'ANYWHERE TO WORK' A DATA MODEL FOR SELECTING WORKPLACES ACCORDING TO INTENTS AND SITUATIONS

HITOSHI KUMAGAI, NAOKI ISHIBASHI, YASUSHI KIYOKI
Musashino University, Graduate School of Data Science, Tokyo, Japan
g2251001@stu.musashino-u.ac.jp, n-ishi@musashino-u.ac.jp,
y-kiyoki@musashino-u.ac.jp

In this paper, we proposed a new workplace data model and its calculation method. The method was designed to calculate appropriate workplace according to the intents (activities) and situations of a worker. The data model was designed as a semantic space with three knowledge bases: 'Activity-affecting', 'Place-determining', and 'Activity and Place'. Experiments were conducted to show the different results depending on activities and the contexts of the workplace and presented the feasibility of the proposed data model and calculation method.

Keywords: workplace, active based working, hybrid work, semantic computing, information modeling

University of Maribor Press

DOI https://doi.org/10.18690/um.feri.5.2023.6
ISBN 978-961-286-745-4

1 Introduction

1.1 'Workplace': research definition

'Workplace', where the present study focuses on. It is also called 'office'. However, recently, the term; 'workplace' is often used with winder means as a place to work. A typical person who uses the workplaces can be 'knowledge workers', Drucker [1] coined this term and defined it as 'high-level workers who apply theoretical and analytical knowledge, acquired through formal training, to develop products and services'. For knowledge creation, Nonaka [2] developed the 'SECI model', and divided it into four-dimensions; each dimension was called 'Ba', which means 'place' in Japanese. Nonaka notes that knowledge creation is a spiral through the 'Ba' with some human interactions. 'Ba' does not necessarily mean physical place, although each 'Ba' can be connected to certain workplace (**Figure 1**).

The number of knowledge workers has increased, and a research firm has been estimated to have more then one billion workers [3]. Hence, 'knowledge workers' are the key players in economic society, and the preparation of the workplace becomes more important.

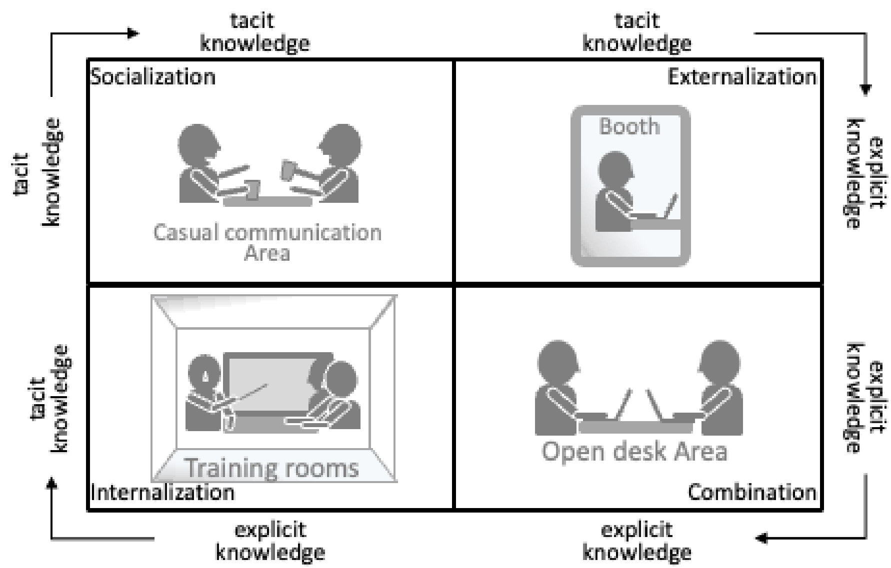


Figure 1: SECI model [2] applied to workplaces
Source: own.

Here we defined several terms in this study as follows;

- **Workplace**: Places where 'workers' are working, which includes conventional 'centre office', 'home office' (work from home), and the '3rd place'
- **Workers**: People who are knowledge workers, but not limited to these, which includes people whose jobs are information processing and do not have essential reason to use any physical place.
- **Centre office**: Physical workplaces (offices) of the organisations of the "workers"
- **Home office**: the home of the worker from where they can work.
- **The 3rd place**: An alternative workplace besides the centre and home offices, such as, a shared service office, café, library or anywhere to work.
- **Functional spaces**: Components of physical workplaces, such as desks (workstations), open communication spaces, meeting rooms, phone booths, or others.
- **Workplace services**: Services that are provided to the workers in workplaces, such as reception, beverages, canteens, or others.
- **Workplace settings**: Features of a workplace, which comprises a set of 'functional spaces' and 'workplace services'.

1.2 Recent workplace problems

In the three years since the emergence of COVID-19, workplace circumstances have changed drastically. The term 'hybrid work' has become common, which refers to the combination of working at the centre office and remotely, particularly from home. Although the movement for flexible working from anywhere appeared 20 years ago, as mentioned in Chapter 2, it had been adopted by only a few advanced technology companies. However, during the COVID-19 pandemic, many workers were forced to work from home, with many organisations rapidly introducing remote communication tools, and workers having to acquire remote communication literacy faster than in the last decade. However, whether workers can work from anywhere or should come to centre offices still remains controversial. Some GAFA executives have called for employees to return to the centre office over their resistance, despite the fact that their company appears to be better able to utilise IT tools for remote working. [4]. The hybrid work model, which is a compromise or mixture of working from centre office and from anyplace, seems to be the new normal for workplaces.

Workers have now become more flexible for anywhere to work, however, this means that they must select more appropriate workplace for their productivity in complex situations. In addition, facility managers who are responsible for planning, implementing, and maintaining the workplace of an organisation, have more difficulties in planning the size, or workplace settings (**Figure 2**).

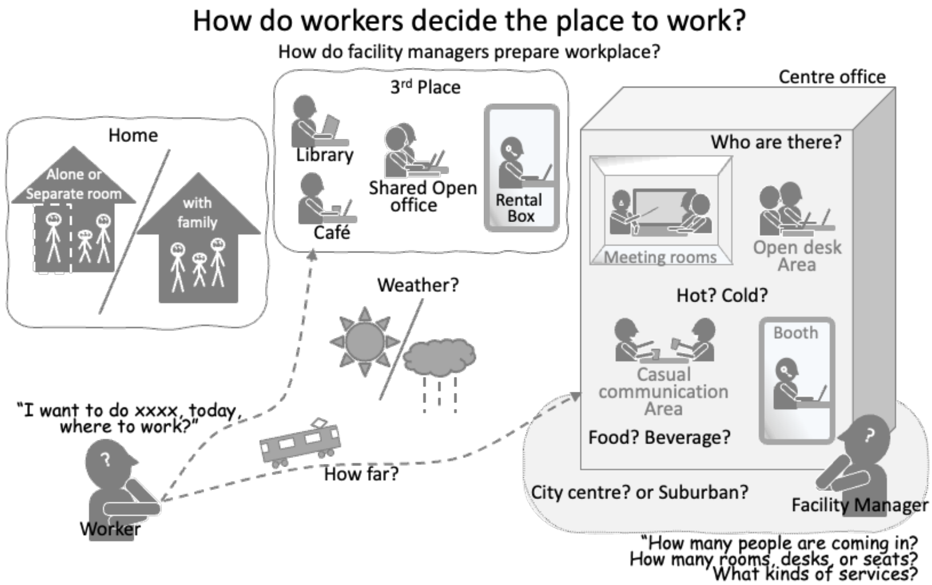


Figure 2: Problems of hybrid work.
Source: own.

1.3 Research journey and scope of the proposal of this study

Investment in a new workplace (physical centre office) is immense. Therefore, improving workplaces using the 'trial and error' approach is difficult. The current planning of physical workplaces has been a conceptual approach; some experienced and knowledgeable designers define a concept for a new workplace with a small study of the current work situations of the organisation. Although this study could predict the volume of each functional facility in current settings, it cannot predict changes in a new setting. For example, the concept might state that 'The workers should communicate casually in open spaces rather than talk formally in a meeting room', and recommend that the client prepare some open communication spaces. However, the study, if the current setting of the client does not have such spaces, then an estimated number of workers will use such an open communication space cannot be made. In other word, explanatory variables of conventional mathematical method, such as operations research, might not be provided in current workplace planning practice. In addition, we must have challenged to treat multiple and complex contexts of the workplace to solve the problems in hybrid work situation as mentioned in previous section. Although, collecting multiple and complex data is still difficult, many sensors, including social sensors, are emerging and those will help us to collect the data in the near future.

Therefore, a data model that describes behaviours and preferred workplaces of the workers must be constructed. An indication for the future of this model is the digital twin of self-driving cars. Data collection is no longer being conducted in the real world but in digital twins where virtual drivers drive with virtual cars in virtual towns. The future objective of this research is to establish a workplace digital twin, where virtual workers work in a virtual workplace setting, which can predict the comfort and productivity of the workers.

This study is the first step of the entire journey for a workplace digital twin and proposes a data model in which a worker can find an appropriate place to work in complex situations.

2 Discussion and research

2.1 Discussions in workplace

Over the last 20 years, workplace-setting trends have been changed slightly. As knowledge workers have become the core human-capital of an economic society, some people, particularly executives of advanced technology companies, believe that the workers must be more communicable to the knowledge creation spiral reported by Nonaka et al [2]. However, knowledge workers must transform tacit knowledge into explicit knowledge. As a result, workers must concentrate to create knowledge. Therefore, knowledge workers must engage in contradictory activities, such as communication and concentration.

In 2004, a Dutch consultant Veldhoen [5] coined the term 'activity based working (ABW)'. His established company, Veldhoen + Company, notes that: 'ABW creates a space that is specifically designed to meet the physical and virtual needs of individuals and teams'. [6] The ABW concept has become popular among facility managers particularly in Northern Europe, Australia, and Japan.

The COVID-19 pandemic accelerated this movement; however, the situation has become more complicated with hybrid work. Workers and facility managers obtained more options regarding work location. Thus, several data models and calculation methods are required, which allow workers to select a workplace.

2.2 Research for data model of intent of people based on situation

Workers and workplace settings may vary, and a single type does not seem to be present in the open world. Thus, the workplace data model of should be treated as a closed-world assumption.

Research conducted by Yokoyama et al. [7] proposes an 'information-ranking method' of facilities and services based on the dynamic contexts (intent/situation) of train passenger with a semantic space model. They had presented a method that calculate the appropriate facility or service in complex situation by using semantic space model. The setting of their study was similar to that reported in this study, in which a place based on dynamic and static contexts of a person is selected. We assumed that the semantic space model could be applied to workplace data modeling. If the contexts of the workplace could be defined, we could calculate the behaviours of the workers.

2.3 Proposed data model and calculation method of 'Anywhere to work'

2.4 Data model aim

The aim of the data model proposed in this study is to calculate appropriate workplaces based on the context of the workplace, and the intentions and situations, of a worker using knowledge bases. In this study, as the first step, we aimed to calculate a single appropriate workplace for a worker in a set of their situations. Then we will aim to calculate the work journey of the workers in the future. Therefore, in this study, we set the workplace as the objective variable and the other parameters for the context of the workplace as the explanatory variables.

2.5 Approach

The process through which workers select their workplace must be determined. The ABW concept recommends that workers select an appropriate place depending on their 'activity', such as solo work, casual communication, or official meetings. Therefore, 'activity', one of a dynamic intent of a worker, can be the primary context of a workplace. Traditionally, in workplace planning, facility managers use their knowledge to correlate the activities of the workers and functional places. If workers had to work daily at only their centre office, this primary correlation could be sufficient. However, more complex contexts have recently emerged for hybrid work situation.

In this study, we raised contexts of workplace in 'Dynamic/Static' and 'Intention/Situation' categories, based on the study by Yokoyama et al. [7]. We then divided the contexts of workplace into 'Personal/Interpersonal' and 'Environmental (Place-oriented/General)'. This scheme made it easier to raise some context in the determination of workplaces by the workers; however, the manner in which a worker decides on a place to work in these contexts remains complicated. Finally, we found another axis: the 'Activity-affecting' and the 'Place-determining' contexts. (**Figure 3**).

Activity-affecting contexts: Affects the productivity of the intent ('Activity') or motivation of a worker for doing an activity (intent) such as, psychological safety level, attendees (who will be) in the centre office, or indoor quality (such as temperature and humidity).

Place determining context: Affects directory the determination of a **worker** for a place, such as the weather and access (commuting) to the centre office or area of the centre office.

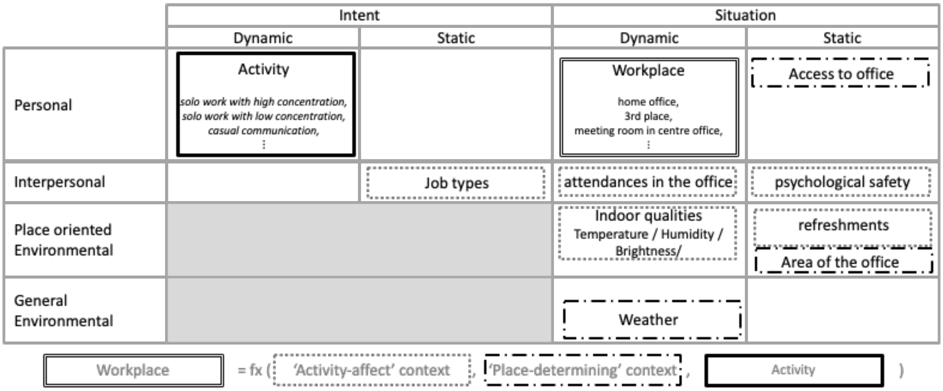


Figure 3: Example of the contexts

Source: own.

2.6 'Tri-knowledge-base with personal context vectors model': Proposed data model concept

In this study, we set the possible 'Workplace' options into vector $\boldsymbol{y}$ (**Table 1 lists** all symbols of this proposed model)**.** The proposed model calculated that the more appropriate workplace y_i will be the bigger in a set of workplace contexts. We set the possible activity options into vector $\boldsymbol{x}$. When a worker wanted to do x_i (an activity), the value of x_i was set to '1' and all other items x_j were set to '0'. If we could define the correlation between in matrix $\boldsymbol{M}$, we can calculate $\boldsymbol{y}=\boldsymbol{Mx}$.

Findings mentioned in the previous section noted 'Activity' as the primary context, as well as the 'Activity-affecting' and 'Place-determining' contexts as complementary contexts, allowing us to describe the relationship among the contexts of workplace into three correlations. Consequently, we easily defined each correlation as a knowledge base.

Primary knowledge base $\mathbf{M}_{\mathbf{ap}}$: Correlation between 'Activity and Place'

Complementary knowledge bases:

$\mathbf{M}_{\mathbf{a}}$: Correlation between 'Activity' and 'Activity-affecting' context
$\mathbf{M}_{\mathbf{p}}$: Correlation between 'Place' and 'Place-determining' context

We set the complementary contexts of workplace as vector $\boldsymbol{c_a}$ for 'Activity-affecting', and $\boldsymbol{c_p}$ for 'Place-determining' context. Subsequently, we adopted the result of the calculation: $\boldsymbol{x}'=\boldsymbol{c_{ai}M_a}x$ as the adjusted value of $\boldsymbol{x}$, and in the same way, $\boldsymbol{y'}=\boldsymbol{c_{pi}M_p}$ adjusted the value of $\boldsymbol{y}$. Then, we formulated:

$$\mathbf{y}= \mathbf{y'M_{ap}x'}= (\mathbf{c_{pi}M_p})\mathbf{M_{ap}}(\mathbf{c_{ai}M_a}x)$$

These correlations might differ depending on the worker. However, significant efforts were made to prepare knowledge base for each worker. To simplify this problem, we adopted the personal context vector $\boldsymbol{v}$($\boldsymbol{v_{ai}}$ for $\boldsymbol{c_{ai}}$/ $\boldsymbol{v_{pi}}$ for $\boldsymbol{c_{pi}}$). It weighed the extent to which each complementary workplace context affected the results of choosing a place. For a worker, weighting the personal context vectors for each context of the workplace ($\mathbf{c_a}$, $\mathbf{c_p}$) was easier. Therefore, $\mathbf{c_{ai}v_{ai}}$ was applied instead of $\mathbf{c_{ai}}$, similarly, $\mathbf{c_{pi}v_{pi}}$ was applied instead of $\mathbf{c_{pi}}$. Consequently, we calculated the proper workplace $\boldsymbol{y}$ as follows (**Figure 4**) .

$$\mathbf{y}=\{(\mathbf{c_{ai}v_{ai}})\ \mathbf{M_p}\}\mathbf{M_{ap}}\{(\mathbf{c_{ai}v_{ai}})\mathbf{M_a}x\}$$

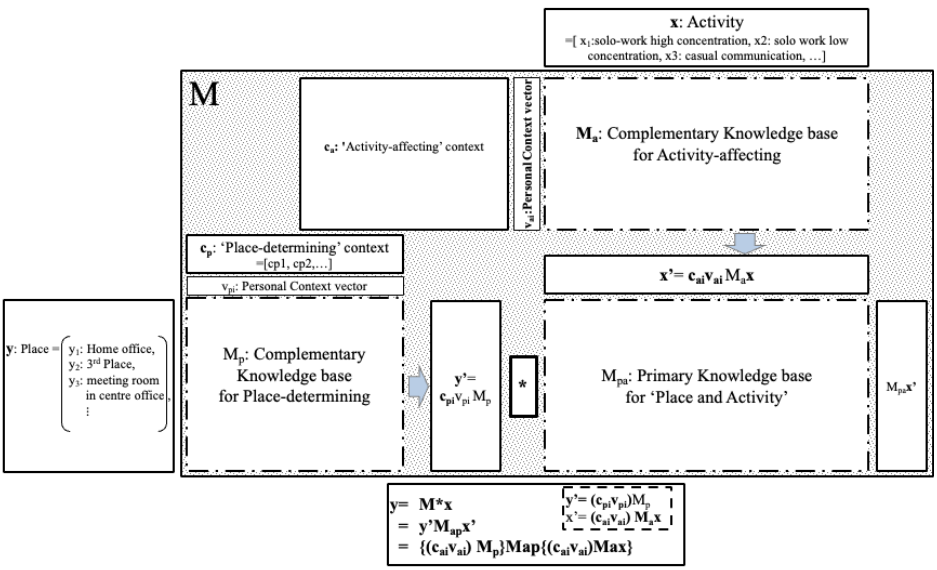


Figure 4: Proposed data model structure
'Tri-knowledge-base with personal context vectors model'

Source: own.

Table 1: Definitions of proposed data model symbol

Symbol	Definition	Explanation	Example
y	Workplace: Objective variable (vector)	Result of the more proper workplace yi will be the bigger in a context	$\mathbf{y_1}$:home office, $\mathbf{y_2}$:3rd place, $\mathbf{y_3}$:meeting room in centre office, ⋮
x	Activity: Primary explanatory variable (vector)	Activity which a worker is intent on doing	$\mathbf{x_1}$:solo work with high concentration, $\mathbf{x_2}$:solo work with low concentration, x_3:casual communication, ⋮
$\mathbf{c_{ai}}$	Activity-affecting context (vector)	Affects the productivity of the intent ('activity') or motivation of worker for an 'activity'	$\mathbf{c_{a1}}$: psychological safety level, $\mathbf{c_{a2}}$: attendances in the centre office, $\mathbf{c_{a3}}$: temperature (indoor), ⋮
$\mathbf{c_{pi}}$	Place-determining context (vector)	Affects directory the determination of a worker for a place	$\mathbf{c_{p1}}$: weather, $\mathbf{c_{p2}}$: access to the centre office, ⋮
$\mathbf{M_{ap}}$	Primary knowledge base (Matrix)	Correlation between 'Activity and Place' the larger is the more related	$\mathbf{y_1}$:home office to $\mathbf{x_1}$:solo work with lower concentration = 1.0, $\mathbf{y_3}$:meeting room in centre office to $\mathbf{x_3}$:formal communication = 0.4, ⋮
$\mathbf{M_a}$	Complementary knowledge bases (Matrix)	Correlation between 'Activity' and 'Activity-affecting' contexts the larger is the more related	$\mathbf{x_1}$:solo work with lower concentration to $\mathbf{c_{a2}}$: attendances in the center office = 0.4, $\mathbf{x_3}$:casual communication to $\mathbf{c_{a1}}$:psychological safety level =1.0, ⋮
$\mathbf{M_p}$	Complementary knowledge bases (Matrix)	Correlation between 'Place' and 'Place-determining' contexts the larger is the more related	$\mathbf{y_1}$:home office to cp1:weather =1.0, $\mathbf{y_3}$:meeting room in centre office to $\mathbf{c_{p2}}$:access to the centre office =0.6, ⋮
v_{ai}	Context vector for Activity-affecting context	Each worker weights the "Activity affecting contexts"	$\mathbf{v_{a1}}$= 0.5 then $\mathbf{x_3}$ **to** $\mathbf{c_{a1}}$ is adjusted as 1.0*0.5=0.5
v_{pi}	Context vector for "Activity affecting contexts"	Each worker weighs the Activity-affecting context	$\mathbf{v_{p1}}$=0 then $\mathbf{y_1}$ to $\mathbf{c_{p1}}$ = is adjusted as 1.0*0=0

3 Prototype system implementation

3.1 Assumed applicable area

In this study, we conducted calculations using sample data to confirm that the working the model. We assumed a simple organisation in Tokyo, Japan, with simple workplace settings in the summer season.

3.2 Functional overview 3-Type / 4-module

We designed a prototype system based on Tri-knowledge-base. In practice with the assumed the contexts of workplace, two types of 'Activity-affecting' contexts were observed; one type was not dependent on any place, while the other was dependent on the centre offices. Therefore, we divided the 'Activity-affecting' contexts calculation into two. As a result, the system had four modules in three types (**Figure 5**).

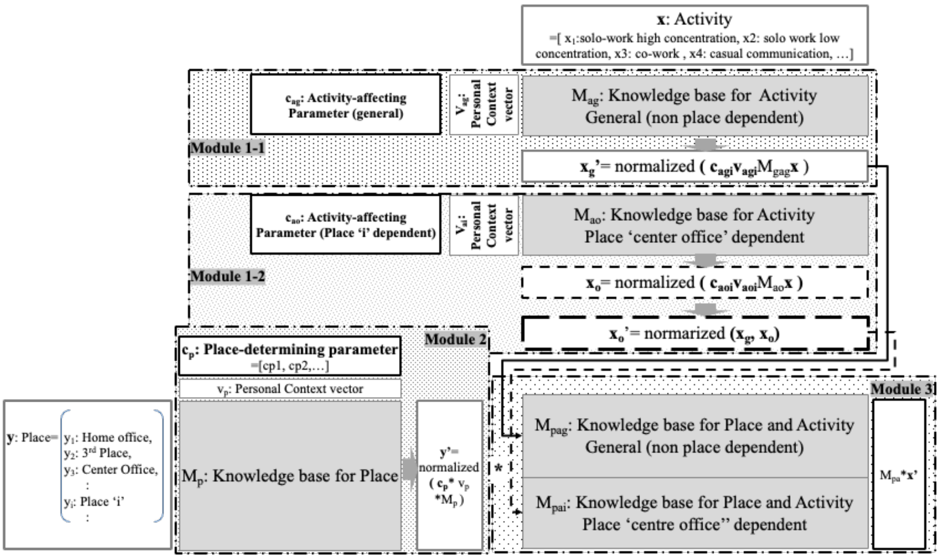


Figure 5: Modules of the prototype system

Source: own.

- Module 1 (1-1, 1-2) 'Activity-affecting' context calculation
  The first module calculated **x'**: 'Activity-affecting' context and divided it into two sub-modules.
  - Module 1-1: General (none place dependent)
    This module calculated 'General (none place dependent)' context. We defined the parameters of the context as $\mathbf{c_{ag}}$ and knowledge base as $\mathbf{M_{ag}}$. The result: $\mathbf{x_g}$**'** was normalised and applied to the final calculation 'Activity and Place General (none place dependent)' with knowledge base $\mathbf{M_{apg}}$ in Module 3.
  - Module 1-2: Place dependent

In this experiment setting, some 'Activity-affecting' contexts which depended on the place 'centre office'. We defined the parameters of the contexts as $\mathbf{c_{ao}}$, and knowledge base as $\mathbf{M_{ao}}$. The result: $\mathbf{x_o}$ was normalised in these contexts, added to $\mathbf{x_g}$,**'** and then normalised to $\mathbf{x_o}$**'.** The result: $\mathbf{x_o}$**'** was applied to the calculation only for 'Activity and Place' knowledge base 'centre office' dependent $\mathbf{M_{apg}}$ in Module 3.

Another intermediate calculation: $\mathbf{x_o}$, might occur in other place-dependent workplace contexts.

- Module 2: 'Place-determining' context calculation

  Module 2 calculated 'Place-determining' context. We defined $\mathbf{c_p}$ as the context parameter, and $\mathbf{M_p}$ as the knowledge base. Result: **y'** was normalised.

- Module 3: 'Activity and Place'

  The final module calculated 'Activity and Place' with the primary knowledge base $\mathbf{M_{ap}}$. In this experiment, the knowledge base was divided into 'none place dependent' (M_{apg}) and 'centre office dependent' (M_{apo}), and applied to the results of Module1 (1-1, 1-2) and Module 2.

- Personal context vectors

  We defined one personal context vector item as a parameter of the complementary context of the workplace, $\mathbf{c_a}$ and $\mathbf{c_p}$. The context vector v_i was set by each worker, in advance, who was the system user. In addition, we set different context vectors for different options of a parameter if it could vary from person to person. For example "Indoor temperature", was set basically 22 to 28°Cas the comfortable range. However, the feeling of 'Indoor temperature' might vary depending on the person. Therefore, we divided the range into three, 22-24/24-26/26-28, and applied to same correlation to the knowledge base. If a worker felt uncomfortable in the band of 22-24, the person could weigh lower on their context vector, such as 0.5 or 0. Thus, personal preferences could be included in the personal context vector.

3.3 Parameter, correlation, and normalisation range

In this experiment, all complementary contexts ($\mathbf{c_{ai}}$ and $\mathbf{c_{pi}}$) were defined from '0' to '1'. If several options were available for a parameter, such as very good/good/neutral/bad/very bad in 'Psychological safety level', they were divided into exclusive options; only the value of selected option became '1' and rest were set to '0'.

In addition, we set the range of correlations in the knowledge bases from zero to one. Therefore, multiple results of one parameter (the context of the workplace) and correlation (knowledge base) fell within the range of 0 to 1.
Finally, we normalised the matrix product by the average and divided the matrix product by the number of parameters. Consequently, the objective variable $\mathbf{y}_i$ fell within the range of 0 to 1.

4 Experiment

4.1 Experimental context parameters and knowledge bases

For the experiment, we defined the workplace options, activity options and complementary contexts of workplace parameters and personal context vectors, as shown in **Table 2**, and knowledge bases, as shown in **Figure 6-9**.

Table 2: the parameters of the experiment.

Symbol	definition	Options	Actual value	Context Vector
y	Workplace: the objective variable (vector)	$\mathbf{y}_1$: home office; Live alone or separate room $\mathbf{y}_2$: home office; Live with family $\mathbf{y}_3$: 3rd place; Café or Library $\mathbf{y}_4$: 3rd place; Shared open office $\mathbf{y}_5$: 3rd place; Rental Bos $\mathbf{y}_6$: Centre office; Booth $\mathbf{y}_7$: Centre office; Open desk $\mathbf{y}_8$: Centre office; Open communication small $\mathbf{y}_9$: Centre office; Open communication small $\mathbf{y}_{10}$: Centre office; Meeting room	Results can vary depends on the context	Not applied
x	Activity: primary explanatory variable (vector)	$\mathbf{x}_1$: solo work; high concentration, $\mathbf{x}_2$: solo work; low concentration, x_3: co-work x_4: casual communication x_5: formal communication	exclusive options	Not applied
		'Activity-affecting contexts': $\mathbf{c}_a$ - General (none place dependent): C_{ag}		
$\mathbf{c}_{ag1}$	Job type	$\mathbf{c}_{ag11}$: Administration $\mathbf{c}_{ag12}$: Coordinator $\mathbf{c}_{ag13}$: Business planning $\mathbf{c}_{ag14}$: R&D	Percentage (total 100%)	One for all options

Symbol	definition	Options	Actual value	Context Vector
		c_{ag15}: Sales		
c_{ag2}	Psychological safety level	c_{ag21}: Very good c_{ag22}: Good c_{ag23}: Neutral c_{ag24}: Bad c_{ag25}: Very bad	exclusive options	One for all options
		- Place 'centre office' dependent		
c_{ao1}	Attendances	c_{ao1}: preferable people is there	0/1	Applied one
c_{ao2}	Attendances	c_{ao2}: dislike people is not there	0/1	Applied one
c_{ao3}	Attendances	c_{ao3}: Team member(s) be there	0/1	Applied one
c_{ao4}	Indoor quality; temperature	c_{ao42}: 22-24℃ c_{ao43}: 24-26℃ c_{ao44}: 26-28℃	exclusive options	One for each option
c_{ao5}	Indoor quality; humidity	c_{ao52}: 35-45% c_{ao53}: 45-55% c_{ao54}: 55-65%	exclusive options	One for each option
c_{ao6}	Indoor quality; CO2(ppm)	c_{ao6}: ppm	1-([actual ppm] -1000)/1500	Applied one
c_{ao7}	Indoor quality; Brightness on desktop	c_{ao71}: Less 300Lx c_{ao72}: 300-600Lx c_{ao73}: Over 600Lx	exclusive options	One for each option
c_{ao8}	refreshment	c_{ao8}: Drink	0/1	Applied one
c_{ao9}	refreshment	c_{ao9}: Snack	0/1	Applied one
c_{ao10}	refreshment	c_{ao10}: Meal	0/1	Applied one
		'Place-determining contexts': c_p		
c_{p1}	Weather: Rain chance forecast at last 21pm	c_{p11}: 0% c_{p12}: 10-40% c_{p13}: 50% c_{14}: 60-90% c_{p15}: 100%	exclusive options	One for all options
c_{p2}	Area of the office	c_{p21}: Central 3-wards Tokyo c_{p22}: Central 5-ward c_{p23}: Dedicated Big Cities c_{24}: Others	exclusive options	One for all options
c_{p3}	Commuting time	c_{p31}: In 30-mins c_{p32}: 30 - 60 mins c_{p33}: 50% c_{p34}: 60-120 mins c_{p35}: Over 120 min	exclusive options	One for all options

	x1: solo work; high concentration,	x2: solo work; low concentration,	x3: co-work	x4: casual communication	x5: formal communication
y_1: home office; Live alone or separate room	1.0	0.8	0.0	0.2	0.8
y_2: home office; Live with family	0.6	0.6	0.0	0.2	0.2
y_3: 3rd place; Café or Library	0.6	0.6	0.0	0.0	0.0
y_4: 3rd place; Shared open office	0.4	0.6	0.4	0.2	0.6
y_5: 3rd place; Rental Bos	0.6	0.4	0.0	0.0	0.4
y6: centre office; Booth	0.8	0.2	0.0	0.0	0.0
y7: centre office; Open desk	0.6	0.8	0.6	0.4	0.2
y8: centre office; Open communication small	0.4	0.6	1.0	0.8	0.2
y9: centre office; Open communication small	0.0	0.8	0.8	1.0	0.4
y10: centre office; Meeting room	0.0	0.0	0.2	0.4	1.0

Figure 6: Knowledge base; M_{ap}: 'Activity and Place'

Source: own.

		x1: solo work; high concentration,	x2: solo work; low concentration,	x3: co-work	x4: casual communication	x5: formal communication
Job type	c_{ag11}: Administration	0.4	0.6	0.4	0.4	0.8
	c_{ag12}: Coordinator	0.4	0.6	0.6	0.4	1.0
	c_{ag13}: Business planning	1.0	0.8	0.8	1.0	0.4
	c_{ag14}: R&D	1.0	0.8	1.0	1.0	0.4
	c_{ag15}: Sales	0.6	1.0	0.6	0.8	0.6
psychological safety level	c_{ag21}: Very good	0.4	0.6	0.8	1.0	0.6
	c_{ag22}: Good	0.4	0.6	0.6	0.8	0.6
	c_{ag23}: Neutral	0.4	0.4	0.4	0.4	0.4
	c_{ag24}: Bad	0.2	0.2	0.2	0.2	0.4
	c_{ag25}: Very bad	0.2	0.2	0.2	0.0	0.2

Figure 7: Knowledge base; M_{ag}: 'Activity-affecting' General, none place dependent

Source: own.

		x1: solo work; high concentration,	x2: solo work; low concentration,	x3: co-work	x4: casual communication	x5: formal communication
Attendances	c_{ao1}: preferable people is	0.4	0.8	0.8	1.0	0.6
	c_{ao2}: dislike people is not	0.0	0.6	0.4	1.0	0.2
	c_{ao3}: Team member(s) be	0.4	0.6	0.6	0.6	0.8
Indoor quality; temperature	c_{ao42}: 22-24°C	0.8	0.8	0.6	0.8	0.4
	c_{ao43}: 24-26°C	0.8	0.8	0.6	0.8	0.4
	c_{ao44}: 26-28°C	0.8	0.8	0.6	0.8	0.4
Indoor quality; humidity	c_{ao52}: 35-45%	0.8	0.8	0.6	0.8	0.4
	c_{ao53}: 45-55%	0.8	0.8	0.6	0.8	0.4
	c_{ao54}: 55-65%	0.8	0.8	0.6	0.8	0.4
Indoor quality; CO2(ppm)	1-([actual ppm] -1000)/1500	1.0	0.8	0.6	0.6	0.6
Indoor quality; Brightness on desktop	c_{ao71}: Less 300Lx	0.2	0.2	0.2	0.6	0
	c_{ao72}: 300-600Lx	0.8	0.8	0.6	0.8	0.8
	c_{ao73}: Over 600Lx	0.2	0.2	0.4	0.2	0.6
refreshment	c_{ao8}: Drink	0.6	0.8	0.6	1.0	0.2
	c_{ao9}: Snack	0.4	0.4	0.4	1.0	0.0
	c_{ao10}: Meal	0.4	0.4	0.4	0.8	0.0

Figure 8: Knowledge base; M_{ao}: 'Activity-affecting' Place, centre office dependent.

Source: own.

	Rain chance forcast at last 21pm					Area of the office				Commuting time			
	0%	10%-40%	50%	60-90%	100%	Central 3-wards	Central 5-ward	Dedicated Big Citis	Others	In 30-mins	30 - 60 mins	60-120 mins	Over 120 min
y_1: home office; Live alone or separate room	0.4	0.4	0.6	0.8	1.0	0.2	0.6	0.8	1.0	0.4	0.6	0.8	1.0
y_2: home office; Live with familiy	0.4	0.4	0.6	0.8	1.0	0.0	0.4	0.6	0.8	0.4	0.6	0.8	1.0
y_3: 3rd place; Café or Library	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.4	0.6	0.0	0.2	0.4	0.6
y_4: 3rd place; Shared open office	0.4	0.4	0.4	0.2	0.2	0.2	0.4	0.6	0.8	0.2	0.4	0.6	0.8
y_5: 3rd place; Rental Bos	0.4	0.4	0.4	0.2	0.2	0.2	0.4	0.6	0.8	0.2	0.4	0.6	0.8
y6: centre office; Booth	0.5	0.5	0.5	0.3	0.0	0.8	0.5	0.3	0.0	0.8	0.6	0.2	0.0
y7: centre office; Open desk	0.5	0.5	0.5	0.3	0.0	0.8	0.5	0.3	0.0	0.8	0.6	0.4	0.2
y8: centre office; Open communication small	0.5	0.5	0.5	0.3	0.0	0.8	0.5	0.3	0.0	0.8	0.8	0.6	0.4
y9: centre office; Open communication small	0.5	0.5	0.5	0.3	0.0	0.8	0.5	0.3	0.0	1.0	0.8	0.6	0.4
y10: centre office; Meeting room	0.5	0.5	0.5	0.3	0.0	0.8	0.5	0.3	0.0	0.6	0.4	0.2	0.0

Figure 9: Knowledge base; M_p: 'Place-determining'

Source: own.

4.2 Visualization of Results

We prepared sample data that can show the features of the model. The system lists the two results in a line graph; the dashed line describes the results of the primary knowledge base for 'Activity and Place', and the solid line describes the results of the complementary contexts of the workplace. A place with a higher value is preferable to other places in the workplace.

4.3 Experiment

4.4 Result for different activities

First, we created three sample datasets and set activities differently but the same for all other complementary contexts of the workplace (**Figure 10**). The shapes of the results for both the primary knowledge base (dashed line) and with-contexts-of-workplace (solid line) were similar. However, some points of with-contexts-of-workplace (circles in the graphs) differed from the primary points. This indicates that the context of the workplace affects differently.

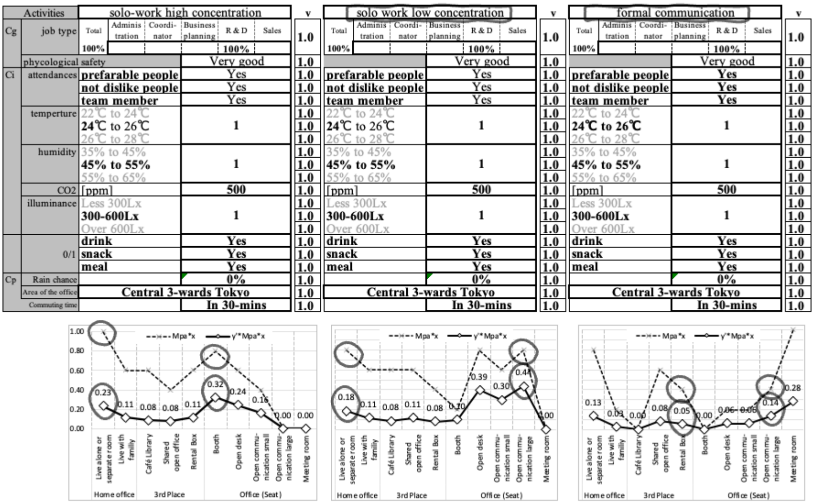


Figure 10: Results with complementary context are different from the primary knowledge base

Source: own.

4.4.1 Results for different complementary contexts

Second, we prepared three sample datasets and set either different 'Activity-affecting context' or different 'Place-determining context' for the same activity (**Figure 11**). Both types of workplace contexts generated different preferences.

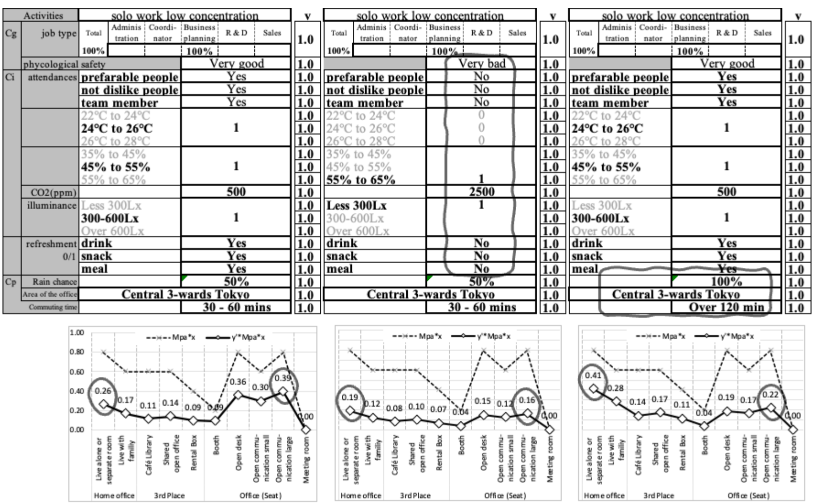
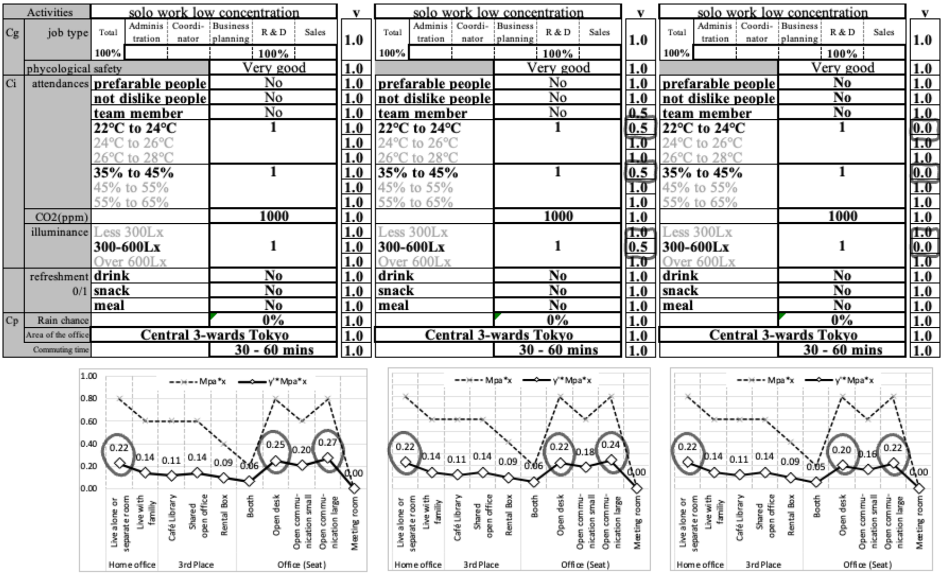


Figure 11: Results for different complementary context

Source: own.

4.4.2 Results for different personal context vectors

Finally, we prepared three sample datasets and set the same activity and complementary contexts for the workplace, but with different personal context vectors (see **Figure 12**). The results were not much different from each other, but slightly changed the rank of preferability (circles in the graphs).



			Value (all three datasets)	v (1)	v (2)	v (3)
	Activities		solo work low concentration			
Cg	job type	Total 100% (Adminis tration / Coordi-nator / Business planning / R & D / Sales)	R & D 100%	1.0	1.0	1.0
	phycological safety		Very good	1.0	1.0	1.0
Ci	attendances	prefarable people	No	1.0	1.0	1.0
		not dislike people	No	1.0	1.0	1.0
		team member	No	1.0	0.5	1.0
		22°C to 24°C	1	1.0	0.5	0.0
		24°C to 26°C		1.0	1.0	1.0
		26°C to 28°C		1.0	1.0	1.0
		35% to 45%	1	1.0	0.5	0.0
		45% to 55%		1.0	1.0	1.0
		55% to 65%		1.0	1.0	1.0
	CO2(ppm)		1000	1.0	1.0	1.0
	illuminance	Less 300Lx		1.0	1.0	1.0
		300-600Lx	1	1.0	0.5	0.0
		Over 600Lx		1.0	1.0	1.0
	refreshment 0/1	drink	No	1.0	1.0	1.0
		snack	No	1.0	1.0	1.0
		meal	No	1.0	1.0	1.0
Cp	Rain chance		0%	1.0	1.0	1.0
	Area of the office		Central 3-wards Tokyo	1.0	1.0	1.0
	Commuting time		30 - 60 mins	1.0	1.0	1.0

Figure 12: Results for different context vector
Source: own.

5 Conclusions and further scope

Herein, we proposed a data model and calculation method with three knowledge bases and the contexts of workplace, and showed the possibility of selecting appropriate workplaces. The system afforded different results with the complex contexts of workplace from the result with only 'Activity and Place' knowledge base, which has been used for traditional workplace planning. However, several practical issues remain unresolved.

5.1 Is there sufficient context?

Some readers of this paper may state that they have different contexts to decide the workplace. Particularly, 'activities' as the primary context, must be well modeled. In this study, we prioritized the method to calculate in complex workplace context. However, we must define the activity model for more practical situations. Furthermore, we believe that the contexts of the workplace and knowledge bases might be different from a set of organisational and workplace settings. In our prototype system, we manually set up the contexts of the workplace and knowledge base. Therefore, the system must be improved to easily establish context and knowledge bases.

5.2 Are the 'Activity-affecting' and 'Place-determining' contexts related each other?

Here, we have determined that 'Activity-affecting' and 'Place-determining' contexts are related each other. Therefore, the result: **x'** of 'Activity-affecting' context has multiplied by the results: **y'** of 'Place-determining' context as $\mathbf{y} = \mathbf{y}'\mathbf{M}_{pa}\mathbf{x}'$. If there is no relationship between 'Activity-affecting' and 'Place-determining', we can add **y'** to $\mathbf{M}_{pa}\mathbf{x}'$; as $\mathbf{y} = \mathbf{y}' + \mathbf{M}_{pa}\mathbf{x}'$. The formula means that the 'Place-determining' context will less affect, if the result; **x'** of 'Activity-affecting' context becomes larger. We aim to investigate this relationship by applying it to actual settings in the future.

5.3 How should the value be normalised?

Here, we used the average to normalise the results. Although a strategy for normalization is currently unavailable, we aim to investigate the normalization way in the next step.

5.4 How can the future prediction of the contexts of workplace be collected?

Some workplace contexts include future prediction, such as attendance of other people, indoor quality (temperature/humidity) of tomorrow. Each workplace context cannot be collected by any sensor and must be predicted using two types of method.

1) Using some other prepared information, e.g., for attendances context, due to COVID-19, some organisations adopted 'Office access control'. The organisations ask the workers to book in advance to come to office. The system can provide future attendance for a person.

2) Alternatively, the system may make infererences using knowledge bases and past data.

6 Future possibility and Next steps

6.1 Future possibility of the proposed model

The calculations were conducted manually and individually using the prototype system. If implemented as a real-time online system in an actual setting, the model can serve as a personal assistance tool for workers. This tool, which connects to schedule organising applications, can make workers more productive and comfortable in complex workplace contexts.

If the system can handle multiple data simultaneously, facility managers can use it as a simulator to plan workplace settings. A facility manager can set functional spaces and workplace services in several options, and then simulate the occupancy rate of the virtual centre office and estimate the excess or deficiency.

6.2 Next step of the research

In the next step, we plan to prepare a more practical system and apply it to an actual setting. Subsequently, we aim to evaluate the functionality of the model, contexts of the workplace, and knowledge bases.

However, the study encounters a challenge; therefore, we aim to collect more dynamic intent (activity) data and the feelings of workers. Currently, we can collect such intent data from only a few questionnaires. However, we desire to have more continuous and extensive data to improve this model. Therefore, we aim to develop service applications, such as the personal assistance mentioned in the previous section.

References

[1] Peter F. DRUCKER (1959), *Landmarks of Tomorrow*, Harper colophon books

[2] Ikujiro NONAKA, (1990). Management of Knowledge Creation. Tokyo: Nihon Keizai Shinbun-sha.

[3] Craig ROTH (2019, December 11), *2019: When We Exceeded 1 Billion Knowledge Workers, Gartner Blog Network,* https://blogs.gartner.com/craig-roth/2019/12/11/2019-exceeded-1-billion-knowledge-workers/#:~:text=At%20some%20point%20this%20year,many%20knowledge%20workers%20in%20history, Retrieved December 21st 2022

[4] Jack KELLY, (2021, April 1), *Google Wants Workers To Return To The Office Ahead Of Schedule: This Looks Like A Blow To The Remote-Work Trend*, Forbes, https://www.forbes.com/sites/jackkelly/2021/04/01/google-wants-workers-to-return-to-the-office-ahead-of-schedule-this-looks-like-a-blow-to-the-remote-work-trend/?sh=43dec3c11575, Retrieved December 21st 2022

[5] Erik VELDOHOEN (2004), The Art Of Working, Academic Service

[6] Veldhoen + Company, *Rethink the way we work Activity Based Working,* https://www.veldhoencompany.com/en/activity-based-working/, Retrieved December 21st 2022

[7] Yokoyama, M., Kiyoki, Y., & Mita, T. (2019). A Correlation Computing Method for Integrating Passengers and Services in Semantic Anticipation. Information Modelling and Knowledge bases XXX, 312, 435., IOS Press