 55% of whole duration, both longer and more frequently; next came the "Meeting Space" (S-DR: over 10%; S-F: 0.4 time/hour). The "Same-Group" range, the "Other Specialty", and the "Relaxation Space" were occupied less frequently. The least used areas were the "Other-Group", the "Smoking Corner", and the "Stair & Elevator Hall".

Table 5-3 Comparison of Workers' Staying in WP and WOP workplaces

Items	Partition walls setting	Work Territory				Public Territory				Move in workplace	Outside workplace
		Own-Seat Nearby	Same-Group	Other-Group	Other Specialty	Meeting Space	Relaxation Space	Smoking Corner	Stair & Elevator hall		
S-DR [%]	WP	59.5 (20.4)	2.4 (3.8)	0.5 (1.3)	1.2 (2.5)	11.1 (14.2)	2.2 (4.8)	0.9 (1.9)	0.4 (0.7)	5.3 (2.3)	16.5 (15.7)
	WOP	* 55.8 (18.4)	2.8 (3.7)	0.6 (1.3)	** 4.7 (8.4)	10.3 (13.3)	2.7 (5.8)	1.1 (2.3)	** 0.1 (0.5)	** 6.1 (2.4)	15.8 (11)
S-F [Time/hour]	WP	2.3 (1.3)	0.5 (0.6)	0.1 (0.2)	0.3 (0.4)	0.4 (0.5)	0.3 (0.4)	0.1 (0.3)	0.1 (0.2)	4.7 (2.6)	0.8 (0.5)
	WOP	* 2.1 (0.9)	0.4 (0.5)	0.1 (0.2)	** 0.6 (0.7)	0.4 (0.5)	0.3 (0.4)	0.1 (0.3)	0.1 (0.1)	4.9 (2)	* 0.9 (0.5)

WP: with partition; WOP: without partition. Number in blanket: Standard deviation S: Staying; DR: Duration rate; F: Frequency

* p<0.05 **p<0.01 (p: significant difference by comparing the item of WOP with WP)

According to Table 5-4 and Fig. 5-4, in both WP and WOP workplaces, when workers used the space for staying, without considering the location of space, over 10% of staying frequency is within 1 min/time. Around 30% of staying frequency is 1~5 min/time, around 15% of staying frequency is 5~10 min/time, only 13~17% of staying frequency is over 30 min/time.

In the work territory, the workers of both WP and WOP workplaces used the "Own-seat nearby" for long time staying more frequently, proved by 60% of their staying frequency there is over 5 min/time. Also in the work territory, when workers used the "Same-Group", "Other-Group" and "Other Specialty" for short time staying more, as around 60% of their staying frequency is within 5 min/time.

In the public territory, the workers of both WP and WOP workplaces used the "Meeting space" for long time staying more frequently, as over 50% of their staying frequency there is over 10 min/time. The "Relaxation Space" and the "Smoking Corner" is used by workers for short time staying more frequently, as around 70% of their staying frequency is within 5 min/time.

By comparing the proportion of workers staying frequency according to duration per unit time in WP workplace and the WOP workplace, the most significant difference appeared at the "Other-Group". As in WP workplace, 41% of workers' staying

frequency is within 1 min, 22% higher than the ones of the WOP workplace workers. The reason might be, as the visual contact was blocked by the partition walls, the workers sometimes would visit the staffs in other specialty ranges without knowing the one he/she visited was absent, and therefore caused the short time staying there.

Table 5-4 Workers' staying frequency according to duration per time

WP workplace

Staying duration per time: t [min]	Work territory				Service territory				Sum
	Own-Seat Nearby	Same-Group	Other-Group	Other Specialty	Meeting Space	Relaxation Space	Smoking Corner	Stair & Elevator hall	
t≤1	171 (8.6)	49 (22.6)	16 (23.2)	72 (40.9)	31 (10)	64 (31.2)	3 (2.2)	48 (51.9)	452 (13.1)
1<t≤5	587 (29.8)	104 (47.9)	35 (50.7)	78 (44.3)	74 (24.4)	82 (40)	81 (72.6)	31 (33.9)	1072 (35.3)
5<t≤10	316 (16)	26 (12)	9 (13)	14 (8)	44 (14.5)	23 (11.2)	26 (23.3)	12 (13.1)	470 (15)
10<t≤30	558 (28.3)	33 (15.2)	7 (10.1)	11 (6.3)	90 (29.7)	29 (14.1)	2 (1.8)	1 (1.1)	731 (23.1)
30<t	340 (17.2)	5 (2.3)	2 (2.9)	1 (0.6)	65 (21.4)	7 (3.4)	0 (0)	0 (0)	420 (13.5)
Sum	1972 (100)	217 (100)	69 (100)	176 (100)	304 (100)	205 (100)	112 (100)	92 (100)	3145 (100)

Number in blanket: Proportion of frequency in given staying duration per time [%].

WOP workplace

Staying duration per time: t [min]	Work territory				Service territory				Sum
	Own-Seat Nearby	Same-Group	Other-Group	Other Specialty	Meeting Space	Relaxation Space	Smoking Corner	Stair & Elevator hall	
t≤1	114 (7.8)	10 (21.3)	6 (21.4)	80 (19)	3 (1.1)	49 (29.5)	3 (2.3)	15 (57.7)	278 (11.1)
1<t≤5	350 (24.1)	16 (36)	10 (35.7)	171 (40.6)	68 (25.9)	67 (40.7)	68 (62.7)	7 (26.9)	757 (30.2)
5<t≤10	245 (16.9)	8 (18)	6 (21.4)	81 (19.2)	45 (17.1)	13 (7.9)	26 (24)	3 (11.5)	427 (17)
10<t≤30	415 (28.6)	7 (15.7)	5 (17.9)	71 (16.9)	84 (31.9)	29 (17.6)	12 (11.1)	1 (3.8)	624 (24.9)
30<t	327 (22.5)	4 (9)	1 (3.6)	18 (4.3)	63 (24)	7 (4.3)	0 (0)	0 (0)	420 (16.8)
Sum	1451 (100)	45 (100)	28 (100)	421 (100)	263 (100)	165 (100)	109 (100)	26 (100)	2506 (100)

Number in blanket: Proportion of frequency in given staying duration per time [%].

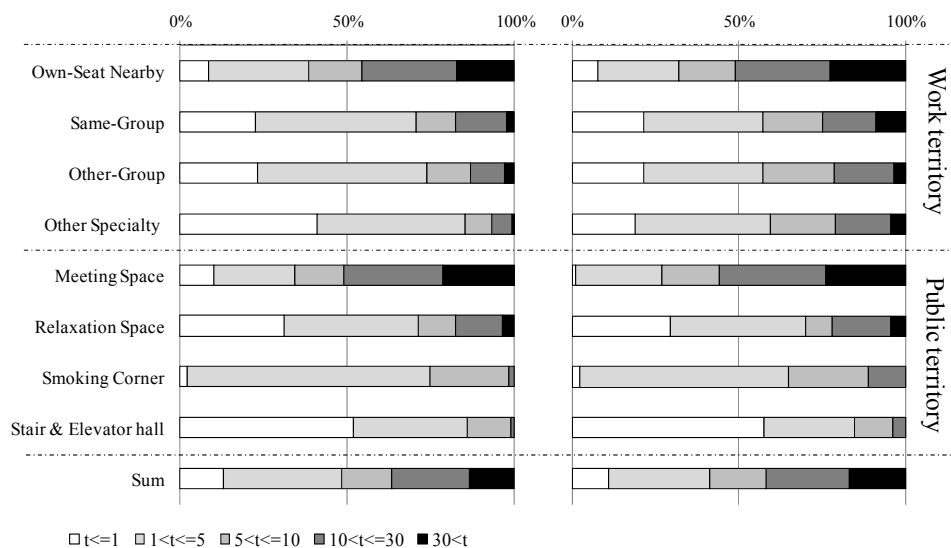


Figure 5-4 Proportion of workers staying frequency according to duration per unit time

5.3.2 Workers' verbal communication in places in each workplace

As shown in Table 5-5, a comparison of VC-DR and VC-F in both workplaces showed the same sequence of values as shown above. To be specific, the “Own-seat nearby” zone was used for verbal communication by workers most of all (VC-DR: over 45%; S-F: over 1 time/hour). It was followed by the “Meeting Space” (VC-DR: over 20%; S-F: 0.3 time/hour), and then by the “Same-Group” range, the “Other Specialty”. The “Relaxation Space”, which were also occupied and used for verbal communication (VC-DR: 3.1%~8.1%; VC-F: within 0.3 time/hour).

Table 5-5 Comparison of Workers' Verbal Communication in WP and WOP workplaces

Items	Partition walls setting	Work Territory				Public Territory				Move in workplace	Outside workplace
		Own-Seat Nearby	Same-Group	Other-Group	Other Specialty	Meeting Space	Relaxation Space	Smoking Corner	Stair & Elevator hall		
VC-DR [%]	WP	47.3 (27.4)	8.1 (15.1)	1.6 (5.6)	3.1 (6.7)	27.5 (35.1)	4.6 (10.4)	2.5 (6)	0.3 (0.9)	5 (4.4)	-
	WOP	45.4 (25.7)	6.1 (7.9)	1.1 (2.5)	** 8.2 (15.1)	22.4 (24.7)	6.7 (15.8)	2.1 (5.3)	0.2 (1)	** 7.8 (6.3)	-
VC-F [Time/hour]	WP	1.4 (1.1)	0.3 (0.5)	0.1 (0.2)	0.2 (0.3)	0.3 (0.5)	0.2 (0.3)	0.1 (0.2)	0 (0)	1.7 (1.4)	-
	WOP	** 2.1 (0.9)	* 0.4 (0.4)	0.1 (0.2)	* 0.3 (0.5)	0.3 (0.4)	0.2 (0.3)	0.1 (0.2)	0 (0.1)	1.8 (0.9)	-

WP: with partition; WOP: without partition. Number in bracket: Standard deviation VC: Verbal communication; DR: Duration rate; F: Frequency
* p<0.05 **p<0.01 (p: significant difference by comparing the item of WOP with WP)

5.3.3 Comparison of workers' space use and verbal communication in different workplaces

A comparison of the relevant items in the each workplace (in Tables 5-3 and 5-5) shows that, the duration and frequency of workers' staying and engaging in verbal communication in “Other Specialty” area at WOP workplace was significantly higher. Although workers' S-DR and S-F “Own-seat nearby” in the WOP workplace was significantly lower (S-DR: 55.8 vs. 59.5; S-F: 2.1 vs. 2.3), its VC-F was significantly higher (VC-F: 2.1 vs. 1.4).

5.3.4 Comparison of proportions of workers' verbal communication while at different locations in the two workplaces

As presented in Table 5-6, at places designated “Work Territory” in both the WP and WOP workplaces, except for the “Own-seat nearby”, the VC/S-DQs are over or around 80%. This means that when workers left the “Own-seat nearby” area for other

Table 5-6 Comparison of Workers' VC/S-DQ in WP and WOP workplaces

Items	Partition walls setting	Work Territory				Public Territory				Move in workplace	Sum
		Own-Seat Nearby	Same-Group	Other-Group	Other Specialty	Meeting Space	Relaxation Space	Smoking Corner	Stair & Elevator hall		
VC/S-Q [%]	WP	20.8	91.9	89.4	82.0	92.6	78.0	72.1	21.9	22.5	30.5
	WOP	34.4	91.1	80.0	79.3	91.8	82.8	70.3	48.6	46.3	48.3

WP: with partition; WOP: without partition. VC/S-Q: the quotient of verbal communication duration divided by staying duration

places in the “Work Territory”, the probability of verbal communication occurring is very high. In the “Public Territory”, the VC/S-DQ of the “Meeting Space” was the highest of all (over 90%), which showed how conducive it was to verbal communication. Next came the “Relaxation Space” (around 80%) and the “Smoking Corner” (around 70%), which showed that these places also play a significant role in promoting verbal communication in the “Public Territory”.

By comparing the VC/S-DQ of the WP workplace with that of the WOP workplace, it was found that Sum of VC/S-DQ of the WOP workplace is much higher than that of the WP workplace. The same higher tendency appeared at the VC/S-DQ of the “Own-seat nearby” in the WOP workplace (WP: 20.8 vs. WOP: 34.4). Although the VC/S-DQs of the “Stair & Elevator Hall” and the “Moving in workplace” in each workplace were also different, the influence of these differences was not significant, considering the lower S-DRs at these places. This result shows that there is a higher proportion of verbal communication among workers when they stayed “Own-seat nearby” in the WOP workplace.

The above analysis shows that in the “Work Territory” of both the WP and WOP workplaces, workers’ stayed and orally communicated the most when staying at the “Own-seat nearby”. When they left “Own-seat nearby” for other places in the work territory, the proportion of their verbal communication in staying duration was over 80%. In the “Public Territory”, the “Meeting Space” was stayed in the most for verbal communication, while the “Relaxation Space” and the “Smoking Corner” were also strongly characterized by verbal communication among workers. Compared with the WP workplace, the WOP workplace made workers to visit and orally communicate with workers in other specialties more, as indicated by a 3.5% higher S-DR and 5.1% higher VC-DR. At the same time, the proportion of workers’ verbal communication when staying “Own-seat nearby” was 13.6% higher.

5.4 Comparison of space use and verbal communication according to workers’ post and specialty in each workplace

In this section, the author compared the workers’ space use and verbal communication in each workplace, in terms of post and specialty.

5.4.1 Comparison of space use and verbal communication on the basis of post

According to Tables 5-7 and 5-8, a comparison of the different workplace workers' staying and verbal communication in terms of post showed the same differences as were revealed in Section 5.3.3. To be specific, the S-DR, S-F, VC-DR, and VC-F of both the PL and RS at the "Other Specialty" in the WOP workplace were significantly higher than they were in the WP workplace. In addition, compared with PL, only the RS's VC-F "Own-seat nearby" was significantly higher (WP:1.3 vs. WOP:2.2), while the difference in the VC/S-DQ of the two workplaces is greater (WP:18.8 vs. WOP:34.1). At the same time, their VC-DR in the "Meeting Space" was significantly lower. This result shows that the WOP workplace induced both PL and RS to visit and orally communicate more in other specialty areas. Moreover, the WOP workplace made RS orally communicated more frequently, and also induced a higher proportion of communication among those staying at "Own-seat nearby". Thereby it causing them to orally communicate less in the "Meeting Space". On the contrary, the results of PL remained almost unchanged in the "Meeting Space".

Upon combining the items of PL with those of RS in both the WP and WOP workplaces, the author see that in both workplaces, PL's Sum of VC/S-DQ is around 10% higher than that of RS. This result indicates that their type of work requires more verbal communication at "Own-seat nearby" in the Work Territory, the S-DRs of PL are significantly lower (around 6-8%) than those of RS, though their VC/S-DQs are higher than those of RS. In addition, compared with RS in both workplaces, PLs' staying and communicating in the "Meeting Space" was significantly more. This result is indicated by an approximately 10% higher S-DR, an over 0.2 time/hour higher S-F, an over 10% higher VC-DR, and an approximately 0.3 higher time/hour VC-F. On the contrary, the values for PLs' same items in the "Relaxation Space" were significantly lower.

The above results show that, compared to the WP workplace, both PL and RS stayed at and orally communicated more in the "Other Specialty" space. In addition, in the WOP workplace, the difference in RS' verbal communication upon staying "Own-seat nearby" in the two workplaces was 15.3%, much more than that of PL. Moreover, the comparison of PL and RS in both workplaces showed that PLs' work requires more verbal communication, which causes them to stay and orally communicate more in the "Meeting Space". Additionally, even on staying at "Own-seat nearby" the probability of PLs' verbal communication was higher.

Table 5-7 Comparison of workers' Staying and Verbal Communication in WP and WOP Workplaces by post

Items	Post	Work Territory						Public Territory						Move in Workplace		Outside Workplace								
		Own-Seat Nearby			Other-Group			Other Specialty			Meeting Space		Relaxation Space				Smoking Corner		Stair & Elevator hall					
		WP	WOP		WP	WOP		WP	WOP		WP	WOP		WP	WOP			WP	WOP		WP	WOP		WP
S-DR [%]	PL	●54.8 (19)	●49 (14.9)	2.3 (2.5)	2.4 (1.9)	0.4 (1)	0.5 (0.9)	1.2 (1.8)	5.2 (5.6)	▲17.2 (16.5)	▲17.6 (14)	●0.7 (1.1)	●0.9 (1.9)	0.4 (0.4)	▲0.5 (1.1)	5.5 (1.4)	6.5 (2.2)							
	RS	60.7 (20.6)	57.2 (18.8)	2.5 (4)	2.9 (4)	0.5 (1.4)	0.6 (1.4)	1.2 (2.6)	4.6 (8.9)	9.6 (13.2)	8.7 (12.7)	2.6 (5.3)	3 (6.2)	0.9 (0.8)	1.2 (0.2)	5.3 (2.5)	6.1 (2.5)							
S-F [Time/hour]	PL	2.1 (1.2)	●2 (0.6)	0.6 (0.6)	0.5 (0.4)	0.1 (0.1)	▲0.2 (0.2)	0.2 (0.4)	▲0.8 (0.7)	▲0.6 (0.4)	▲0.6 (0.4)	●0.1 (0.1)	0.2 (0.3)	0.1 (0.2)	0.2 (0.2)	4.3 (2.2)	▲5.4 (1.5)							
	RS	2.4 (1.3)	2.2 (0.9)	0.4 (0.6)	0.4 (0.5)	0.1 (0.2)	0.1 (0.2)	0.3 (0.4)	0.6 (0.7)	0.4 (0.5)	0.3 (0.5)	0.3 (0.4)	0.3 (0.4)	0.1 (0.3)	0.1 (0.2)	4.7 (2.7)	4.8 (2)							
VC-DR [%]	PL	45.7 (24.2)	●40.6 (21.9)	5.4 (6.8)	5.3 (4.2)	1 (2.8)	1.1 (1.9)	3.5 (3.9)	8.7 (12.3)	▲37 (27.1)	▲34.7 (26.1)	●1.8 (4.4)	●1.3 (3.8)	1.5 (3.4)	●0.7 (2.1)	3.8 (3.5)	6.8 (3.5)							
	RS	47.4 (28.1)	49.3 (26.1)	8.8 (16.5)	6.3 (8.4)	1.7 (6.1)	1.2 (2.6)	3.3 (7.2)	7.7 (15.6)	25.2 (26.6)	17.3 (23.3)	5.3 (11.3)	7.8 (17.1)	2.7 (6.5)	2.4 (5.7)	5.3 (4.5)	8 (6.7)							
VC-F [Time/hour]	PL	1.4 (1.1)	●1.7 (0.6)	0.4 (0.4)	▲0.5 (0.4)	0.1 (0.1)	▲0.1 (0.2)	0.2 (0.2)	▲0.6 (0.5)	▲0.6 (0.4)	▲0.5 (0.4)	●0.1 (0.1)	0.2 (0.3)	0.1 (0.2)	0.1 (0.1)	1.8 (1.4)	▲1.8 (0.9)							
	RS	1.3 (1.1)	2.2 (0.9)	0.3 (0.5)	0.4 (0.4)	0.1 (0.2)	0.1 (0.1)	0.2 (0.4)	0.4 (0.5)	0.3 (0.5)	0.2 (0.6)	0.2 (0.3)	0.2 (0.3)	0.1 (0.2)	0.1 (0)	1.6 (1.4)	1.3 (0.9)							
S Staying.	VC: Verbal communication. DR: Duration rate. F: Frequency. WP: with partition; WOP: without partition. Number in blanket: Standard deviation																							

S: Staying. VC: Verbal communication. DR: Duration rate. F: Frequency. WP: with partition; WOP: without partition. Number in blank: Standard deviation
 * p<0.05 **p<0.01 (p: significant difference by comparing the item of WOP with WP) PL: Project leader; RS: Regular staff
 ▲:Significantly higher than others in the same workplace p<0.05; ● :Significantly lower than other in the same workplace

Table 5-8 Comparison of workers' VC/S-DQ in WP and WOP Workplace according to post

Items	Post	Work Territory						Public Territory				Move in Workplace		Sum							
		Own-Seat Nearby		Same-Group		Other-Group		Other Specialty		Meeting Space					Relaxation Space		Smoking Corner		Stair & Elevator hall		
		WP	WOP	WP	WOP	WP	WOP	WP	WOP	WP	WOP	WP	WOP		WP	WOP	WP	WOP	WP	WOP	
VC/S-DQ	PL	31.3	35.4	90.5	93.5	96.8	98.3	71.6	83.3	91.7	93.3	76.7	77.5	75.7	61.3	25.6	70.7	21.6	50.2	39.2	55.1
[%]	RS	18.8	34.1	92.2	89.2	88.0	76.5	84.6	78.3	91.0	88.4	78.0	84.4	71.6	67.5	20.9	16.2	22.7	45.3	28.5	46.7

VC/S-DQ: the quotient of verbal communication duration divided by stay duration. WP: with partition; WOP: without partition. PL: Project leader; RS: Regular staff

VC/S-DQ: the quotient of verbal communication duration divided by stay duration. WP: with partition; WOP: without partition. PL: Project leader; RS: Regular staff

5.4.2 Comparison of space use and verbal communication on the basis of specialty

As shown in Tables 5-9 and 5-10, regardless of their specialty, the staff's S-DR, S-F, VC-DR, and VC-F at the "Other Specialty" in the WOP workplace were significantly higher, except for the ADS's VC-DR. In addition, all staffs' VC-F and VC/S-DQ of "Own-seat nearby" was higher. This analysis shows that the WOP workplace induced staffs from all specialties to visit and orally communicate more at the "Other Specialty", and induced the staffs to orally communicate more when staying "Own-seat nearby". However, unlike the staffs of the other two specialties, the EDS's S-DR and S-F "Own-seat nearby" in the WOP workplace were significantly lower than those in the WP workplace. At the same time, the differences in S-DR, S-F, VC-DR, and VC-F in both workplaces were much more than that of other two specialties. This result might be due to the location of the ED specialty, in that the center position made it more convenient for the EDS to visit and stay in "Other Specialty", particularly in the WOP workplace.

The author then correlated the staff staying and engaging in verbal communication for each specialty in both the WP and WOP workplaces. The results showed that in both workplaces, ADS's Sum of VC/S-DQ was more than 0.6% higher than the same items of the staffs in the other two specialties. This result indicates that the work type of ADS requires a greater degree of verbal communication in staying duration. At the same time, ADSs' VC/S-DQ at "Own-seat nearby" in both workplaces was also the highest of all. Furthermore, they had a significantly greater degree of staying and verbal communication in the "Relaxation Space", as indicated by an over 3.5% higher S-DR, an over 0.3 time/hour higher S-F, an over 8.6% higher VC-DR, an over 0.2 time/hour higher VC-F, and an over 40% higher VC/S-DQ. These results may be due to the location of their specialty range located further away from the "Meeting Space". Therefore, it makes them more likely to stay and communicate in the "Relaxation Space", which is nearer to their specialty range and more convenient to access.

EDS's Sum of VC/S-DQ in both workplaces was lower than that of ADS but higher than that of SDS. In particular, compared with staffs from other specialties, EDS's staying and verbal communication in the "Other Specialty" places was significantly more, as indicated by an over 0.3 time/hour higher S-F, an over 3.1% higher VC-DR, and an over 0.2 time/hour higher VC-F. This result may be due to the location of their specialty range, which is between the other two specialty ranges, thus, making it more convenient for them to visit other specialties.

Table 5-9 Comparison of workers' Staying and Verbal Communication in WP and WOP Workplaces by Specialty

Items	Specialty	Work Territory						Public Territory						Move in Workplace		Outside Workplace				
		Own-Seat Nearby	Same-Group		Other-Group		Other Specialty	Meeting Space	Relaxation Space		Smoking Corner	Stair & Elevator hall								
			WP	WOP	WP	WOP			WP	WOP		WP	WOP	WP	WOP		WP	WOP		
S-DR [%]	ADS	60.8 (19.8)	58.7 (16)	2.1 (3.4)	2.8 (4.3)	0.6 (1.3)	0.8 (1.3)	1.2 (2.9)	2.7 *	10.4 (11.9)	9 (13.1)	5 ▲ (6.9)	5.1 (7.8)	1.2 (2.4)	1.1 (0.6)	0.3 (0.8)	5.4 (2.2)	6.1 * (2.7)	13 (11.5)	13.6 (8.8)
	EDS	58.3 (17.7)	50.5 * (20.2)	2.9 (4.2)	2.8 (3.9)	0.3 (0.8)	0.5 (1.2)	1.9 ▲ (2.7)	7.8 ** (10.4)	9 (9.9)	10.9 (14.9)	9 (2.9)	1.6 (4)	1.1 (2.6)	0.8 (0.9)	0.3 (0.2)	5.9 (2.7)	6.3 (2.4)	19.4 (15.2)	18.3 (13.4)
	SDS	59.6 (24)	59.3 (17.4)	2.1 (3.5)	2.8 (2.3)	0.5 (1.7)	0.5 (1.5)	▲ (0.4)	3.1 ** (5.7)	14.7 (19.8)	11.3 (11)	0.7 (1.2)	0.7 (1.9)	0.8 (1.6)	0.5 (0.4)	0.1 (0.1)	4.5 (1.6)	5.8 ** (1.9)	16.7 (19.3)	15.5 (9.2)
S-F [Time/hour]	ADS	2.6 (1.5)	2.3 (0.8)	0.5 (0.7)	0.4 (0.5)	0.2 (0.3)	0.1 (0.2)	0.2 (0.2)	0.4 ** (0.6)	0.4 (0.6)	0.3 (0.6)	▲ (0.5)	0.5 (0.5)	0.2 (0.4)	0.1 (0.2)	0.1 (0.2)	5 (3.2)	5.3 (2.5)	0.9 (0.5)	1 (0.6)
	EDS	2.3 (1.2)	1.8 * (0.9)	0.6 (0.7)	0.5 (0.5)	0.1 (0.1)	0.1 (0.2)	▲ (0.6)	0.9 ** (0.9)	0.4 (0.5)	0.4 (0.5)	0.2 (0.2)	0.2 (0.2)	0.1 (0.3)	0.2 (0.2)	▲ (0.1)	4.8 (2.6)	4.8 (1.7)	0.8 (0.6)	1 (0.5)
	SDS	2.1 (0.9)	2.3 (0.8)	0.4 (0.3)	0.5 (0.4)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)	0.4 ** (0.5)	0.5 (0.4)	0.4 (0.4)	0.2 (0.2)	0.2 (0.2)	0.1 (0.1)	0.1 (0.1)	0 * (0.1)	4 (1.7)	4.6 (1.2)	0.8 (0.4)	0.8 (0.4)
VC-DR [%]	ADS	51.2 (25.9)	50.4 (23.8)	6.2 (11.6)	6.3 (10.4)	1.5 (4)	1.5 (2.4)	2.3 (6.9)	4.5 (11.5)	19.2 (20.8)	15.8 (21.7)	▲ (10.7)	12.2 (19.4)	3.2 (8)	1.8 (4.7)	0.4 (0.9)	5.3 (3.2)	6.9 ** (5.4)	-	-
	EDS	46 (24.8)	41.9 (28.6)	9.5 (18.7)	5.7 (6.2)	1.5 (2.5)	1.3 (3.1)	▲ (8)	13 ** (18.6)	27.6 (25.3)	23.1 (27.4)	1 (3.3)	3.2 (5.3)	2.3 (5.7)	0.2 (0.7)	0 * (0.2)	6.4 ▲ (3.3)	9.4 * (4.7)	-	-
	SDS	45.7 (31.7)	45.8 (22.6)	6.7 (12.9)	6.4 (5.2)	2.3 (9.1)	0.3 (1.1)	1.1 (2.1)	6.8 * (12)	▲ (37.1)	30.7 (40.4)	2.1 (4.8)	1.9 (4.8)	0.9 (3)	2.2 (5.5)	0.3 (1)	3.8 (3.3)	5.8 (4.7)	-	-
VC-F [Time/hour]	ADS	1.6 (1.4)	2.3 *** (0.8)	0.4 (0.6)	0.5 (0.5)	0.1 (0.3)	0.1 (0.2)	0.1 (0.2)	0.2 * (0.3)	0.4 (0.6)	0.3 (0.4)	▲ (0.4)	0.3 (0.3)	0.1 (0.3)	0.1 (0.2)	0 (0.1)	1.8 (1.6)	1.6 (1)	-	-
	EDS	1.3 (1)	1.8 ** (0.9)	0.4 (0.6)	0.3 (0.4)	0.1 (0.1)	0.1 (0.2)	▲ (0.3)	0.5 * (0.6)	0.3 (0.4)	0.3 (0.4)	0.1 (0.1)	0.1 (0.2)	0.1 (0.2)	0.1 (0.1)	0 (0)	1.9 (1.5)	1.5 * (0.9)	-	-
	SDS	1.1 (0.6)	2.3 *** (0.8)	0.2 (0.3)	0.4 (0.4)	0.1 (0.1)	0 (0.1)	0.1 (0.1)	0.3 * (0.3)	0.4 (0.4)	0.3 (0.2)	0.1 (0.1)	0.1 (0.2)	0 (0.1)	0 (0)	0 (0)	1.1 (0.6)	0.9 (0.6)	-	-

S: Staying. VC: Verbal communication. DR: Duration rate. F: Frequency. WP: with partition; WOP: without partition. Number in blank: Standard deviation
 * p<0.05 **p<0.01 (p: significant difference by comparing the item of WOP with WP) ADS: Architecture design staff; EDS: Equipment design staff; SDS: Structure design staff
 ▲: Significantly higher than others in the same workplace p<0.05; ●: Significantly lower than other in the same workplace

Table 5-10 Comparison of workers' VC/S-DQ in WP and WOP Workplace according to Specialty

Items	Specialty	Work Territory						Public Territory						Moving in Workplace		Sum			
		Own-Seat Nearby	Same-Group		Other-Group		Other Specialty	Meeting Space	Relaxation Space	Smoking Corner	Stair & Elevator hall		WP	WOP	WP	WOP			
			WP	WOP	WP	WOP					WP	WOP					WP	WOP	
VC/S-DQ [%]	ADS	26.1	38.0	89.3	94.7	90.5	96.3	83.1	82.5	88.5	83.8	81.5	80.1	31.6	58.0	26.1	46.8	35.4	50.5
	EDS	18.8	33.7	93.1	89.7	86.6	99.6	82.2	78.5	95.6	95.7	34.8	42.5	65.4	68.4	11.5	5.9	22.9	49.9
	SDS	17.5	30.5	92.3	84.3	90.5	92.1	75.4	84.3	90.0	85.6	43.2	29.9	64.7	60.1	29.8	37.8	17.1	39.3

VC/S-DQ: the quotient of verbal communication duration divided by stay duration. WP: with partition; WOP: without partition.
 ADS: Architecture design staff; EDS: Equipment design staff; SDS: Structure design staff

SDS's Sum of VC/S-DQ and the VC/S-DQ of "Own-seat nearby" in both workplaces was the lowest of all. However, their VC-DR in the "Meeting Space" was significantly higher than that of the staffs of the other two specialties. The above result indicates that, the Structure Design staffs orally communicated less at their "Own-seat nearby", but used the "Meeting Space" more for verbal communication.

5.5 Conclusions

In this chapter, the author compared workers' space use and verbal communication patterns in a big open plan workplace without partition walls (WOP) and a workplace in which partition walls (WP) separated the specialty ranges. It was ascertained how workers used the spaces of each workplace, and the characteristics of workers' space use and verbal communication in each workplace were clarified in terms of the workers' posts and specialties. The findings are summarized as follows:

1) In both the WP and WOP workplaces, workers spent over 55% of the duration on staying at "Own-seat nearby" of the "Work Territory", where around 50% of their verbal communication time was spent. After "Own-seat nearby", it came the "Meeting Space" in the "Public Territory", where over 20% of workers' verbal communication time was spent. Compared to workers in the WP workplace in terms of duration rate, workers in the WOP workplace stayed 3.5% more and orally communicated 5.1% more in the "Other Specialty" areas. At the same time, the proportion of their verbal communication when staying "Own-seat nearby" was 13.6% more.

2) A comparison of the two workplace workers' staying and verbal communication according to their post showed that the regular staffs' difference in communicating "Own-seat nearby" is 15.3%, much more than that of the project leaders. Meanwhile, other than this, compared in terms of duration rate, project leaders' proportion of verbal communication staying inside workplace is around 10% higher than that of the regular staff. Meanwhile, around 35% of their verbal communication duration took place occurred in the "Meeting Space", which is over 10% higher and 0.3 time/hour more frequently than that of the regular staffs.

3) A comparison of the three specialty staffs' corresponding behavior patterns showed that, the architecture design staffs' proportion of verbal communication staying inside the workplace was highest of all, especially the ones "Own-seat nearby". Meanwhile, over 10% of their verbal communication duration took place in the "Relaxation Space", which is close to their specialty range. This is significantly higher

than the value for the other specialty staffs. Compared in terms of duration rate, the equipment design staffs' staying and verbal communication in the "Other Specialty" places were significantly higher than they were for the other specialty staffs. The structure design staffs' proportion of verbal communication staying inside the workplace was lowest of all, particularly for those "Own-seat nearby".

One important innovative rationale for not using partition walls in a big open plan workplace is to promote communication between workers, especially promote regular staffs more. The findings of this chapter revealed that there was a higher degree of worker communication in the space without partition walls. The detailed findings for the characteristics of workers' space use and verbal communication in terms of post and specialty will be helpful in improving the current layout of territorial workplaces. For example, project leaders' workstations should be located close to the meeting space, since this would make it more convenient for them visit and stay there. In addition, by the analysis, it is found that the architecture design staffs used the relaxation space more frequently for staying and communication as their range is further from meeting space. Therefore, in the workplace layout design, the frequently used public space, such as meeting space, should be distributed evenly to each specialty range. Otherwise the staffs, whose range located further from the meeting space, would use the adjacent public space for meeting.

Note

*1 The verbal communication in this study means the talking and communication detected by worker's voice, therefore the workers' talking on telephone, which is mostly happened at their own seat nearby, is also defined as verbal communication as same as face-to-face communication; additionally, by the testing and suitable wearing method, it have showed that the environmental noise, such as copy machine or broadcasting in noon rest, would not influence the recording accuracy of voice sensor.

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Chapter 6 Conclusion

- 6.1 Summary of the findings in each chapter
 - 6.1.1 Investigation method on the space use and verbal communication by means of sensing technology
 - 6.1.2 Findings concerning the workers' space use and choosing individual workstation behavior in a non-territorial workplace
 - 6.1.3 Findings concerning the workers' pattern of space use behavior in territorial and non-territorial workplaces
 - 6.1.4 Findings concerning the workers' space use and verbal communication patterns in big open plan workplace with and without partition walls
- 6.2 Findings of this dissertation
- 6.3 Future research

6.1 Summary of the findings in each chapter

The uniqueness of this research lies in the clarification of knowledge worker's space use in the territorial and non-territorial workplace, and the space use and verbal communication behavior in the big open plan workplace with and without partition walls. Firstly, the author defined the behavior items (such as the staying, movement and verbal communication behavior) according to the characteristics of the data collected by sensors. Then, the author analyzed items (such as the duration rate and frequency of behavior) in order to not only provide a deeper understanding on workers' behaviors, but also to compare the performances of workplaces. And finally, the author revealed the influence of workplace layouts and workplace system on the workers' space use and verbal communication. Furthermore, by the comparison of workers' behavior in terms of post and specialty, the characteristics of workers' space use and verbal communication is revealed.

6.1.1 Investigation method on the space use and verbal communication by means of sensing technology

In Chapter 2, the author established the investigation methods of recording workers' behavior in the workplace precisely. Firstly, the author verified the threshold value for judging the subjects' movement and staying by the characteristics of subjects' acceleration data obtained according to the video record. Then, the author determined the location zone according to the accuracy of the UWB sensor, determined an optimized position for wearing the voice sensor and the definition of the verbal communication. Finally, the author combined all the data and created a database. The specific verifications and definitions are shown as below:

1) By analyzing the data collected by an acceleration sensor and gaiting process, the author determined the threshold values for defining the subjects' movement and staying.

2) By analyzing the accuracy of the data collected by the UWB sensor, the subjects' temporal location was defined into zones of 6~15 m².

3) By testing the position for wearing the voice sensor and the analysis of the data sample, the utterance duration detected by the sensor is defined as the subjects' verbal communication, but not only personal talking.

4) Finally, the author combined all the data and created a database.

These verifications and definitions set up the structure of this study. On the base of the verifications and definitions, the subsequent investigations were conducted and

the databases were revised

6.1.2 Findings concerning the workers' space use and the choosing of an individual workstation behavior in a non-territorial workplace

In Chapter 3, the author clarified the workers' space use behavior and the choosing of an individual workstation behavior in a non-territorial workplace, and analyzed the relationship between these two behaviors.

1) Findings concerning the pattern of workers' space use

The analysis of workers' space use showed that all investigated workers spent 84.3% of their time on staying at the "Work territory". In the "Work territory", the individual workstation and nearby were used for staying the longest (72.5% of duration) and most frequently (4.2 times/hour). When leaving the individual workstation and nearby for staying at other places in the work territory, in order of the staying frequency, the "Meeting corner side zone" was used more, followed by the "Corridor side zone". In addition, when using the "Meeting corner side zone" and the "Corridor side zone" to use, the workers tended to select the nearest and the alternate zones for use (70% of frequency). Furthermore, the "Meeting corner side zone" was selected more frequently for staying by workers, whose individual workstation was of the same specialty range.

The space use of workers in different posts or specialties also had different characteristics; the detailed findings of this study are listed below:

1) Project leaders spent 64.4% of their time on staying at the individual workstations and nearby, the least of all investigated staff. However, Project leaders spent an aggregate 14.4% of their time on staying at the other areas of the workplace and used the maximum number of different areas per hour. Regular staff spent 72.4% of their time on staying at the individual workstations and nearby. In the "Same-specialty range", Regular staff tended to use the adjacent and alternate "Meeting corner side zone" or "Corridor side zone". Temporary staff stayed at the individual workstation and nearby for 83% of their time, the most steadily.

2) Compared with the staff in other specialties, architecture design staff spent 73% of their time on staying at the individual workstations and nearby, the highest of all staff. In the "Same-specialty range", architecture design staff used a greater number of zones (0.67 per hour), which indicates their work needs more contact with staff of the same specialty. Structure design staff spent much more time on staying at the "Other-specialty range" on leaving the individual workstations and nearby to stay at

other places in the work territory. However, in the “Same-specialty range”, Structure design staff spent the least amount of time. Equipment design staffs used “Same-specialty range” longer and more frequently than staff of other specialties.

2) Findings concerning the workers’ choosing of an individual workstation and their space use correlated with the selected individual workstation’s spatial attribute

When analyzing the workers’ choosing of individual workstations, it was shown that, although the workers were free to locate anywhere, more than 70% of the investigated workers always chose the same workstation or chose the same workstation on most occasions. In total, 90% of the workers located themselves in the same or adjacent areas. Only 10% of the workers chose workstations that were dispersed over the office area.

Workers tended to select individual workstations with spatial attribute differenced by their post. Moreover, workers’ space use showed different characteristics correlated to the spatial attribute of their selected individual workstations. The specific findings are shown as bellow:

1) The “Middle-Meeting corner side” and the “Outer-Meeting corner side” enabled the workers who located their individual workstation there to use the meeting corner more conveniently. And therefore, it enabled them to shorten the time spent visiting and staying at other places in the same area. The “Outer corridor side” and “Middle corridor side” enabled workers who located their individual workstation there to move to other places more easily. The “Inner-Meeting corner side” enabled workers who located there to conveniently use the closest Meeting corner for communication more and made moving to other places easier. Workers with workstations at the “Window side” are seldom visited and stayed at by other workers. This caused them to be less often disturbed.

2) Regarding the post, workers’ tendency to select different types of workstations is a result of their different needs.

Project leaders tended to select individual workstations at the “Inner Meeting corner side” more frequently, as they had to visit more and stay in other areas (10.1% of their time), meanwhile, their duration rate of staying at the own-seat nearby is around 49%, the lowest of all staffs. In contrast, when they selected a workstation at the “Outer Meeting corner side” or the “Middle Meeting corner side”, they visited and stayed less at the other zones of the work territory.

Regular staff selected individual workstations at the “Middle Meeting corner side” more frequently, and visited and stayed at the zones less, meanwhile, their duration rate of staying at the own-seat nearby is around 72%, significantly higher. Moreover, they tended to select an individual workstation at the “Middle Corridor side” or the “Outer Meeting corner side” more frequently as being next to the corridor and the former’s inter-area location made visiting other areas easier.

As temporary staff’s staying at other places and being visited by other staff are much fewer. Therefore, they tended to locate their individual workstations more frequently at the “Window side”, which is seldom visited and stayed at by other workers. As a result, they were less often disturbed.

6.1.3 Findings concerning the workers’ pattern of space use behavior in territorial and non-territorial workplaces

In Chapter 4, by comparing the workers’ pattern of space use behavior and space use way in territorial and non-territorial workplaces, the author quantitatively clarified that the space of non-territorial workplace were occupied more efficiently and more flexibly.

1) Findings concerning the workers’ using way of workstations and meeting corners

By interval observation record, whose frequency was once per 30 min, the findings concerning the workers’ using way at workstations and meeting corners in detail are listed as below:

1) About the using ways of workstations: compared with the territorial workplace, the workstation of the non-territorial workplace holds the 7.3% higher occupancy rate.

2) About the using ways of meeting corners: in the non-territorial workplace, architects and engineers shared used the meeting corner more frequently, and 75% of the meeting corners were evenly used, 19% higher than in the territorial workplace.

3) The average number of attendees is around 3. Therefore, 5 seats of meeting bigger meeting corner table in the territorial workplace were vacant in each unit of communication.

2) Findings concerning workers’ space use

The detailed findings about workers’ space use obtained through the investigation

on workers' staying and movement using the UWB sensor network are listed below:

1) In the investigated non-territorial workplace, workers' duration rate of staying at the individual workstation and nearby was 8.4% higher. Moreover, non-territorial workplace workers stayed 11.6% less in the "meeting corner zone", but 1.4% more in the "workstation zone".

2) Comparing the staying and movement in terms of the posts and specialty, workers in each workplace appeared to be different.

Architects stayed at the individual workstation and nearby about 4% longer than engineers, while engineers visited the architects' specialty range more.

Compared with the regular staff, Project leaders stayed at other workplaces longer, and their more frequent movement inside the individual workstation and nearby indicates that they use adjacent workstations or meeting corners more often. The temporary staff spent over 75% of their time on staying at the individual workstation and nearby.

3) In terms of estimated occupancy rates, the non-territorial workplace workstation had an 8.5% higher proprietary occupancy rate, and its 2.8% higher flexible occupancy rate indicates its workstations are occupied 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.

These findings suggest that the space of workstations and meeting corners of the non-territorial workplace were occupied more efficiently and flexibly than those of the territorial workplace.

6.1.4 Findings concerning the workers' space use and verbal communication patterns in big open plan workplaces with and without partition walls

In Chapter 5, the author clarified the characteristics of workers' space use and verbal communication in a big open plan workplace with partition walls separating the specialties (WP), and a workplace without partition walls (WOP).

The findings are summarized as follows:

1) In both workplaces, workers spent over 55% of their time on staying at the individual workstations and nearby, where around 50% of their verbal communication was occurred. In terms of duration rate, in WOP workplace workers stayed 3.5% more and orally communicated 5.1% more in the "Other Specialty" areas. Moreover, the probability of WOP workplace workers' verbal communication on staying at the

individual workstation and nearby was increased from 20.8% to 34.4%.

2) A comparison of the two post staff's behavior revealed that, without partition walls, the regular staff's verbal communication occurred at the individual workstation and nearby is increased (from 18.8% to 34.1%). Additionally, the regular staff's verbal communication occurred at the individual workstation was increased much more than that of the project leaders (from 31.3% to 35.4%). Moreover, in both workplaces, project leaders' probability of verbal communication when staying inside workplace was around 10% higher than that of the regular staff. In addition, around 35% of project leaders' verbal communication duration occurred in the "Meeting Space," over 10% higher and 0.3 time/hour more frequent than that of the regular staff.

3) A comparison of the three specialty staff's behaviors revealed that: The architecture design staff's probability of verbal communication when staying inside the workplace was the highest of all, especially ones occurred in individual workstation and nearby. In terms of duration rate, the equipment design staff's staying and verbal communication at "Other Specialty" was significantly higher. The structure design staffs' probability of verbal communication when staying inside the workplace was the lowest of all, particularly at the individual workstations and nearby.

The findings above revealed that, by removing the partition walls that separated the specialties, the big open plan workplace can increase the workers' verbal communication. Particularly the verbal communication that occurred in workstations and between workers from different specialties significantly increased.

6.2 Findings of this dissertation

From the 1960s, there have been several types of workplaces were invented or renovated in order to increase the knowledge work productivity. In these renovated or invented workplace, the main purpose is to support the knowledge workers behavior better in order to increase the output of productivity. For example, the non-territorial workplace and the big open plan workplace were innovated to increase the communication between workers. Or to make the space occupied more efficiency and more flexibility, such like the non-territorial workplace. Therefore, clarifying how workers used the space of workplaces and identifying whether the renovation purpose of the workplace was achieved is not only helpful in offering valuable information for improving the workplace layout, but also meaningful for evaluating the performance of the workplace.

This research used sensing technology to acquire and analyze precise survey data on the behaviors of workers in specific workplaces regarding the space use and verbal communication. The analyzed items mainly included the duration rate and frequency of workers' staying and movement, as well as the duration rate and frequency of workers' verbal communication. These items can be hardly recorded continuously without imposing extra burden on the subjects if the sensing technology is not used.

Firstly, the author proposed the method for surveying the subjects' continuous and seamless space use and verbal communication behaviors by using sensing technology. Following, by analyzing the characteristic of the subjects' acceleration data, determining the method of defining location zones, testing the wearing position of voice sensor and the defining verbal communication according to the data characteristics, the author developed the method for revising and combining the data base. This investigation method and the database revising-combining method have been proved to work effectively in the investigations on monitoring the workers' space use behavior.

Using sensors to analyze the workers' space use behavior and verbal communication behavior in workplaces, the author compared the performance of different workplaces on how they support or influence the workers space use. Finally this dissertation not only proved that the non-territorial and big open plan workplace achieved the renovation purpose, but also it quantitatively revealed the specific way in which these workplaces performed better. The detailed findings are the following:

- 1) Compared with the investigated territorial workplace, the space of the investigated non-territorial workplace was occupied more efficiently and more flexibly. This was due to the workstations being used more flexibly and efficiently, and the spaces of meeting corners being occupied more frequently and more evenly.

- 2) Without the partition walls, which separated the specialties in the investigated open plan workplace, the workers' staying and the verbal communication at the place of other specialty ranges increased. Furthermore, the influence of partition walls on regular staff's space use and verbal communication was much greater than to that of project leaders. This indicates that, the by removing the partition walls, workers' communication was increased.

Moreover, by comparing the workers' space use and verbal communication behavior in terms of post and specialty, it was found that:

- 1) Regarding the workers' post, compared with the regular staff, the investigated

project leaders spent the least of their time staying at the individual workstation and nearby, but the most of their time on moving inside the workplace. In addition, they spent more time on visiting and staying at the other places in the workplace or outside of the workplaces. This result indicates that, the work style of project leaders made them contacted or communicated much more with the other workers. This has also been proved by the project leaders' highest staying duration rate at the meeting space in the big open workplace with and without partition walls. Moreover, project leaders' using of more number of zones for staying and their staying is less influenced by the distance from the place they visited to their individual workstation in the non-territorial workplace. This also indicates that project leaders communicated more in despite the distance. Therefore, on designing the workplace layout, the location of project leaders should be arranged so that it would allow them to reach the meeting place conveniently and moving easily. This has also been indicated by the more frequent project leaders' choosing of their individual workstations beside the meeting corner and the main middle corridor in the non-territorial workplace, is most frequently.

All investigated temporary staff spent the most of their time staying at the individual workstation and nearby, but the least of their time moving inside the workplace. This result indicates that, the work style of temporary staff made them concentrated more on solo work. Therefore, on designing the workplace layout, the workstation for temporary staff should be arranged closer for supporting concentrated solo work.

2) Regarding the workers' specialty, compared with staff in other specialties, all investigated architects (staff in Architecture Design specialty), spent more time on staying at the individual workstation and nearby. Additionally, most of the investigated architects, except the ones in the territorial workplace, spent more time on leaving the individual workstation nearby for visiting and staying at the workstations of in the same specialty. Moreover, the duration and probability of architects' verbal communication when staying at the individual workstation and nearby was much higher. Furthermore, compared with architects, most of the investigated engineers, except the staff of the structure design specialty in the big open plan workplaces with and without partition walls, visited and stayed more at the workstation of the other specialties, especially the architects' range. This result indicates that, the work style of architects made them communicate and contact more with the staffs in the same specialty, and be visited more by the staffs in other specialties.

Therefore, the workstation of architects should be designed more conveniently for

other staffs' visiting and staying. In addition, the location of architects' range should be located for staffs of other ranges reached easily.

Moreover, after analyzing the workers' space use behavior, several rules could be proposed in order to create a workplace layout that would increase the occupancy rate at space and would support workers' staying in the workplace.

1) In order to increase the occupancy rate of the workplace, the space for public sharing which is frequently used should be distributed evenly or make it accessible to all workers. Otherwise, if the space for public sharing is located only close to a certain group of workers but further from the most workers' workstations, although these places allow a more convenient use to workers located close to them, this location makes them lose the characteristic of public sharing and transformed them into the exclusiveness of some specialty or post and, at the same time, decreased the occupancy rate. This has also been indicated by the workers' space use at the bigger meeting space in the non-territorial workplace and the smaller meeting corner in the territorial workplace. This has also been proved by the architects' longer and more frequent staying and verbal communication at the relaxation space in the big open plan workplace. In addition, in order to increase the occupancy rate, the number of seats of dispersed small meeting spaces should be responded to the attendance per communication. Otherwise, like the meeting corner in the territorial workplace, more than half of the seats would be vacant per one time of workers' communication on held there.

2) In this dissertation, it was found that the space use behavior of workers is composed of quite a large amount of short time staying. Therefore, the workstation should be designed so that it can be conveniently reached and stayed by not only its owners but also by other workers. This design could create a suitable space environment for short time staying which occurs frequently in workers' space use behavior.

3) In order to increase the workers' communication, or the inter-worker contact represented by the workers' visiting and staying at the other workers' individual workstations, the space environment of the workplace should be designed more openly so as to increase suitable visual contact. This has also been indicated by the increase of workers' staying and verbal communication at other specialty range in the big open plan by removing the partition walls that separated the specialty ranges.

4) After clarifying the workers' choosing of an individual workstation and their space use behavior related to the workstation attribute, the layout distribution or the

furniture design can be improved. For example, in the investigated non-territorial workplace, the frequently selected workstation by Project leaders (such as the “Inner-Meeting corner side” type and the “Inner-Corridor side”) could be especially reserved for Project leaders with responding to the selectors’ number and the choosing rate according to post.

Finally, on the basis of the findings of this dissertation, responding to the insight for increasing knowledge work productivity, the image of ideal workplace could be drawn as follows.

In order to save the space for reducing the input, and responding to workers’ space use for improving teamwork, the layout of workplace should be designed flexible for supporting workers’ various behaviors. Specifically, the workstation could be designed simply with minimizing attached storage locker in order to save more space and make it used more conveniently for other workers’ visiting. Furthermore, with revealing workers’ work styles on the basis of post and specialty, the layout could be designed more suitable to respond to workers’ characteristic of space use and verbal communication for making the teamwork organized more effectively. For instance, the leaders’ workstation should be located close to meeting space and easy for moving. In addition, the location of specialty range that is visited more frequently by other specialty staffs should be arranged easily visited by staffs from other specialties.

In order to increase the verbal communication for increasing knowledge sharing, the density of workstation and the layout of corridor should be well considered, as the short distance between workers and the convenient usage of corridor is helpful to increase verbal communication between workers. Furthermore, the centralized space or furniture for meeting and communication should be divided into smaller ones and distributed evenly in the workplace for shortening the distance from workstation and increasing the occupancy rate. Although the big meeting space is needed in some situation, it is used not so frequently, therefore, with the nearby small meeting furniture assemble together, the workers’ need for holding big meeting could be fully responded without adding special space. Moreover, as too much communication would decrease the workers’ satisfaction with acoustical environment, the soft-fold partition could be equipped, or part of workstations could be designed with fixed partition walls for creating concentrated working environment.

6.3 Future research

This research has clarified the knowledge workers' space use and verbal communication behavior in terms of workplace type and worker's attribute such as post and specialty.

With the development of the sensing technology, it would be possible to obtain more detailed data on knowledge workers' space use, which has a great deal of relevance to the design and renovation of the workplace layout. In addition, by the suitable wearing position of acceleration sensor, the workers' posture could be detected and it would offer more detailed information about workers' space use posture. Furthermore, it is necessary to conduct a survey examining the relationship between knowledge workers' detailed temporal location in a long time investigation, in order to monitor behavior patterns in the whole knowledge work process.

Finally, by the development of sensor technology and facility management, the personal working environment around worker's workstation could be flexibly changed according to workers' attendance and absence, therefore it will offer more comfortable working environment, such as personal lighting and air conditioning determined by worker's personal subjective feeling, and saving the energy at the same time.

With the advanced sensor, the recording of more accurate data, such as the exact location of worker, will offer deeper and more detailed understanding on knowledge workers' space use behavior and their work style.

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Chapter 3

ZHANG Xinnan, Takashi IZATO, Junzo MUNEMOTO, Daisuke MATSUSHITA, Tetsu YOSHIDA: Officers' Space Using Behavior in a Non-territorial Workplace at an Architecture Design Office: An Analysis using the UWB Sensor Network, Journal of Habitat Engineering, Vol. 2, 2010/3, No.1, pp.23–34

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Acknowledgements

I would like to express my appreciation to all the people who have helped me to complete this dissertation.

My deepest thanks go to my supervisors, Professor Dr. Eng. Munemoto Junzo and Professor Dr. Eng. Hokoi Shuichi, for their instructive suggestions and continuous encouragement for my research, their precious advices were fundamental for the completion of this research. Sincere appreciation and gratitude are also extended to Professor Dr. Eng. Takada Mitsuo and Professor Dr. Eng. Katoh Naoki for reviewing this dissertation and providing instructive advices. I would like to sincerely appreciate Associate Professor Dr. Eng. Yoshida Tetsu, for his valuable support and sharing of his time, expertise and experience.

My heartfelt thanks belong to Professor Dr. Eng. Zhang Qi in Tianjin University, for his insightful suggestion and warm encouragement throughout the years. He taught me never give up and insisted on when meeting difficulties in work and life, and has been and will forever be the mentor and example for me in my future career and life. I am particularly grateful to Associate Professor Dr. Eng. Matsushita Daisuke, who taught me how to deal with research and always encourage me to move ahead when I met difficulty.

I would like to sincerely appreciate special thanks go to Mr. Zhang Yi and his wife Mrs. Liu Fangting, without their support, I cannot finish this research work. My sincere appreciate also goes to Professor Dr. Eng. Zhao Jianbo and Professor Dr. Eng. Bian Hongbin in Tianjin University, for their warmhearted help.

I would like to express my sincere thanks to Dr. Eng. Yuan Sinan and Mr. An Joonsang, they are always there to meet and talk about my idea about the research and the questions in the daily life.

I appreciated greatly to the following people, who supported me in the investigation involved in this research. They are Mr. Izato Takashi in TAISEI Corporation, Mr. Takai Hiroaki and Mr. Hirano Katsuhiko in TAKENAKA Corporation, Dr. Eng. Qu Xiaoyu and Mr. Tatsuoka Yuusuke of Munemoto laboratory. They have contributed greatly in this dissertation.

Last, I thank my parents, Mr. Zhang Ying and Mrs. Xu Weimin, for their unconditional love, sacrifices and encouragement. Without their support, I can hardly finish this dissertation. I owe a huge debt of love to them.