A NEW WORKPLACE SERVICE PROVISION MODEL FOR THE KNOWLEDGE WORKERS

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ABSTRACT

A NEW WORKPLACE SERVICE PROVISION MODEL FOR THE KNOWLEDGE WORKERS

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Office workplaces are specialized environments presenting proper workable ambiance and social and communal services for the knowledge workers. The interior architectural parameters are targeted to improve the knowledge workers' productivity, comfort, and well-being. There is a growing demand for personalization and customization in the workplace environment, together with a high level of flexibility regarding where and when to work the knowledge worker. The current workplace services practices were not successful in meeting these growing demands. The study envisions that each knowledge worker can be matched with a temporary/dynamic workspace that suits their personal choices and task requirements through an intelligent matching/bidding system. The proposed system aims to outsource new office workplace service provision by integrating semantic web applications, smart contracts, and ambient intelligence. The new paradigm cannot only meet the participants' emerging demands but also improve occupancy satisfaction and decrease the operation costs of the organizations. The model was formalized and evaluated by web ontology models. The validation of the model was accomplished by use of literature and in-field based studies. Firstly, the validity of the arguments was investigated in a survey, and a simple test for user interface demo

for workplace configuration was executed with the knowledge workers in a co-working office. Then, the applicability of the model in the real world was investigated by interviewing facility managers. The facility managers expressed application-based concerns for the new model and addressed practical handicaps and challenges. However, the model was applicable and presented many advantages for the industry stakeholders.

Keywords: Workplace Service Provisions, Workplace Comfort & Wellbeing Parameters, Smart Contract, Web Ontology Models, Office Workplace Facility Management

ÖZ

BİLGİ ÇALIŞANLARI İÇİN YENİ BİR ÇALIŞMA ORTAMI HİZMET SUNUMU MODELİ

Sarı, Ramazan
Doktora, Yapı Bilimleri, Mimarlık
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Ofis çalışma alanları sahip olduğu sosyal ve müşterek hizmetlerle beraber çalışma ortamı odağında özelleşmiş mekanlardır. İç mekan tasarım unsurları üretkenliği, rahatlığı ve sağlıklı çalışma ortamı sunmak üzere düzenlenir. Artık çalışma ortamlarında giderek artan bir oranda bilgi işçileri tarafından çalışma zamanı ve mekanı konusunda yüsek düzeyde esneklikle beraber kişiselleştirilebilirlik talebi dile getirilmektedir. Fakat mevcut uygulamalar gün geçtikte giderek artan bu talepleri karşılamada yetersizdir. Araştırma çalışması, akıllı eşleştirme ve satin alma sistemlerinin kullanımı ile her bir bilgi işçisine kendisinin yapılandırıp seçimler yapabildiği özel bir çalışma alanı tahsis edilmesini sağlayan bir ofis çalışma alanı hizmet modeli önermektedir. Önerilen model bu amacı gerçekleştirebilmek için içerisinde anlamsal ağ uygulamaları, akıllı sözleşme, ve ortam zekası teknoloji ve yöntemlerini barındırmaktadır. Yeni modelin günlük uygulamalarda yer verilmesi ile çalışanların memnuniyeti, konforu ve üretkenliğinin artmasının yanında firmaların işletme maliyetinin düşürülmesi de sağlanabilecektir. Öneri model web ontoloji modeli olarak ifade edilip değerlendirme çalışmaları yapılmıştır. Modelin geçerliliği bilgi işçileri ve tesis yöneticilerinin geri dönüş ve yorumları ile sağlanmıştır. Öncelikle modelin oluşmasına vesile olan gerekçelerin geçerlilikleri

gerçek bir ortak çalışma ortamındaki bilgi işçileri ile yapılan anket çalışması ile belirlenmiş ve anlamsal ağ arayüzündeki karmaşık kişiselleştirme işlevi basit bir arayüz çalışması ile test edilmiştir. Sonrasında da öneri modelin uygulanabilirliği, tesis yöneticileri ile yapılan mülakat çalışması ile tespit edilmiştir. Tesis yöneticileri, öneri model için uygulamaya dönük kaygılarını ve ortaya çıkabilecek engelleri belirtmişlerdir. Fakat öneri model genel anlamda uygulanabilir bulundu ve sektör paydaşlarına çeşitli faydalar sağlayabileceği ortaya çıkarıldı.

Anahtar Kelimeler: Çalışma Ortamı Hizmet Koşulları, Konfor ve Sağlıklı Çalışma Ortamı Parametreleri, Akıllı Sözleşme, Web Ontoloji Modeli, Ofis Çalışma Ortamı Tesis Yönetimi

Dedication

to Özden and Meryem

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LIST OF ABBREVIATIONS

ABBREVIATIONS

AEC: Architecture, Engineering, and Construction

AmI: Ambient Intelligence

ABW: Activity-Based Working

BIM: Building Information Modelling

BMS: Building Management System

CAVE: Cave Automatic Virtual Environment

CSI: Construction Specification Institutes

CSS: Cascading Style Sheets

EVM: Ethereum Virtual Machine

FM: Facility Management

HTML: Hyper Text Markup Language

HVAC: Heating, Ventilation, and Air Conditioning

ICT: Information and Communication Technology

IDE: Integrated Development Environment

IFAMP: Integrated Framework for Additively Manufactured Products

IoT: Internet of Things

IVE: Immersive Virtual Environment

IEQ: Indoor Environmental Quality

NLP: Natural Language Processing

OWL: Web Ontology Language

PC: Personal Computer

RDF: Resource Description Framework

ROI: Return of Investment

UCD: User-Centered Design

VR: Virtual Reality

WFH: Working from Home

WWW: World Wide Web

CHAPTER 1

INTRODUCTION

Knowledge workers exist in all types of organizations. Considering their value-added activities, their performance and productivity are crucial to the overall performance of an organization. Thus, researchers and professionals provide special attention to increase their productivity.

Office workplaces are specialized environments presenting proper workable ambiance, social and communal services for the knowledge workers. The interior architectural parameters are targeted to improve the workers' productivity, comfort, and wellbeing.

Throughout history, office workplaces have been in a streamlined improvement and development, although the reasons and conditions at background may be varied. Similarly, in current practice, there are emerging demands, shortages of the existing practice, and changing conditions in office workplace services in the knowledge worker perspective, requiring special attention to maintain productivity in the future business world. These changing conditions, shortages of the existing practice, and emerging demands were categorized and explained in the following sub-sections.

1.1 Emerging Demands and Gaps in Workplace Service Practices

The changing aspects and conditions for the future business world are categorized into five items. Each of the items is depicted below:

- **Mobility and Variety in the Workplace**: Workers demand and expect the ability to work remotely through the involvement of autonomous matching of workers and the correct work settings have increased in the last decades (McLaurin, 2022). Furthermore, the workers also desire alternative

workplaces presenting diverse workplace service opportunities. (Bhushan et al., 2021; Jordan & Baker, 2022; Osibanjo, 2022)

- **Personalization and Privacy in the Workplace**: Workers seek more personalized workplace services and a proper environment to present particular privacy levels when needed (McLaurin, 2022).
- **In-Person Relations and Better Work-Life Balance:** Many workers, especially Gen-Z, expect more emotional and emphatic behavior for their personal, social, and emotional needs about work, career, and life. This situation shifts the meaning of work from "work for me" to "work with me" (Bhushan et al., 2021; Craven et al., 2022; Jordan & Baker, 2022; Klein et al., 2022; Moss, 2022; Osibanjo, 2022; Smet et al., 2021, 2022).
- **Demand for More Green and Sustainable Life:** The people's awareness of decreasing global carbon emissions to improve the quality of living has increased. Therefore, they are more sensitive to using greener technologies and business processes in a new era of working (Boyd et al., 2022; Francis et al., 2022; McKinsey, 2022; Schwab & Sternfels, 2022)
- **Increased Digitalized Form of Work:** Virtual teams and electronic workplaces have become an inseparable part of many business activities. The effective use of smart and automatized technologies brings efficiency to many business practices by eliminating time and cost waste, although their investment cost is exceptionally high (Bhushan et al., 2021; Boyd et al., 2022; Craven et al., 2022; Heuvel et al., 2022; Moss, 2022).

Existing workplace services have particular characteristics and represent various benefits to office workplace stakeholders. However, these services cannot meet the emerging demands of the knowledge workers, and in the ongoing years, there is likely to be a wider gap in the situation. The office workplace services require a knowledge worker–centric approach. The decision maker on workplace designation and configuration would be the knowledge worker by incorporating new concepts and technologies, allowing mobility, variety, personalization, customization, and

other necessities in the workplace environment. Therefore, a new workplace service provision model putting the knowledge worker as the decision maker in the designation and configuration of the workplace environment could be proposed.

1.2 A New Workplace Service Provision Scenario

Technology has gotten more and more involved in the business practices. Thus, a knowledge worker can work anywhere in a city when a proper workplace environment could be provided. Therefore, the knowledge worker is not required to be in a central office or home. Considering the available and proper technologies and systems, a workplace service provision scenario was established, as illustrated in Figure 1-1 and presented in the following items.

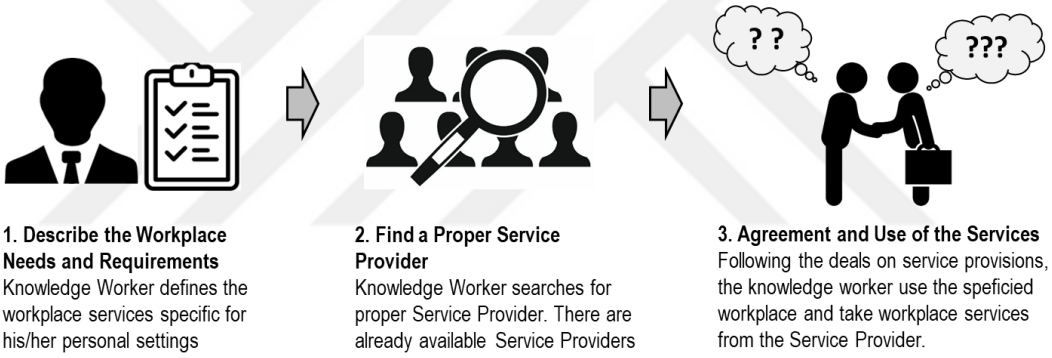

Figure 1-1. The simple illustration of the new workplace service provision scenario

- **Describe the Workplace Needs and Requirements**

The knowledge worker describes a workplace for a specific purpose that would be used for a particular time. For example, a meeting workplace will include several indoor environmental quality (IEQ) parameters and will be used for two hours. Another example could be a concentrated study area with many IEQ parameters requiring specific architectural finishings and furniture. The workplace would be used for three hours in the working days. The workplace desire of the knowledge worker could be set in a user interface that could work on many platforms.

Web ontology models can formally represent the system structure and organization and could easily be applied to the semantic web environment. Once the web ontology models are created, the entire model could be stored in the blockchain, and the smart contract applications could facilitate agreements.

- **Find a Proper Service Provider**

Following the description of workplace services, the knowledge worker looks for a proper service provider to take required workplace services in the web marketplace applications. The application matches the knowledge worker workplace configuration with the service provider's range. The relevant service providers could be listed as a result of the matching. The user interface could allow a 3-D virtual scene of the configured workplace reflecting the knowledge worker's preferences.

- **Agreement and Use of the Services**

After selecting a proper service provider, a service agreement, including the knowledge worker's specific workplace desires, is signed, and the knowledge worker occupies and uses the workplace regarding his/her service provisions. Following the end of the use of the workplace, the knowledge worker evaluates the workplace services and his/her decisions for the workplace to find continuous improvement and the best practices of the workplace services. Blockchain and smart contracts allow workplace-specific agreements between the service provider and the knowledge worker. The workplace configuration parameters could be used as service provisions of the smart contract. Therefore, following the coding, deployed smart contracts could be used for each agreement by only changing the parameter data.

1.3 Problem Statement and Research Questions

The proposed workplace service provision model promotes mobility, maximizes flexibility to decide the workplace service, and puts the knowledge worker in the decision-maker role. The research question states how the knowledge worker –

centric workplace service provision model could be established. With respect to the main question, the following sub-questions are prepared:

- What are the customizable and personalized workplace services?
- How could the user persona, workplace comfort, and wellbeing parameters match the most suitable preferences?
- What are the roles and responsibilities of workplace stakeholders in the proposed model?
- What are the methods and techniques to formalize and represent the proposed model?

1.4 Aim and Objectives

The study aimed to present a mobility system in working time and place and customizable workplace services for knowledge workers. The objectives of the study were presented as follows:

- Description of workplace comfort and wellbeing parameters
- Investigation of user-persona and workplace matching systems and concepts.
- Establishing a model to incorporate the required systems and technologies.
- Identifying the concepts and domains in the proposed model.
- Describe workplace stakeholders' changing roles and responsibilities.

In pursuit of these objectives, the following studies were conducted:

- A workplace service provision model was proposed to allow workplace service configuration and exchange among the knowledge worker and service provider.
- Customizable workplace comfort and wellbeing parameters were collected in the literature and matched with a specific occupant data collection method.

- The process of personalization and customization of workplace services was described, and collaboration and data exchange of the shared data among the concepts of the new model were represented with conceptual maps.
- The method and process of matching relevant workplace designation and services were demonstrated. The data transfer and manipulation through the concepts were described. A unique payment and agreement system was created in smart contracts.
- The web ontology model systematized the proposed model by depicting its domain, concepts, entities, data relations, associations, attributes, and object properties. The web ontology model was evaluated using particular verification and validation methods and applications.
- New roles and responsibilities of the office workplace stakeholders were identified.

1.5 Research Framework

The study consists of three phases, as Figure 1-2 illustrates. The first part is a comprehensive literature review to clarify the necessary methods and technologies to establish the new workplace service provision model. The second part expresses the model's entities, explains the knowledge representation techniques and web ontology models, establishes the domain and concepts of the model, graphical representation of the concepts, relations, and attributes in the processes of the concepts, and implementation practices of the developed web ontology model. The third part evaluates the web ontology model, describes the office workplace stakeholders' changing roles and responsibilities, expresses the new facility management services, and depicts limitations and future implementation practices.

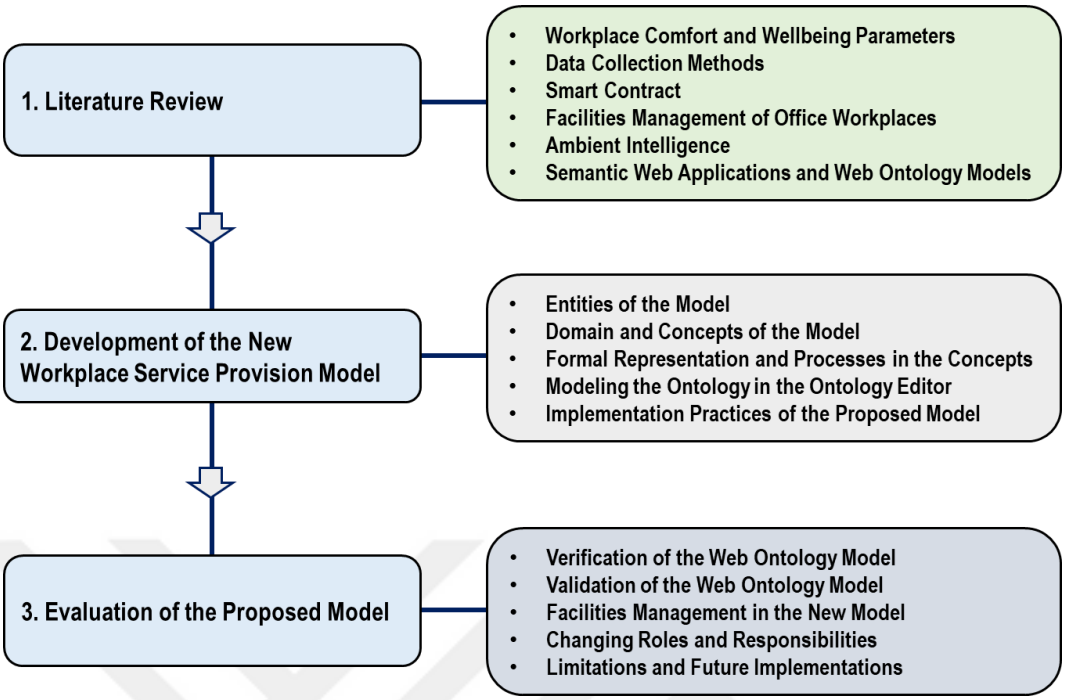

Figure 1-2. The research framework.

1.6 Disposition

The structure of this dissertation consists of five chapters. Following the introduction section, Chapter 2 provides an overview of the required system, methods, and techniques to establish the new workplace service provision model. The key topics reviewed in this section include the history and development of office workplaces, workplace comfort and wellbeing parameters, the available options for user-workplace matching systems, occupant data collection methods, ambient intelligent technology, blockchain and smart contract and semantic web applications, and web ontology models.

Chapter 3 presents the methodology used to establish the ontology model, express the evaluation procedure, and represent the unique methodology to validate the proposed model.

Chapter 4 starts with developing a new user-workplace matching system and particular occupant data collection methods. Following the introduction of entities

of the proposed model, a scenario is expressed to illustrate the workflow and procedure among and between the entities of the proposed model in detail. Then, the domain and concepts of the model are introduced. In addition to formally representing the concepts, the ontology editing process is explained. Two concepts of the model are implemented and expressed in the following sections. Lastly, facility management practices for the new workplace service provision model are presented by referencing the changing aspects and addressing the challenging issues.

Chapter 5 explains the verification and validation studies of the web ontology model compliant with the methodology presented in Chapter 3. After expressing the findings and discussion, the limitations and future implementation studies are represented.

The dissertation is concluded in the last chapter with the overall discussion, referencing the study's unique contribution to literature, limitations of the study, and projections on future work.

CHAPTER 2

LITERATURE REVIEW

This chapter explains existing office workplace concepts and expresses the required and available technologies and systems to establish the new workplace service provision model. The changing conditions and aspects in diverse research fields of office workplaces were tracked and monitored regarding the history and development of office workplaces. The workplace comfort and wellbeing parameters were represented. The user workplace matching systems available in the literature were mentioned. Occupant data collection methods and their particular characteristics to acquire occupant-specific workplace comfort and wellbeing data were illustrated. In pursuit of collecting these occupant-specific workplace comfort and wellbeing parameters, the ambient intelligence concept used to track, monitor, and maintain the standard services in a workplace environment was explained. The potentials of blockchain and smart contract integration with semantic web applications and web ontology models were addressed.

2.1 History and Development of Office Workplaces

- **Architectural Form and Interior Design**

The history of modern office building design goes back to the late 1800s. Architectural form and interior design options were introduced, and various office workplace types were developed such as cellular rooms and Taylorist open plan of early 1900s (Anton, 2015; Gou, 2016), office-landscape (Anton, 2015; Duffy et al., 1992; Gou, 2016), structuralist office (Anton, 2015; Gou, 2016) and action office – cubicles (Anton, 2015; Herman Miller, 2021) of 1950s, combi-office (Anton, 2015;

Grajewski, 1993), activity-based working (ABW) office (Anton, 2015; Becker, Franklin, 1982; Meel, 2020; Murray, 2019) and casual office (Anton, 2015) of 1980s.

Figure 2-1. Sample office buildings constructed between the late 1800s and mid-1900s. Sources: (Early Office Museum, 2016)

Following the maturity of form and interior design in the office environment, further improvements were achieved in increasing the workers' comfort and productivity.

The introduction of personal computers (PCs) and the digital affordances of PCs started to take place in the workstations of knowledge workers in office interiors in the 1970s (Niezabitowska & Winnicka-Jasłowska, 2011).

The value created by knowledge workers in office workplaces has remarkably increased the office buildings' real estate and rental income. The location of office buildings in the cities has become the primary business and commercial zones with proper and specialized social, cultural, and infrastructural needs and requirements. On the other hand, these zones have brought particular problems and handicaps for the knowledge workers, employers, cities, and other stakeholders, such as transportation, real estate, facility management, and sustainability.

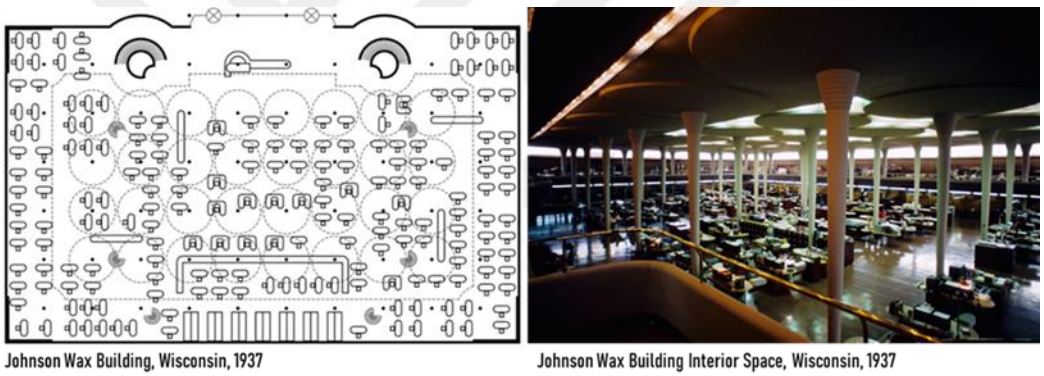

Figure 2-2. Taylorist open plan office workplace. Source for the plan (Anton, 2015) and image (Minner et al., 2010)

The introduction of information and communication technologies (ICT) to the business world enabled remote and distributed working practices as an alternative to the centralized office concept. Telecommuting is a remote and distributed working method introduced in the 1970s to replace commuting with “telecommuting” in response to traffic, sprawl, and scarcity of non-renewable resources (Hensher et al., 2021). Early telecommuting practices presented that telecommuters make substantially fewer vehicle travels (Mokhtarian et al., 1995; Pendyala, R. & Goulias,

1991), select more energy-efficient commute modes such as biking or walking (Bieser et al., 2021), time and cost spent for transportation were preserved for employees to spent for leisure activities and being with family, decrease in vehicle travel diaries increasing the air quality, people with disabilities have more opportunities to participate business (Martel et al., 2021), and best talents located in anywhere in a city could be more accessible (Newman & Ford, 2020).

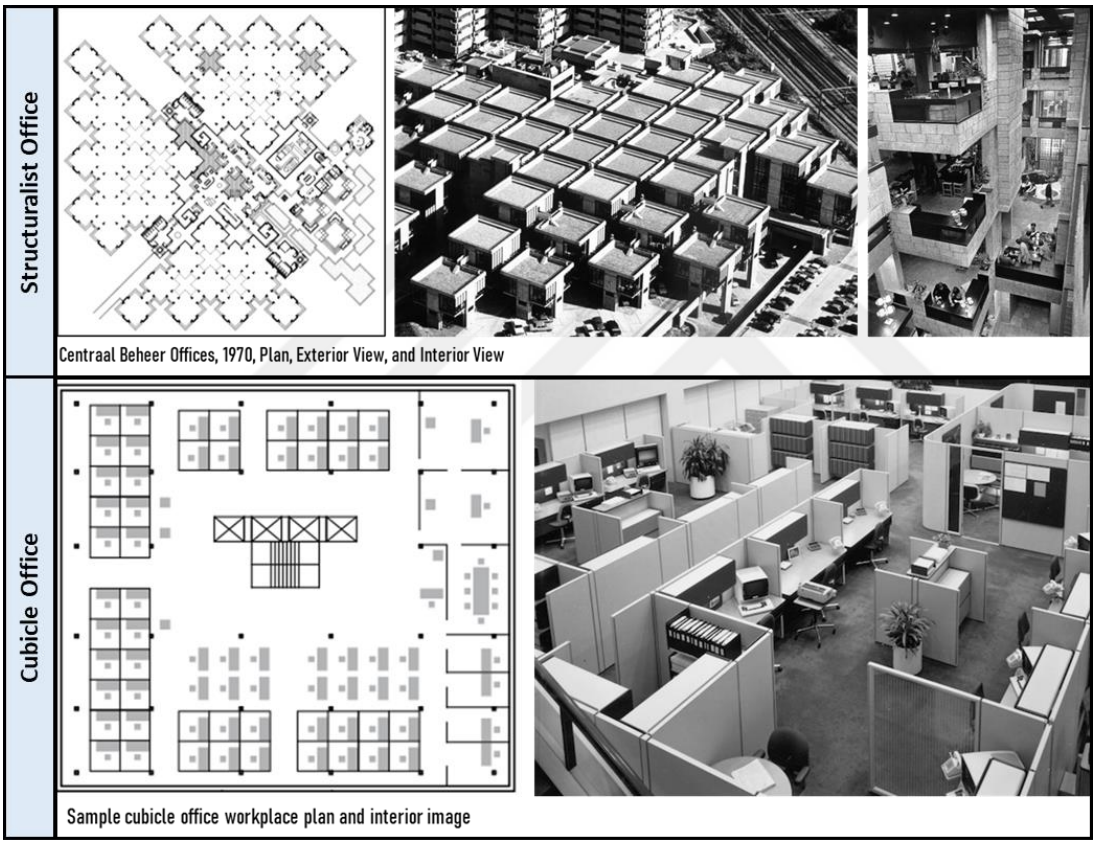

Figure 2-3. Structuralist office (AHH, 2021) and cubicle office (Anton, 2015; Herman Miller, 2021)

Early practices of telecommuting were not expanded widely as expected. Early sociological research presented the barriers in the adoption as (i) individuals required social interaction inherent in being at work, (ii) needed to separate or create a buffer

between home and work roles, and (iii) felt the need to be visibly present to achieve professional advancement (Mokhtarian et al., 1995).

The contribution of technology to office workplaces continued in the 1990s. Office workplaces were equipped with portable and multi-functional devices and equipment such as laptops, cellular phones, voice recorders, etc. (Niezabitowska & Winnicka-Jasłowska, 2011). Office spaces started to be used more efficiently due to the decreased size of devices and equipment; thus, office area per employee has decreased. The introduction of the internet and the increase in data transmission speed have made remote and distributed working popular again. However, rather than telephone connection in the 1970s, the internet was used for remote and distributed working and called virtual and electronic workplaces.

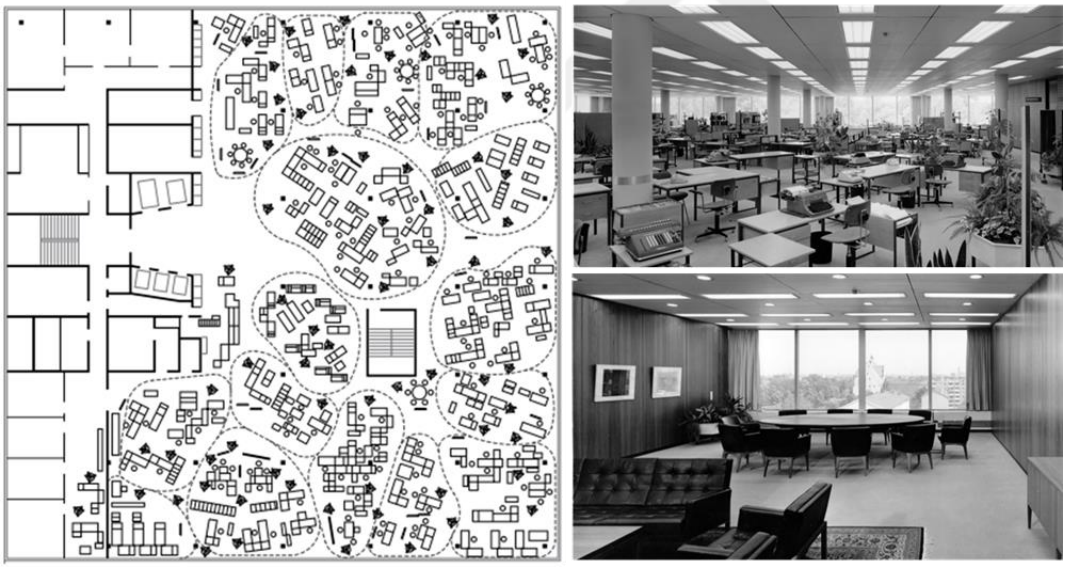

Figure 2-4. A sample plan and workplace images belong to the Osram Headquarters building for the Office-Landscape movement. Source for the plan (Anton, 2015) and images (Heidersberger, 1965)

The development in the internet connection and network structures allowed the creation of virtual offices to proceed in the virtual environment. Thus, expansion and

widespread use of the internet, laptops, and mobile phones enable the move of the workplace from office to out of office such as café and home. The virtual office was developed to enable employees to be assigned to projects regardless of their physical location or formal reporting structure (Held, 1998).

A virtual office is a service that enables employees and business owners to work remotely by providing a range of business functions accessible through the internet (Ugwu, Agha, 2020). Virtual offices provided significant cost savings for organizations against the increase in real estate cost of office areas.

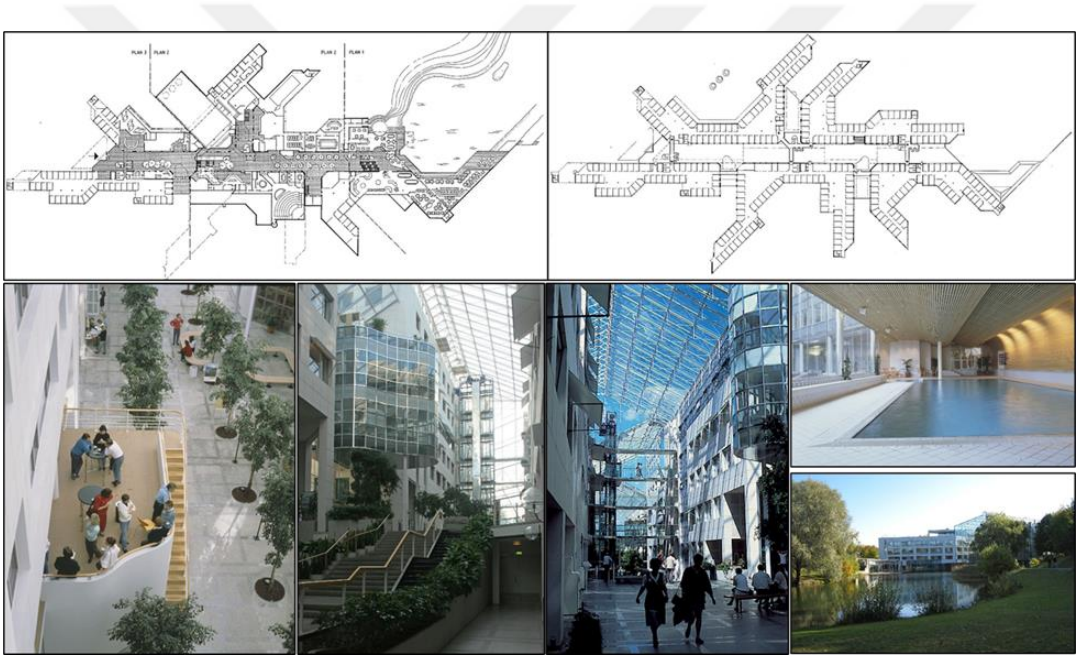

Figure 2-5. SAS Headquarters building is an example of the combi office concept. Source: (NIELSTORP+, 2014)

High investment and advanced improvements in information technologies have made the geographical dispersal and simultaneous integration of many activities possible. Globalization and advances in ICT make virtual teams necessary for most workplaces (Gupta & Pathak, 2018). It has been estimated that more than 60% of

multinational organizations used virtual teams in 2012 (Society for Human Resource Management, 2012).

The shared desk concept was developed in response to decreasing the real estate cost of professional practices by replacing traditional territorial working with an allocation system whereby those who attend the office on a specific day are given a free desk from a pool (Cooper et al., 2017; Maraslis et al., 2016). The shared desk concept is a more commercialized version and efficient use of activity-based working in terms of work environment style, desk assignment, and mobility (Cooper et al., 2017; Joroff et al., 2001; Keeling et al., 2015; Maira et al., 2019).

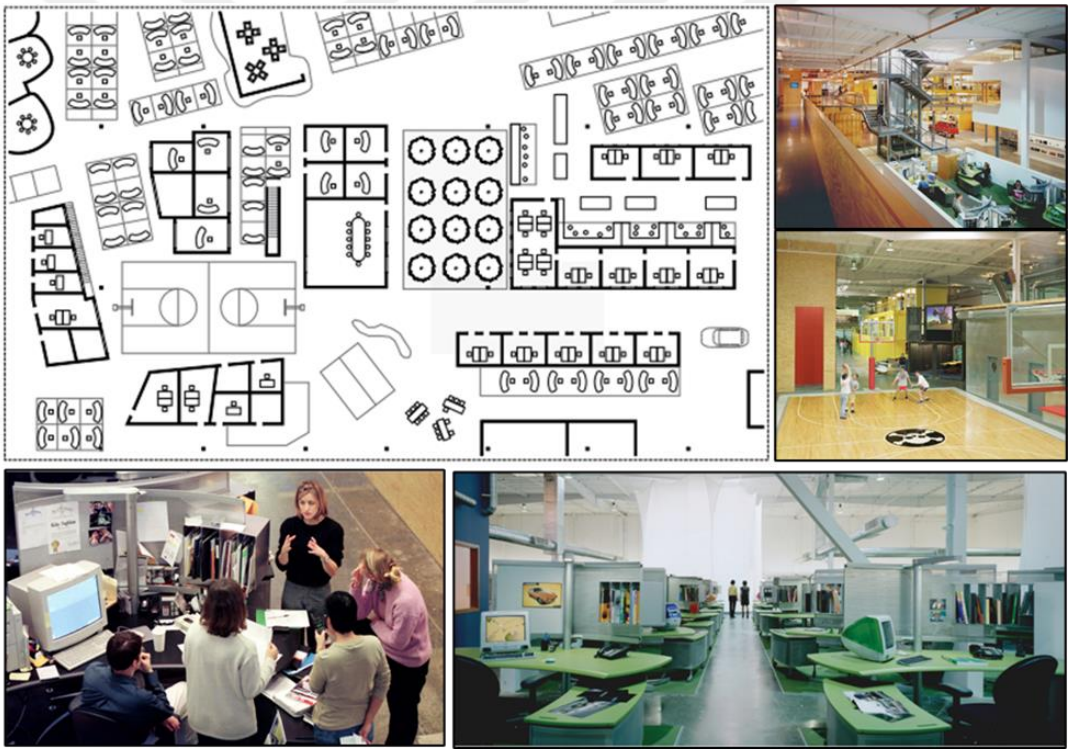

Figure 2-6. TBWA Chiat Day Office Building as an example of a casual workplace. Source: (Clive Wilkinson Architect, 1997)

Although up to 30% reduction in office sizes would be gained (Hirst, 2011), the shared desk concept has been criticized for (i) misunderstanding about whether or

not a desk is occupied (Halford, 2004), (ii) proximity of workers in territorial working allows the better establishment of regular and easy collaboration and discussion between team members working on similar projects or themes, however; the exact synergy cannot be established at hot-desking where the desks belong to no one (Millward et al., 2007), (iii) personalization and customization opportunity available in territorial working cannot be presented (Kleeman, 1992), (iv) the removal of personalization and locational identity led to change at employment relationship to right down to cash nexus, skewing the effort-bargain and undermining any rhetoric of commitment (Cooper et al., 2017).

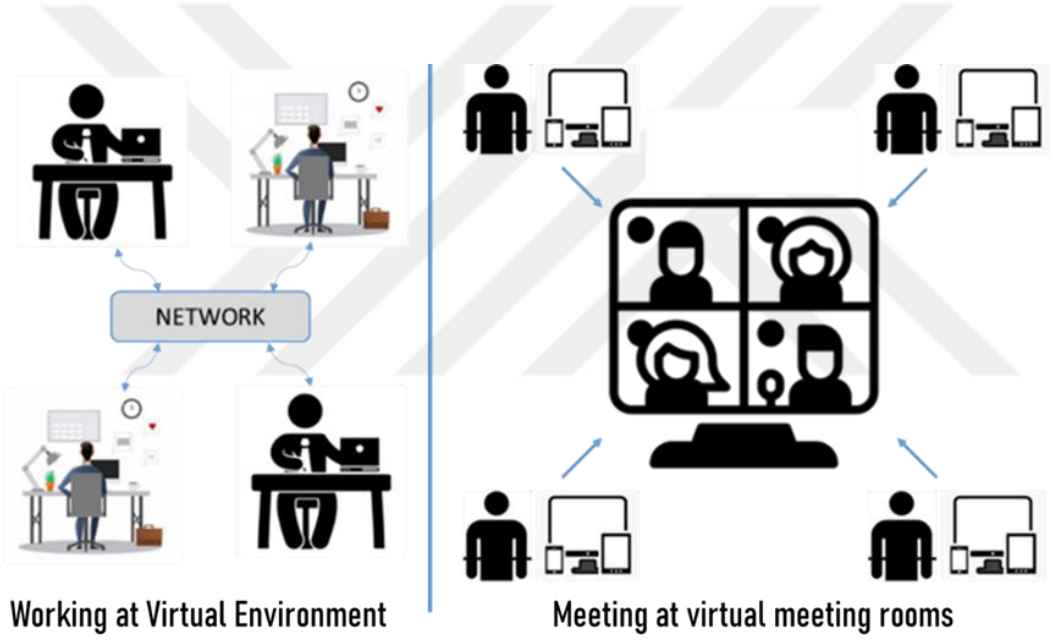

Figure 2-7. Working and meeting in virtual and electronic workplaces.

Wireless internet connection and the introduction of mobile internet devices were two essential contributions presented in the 2000s (Szarejko & Trocka-Leszczynska, 2007). Network structures enable connection to the internet and the continuous and instant existence of people by various devices in cyberspaces. The Internet of Things

(IoT) has been involved in office workplaces, and the smart building concept has started to be implemented.

Ambient Intelligence (AmI) is a system establishing a relationship between people and the environment by gathering data by use of sensors and devices interconnected through a network to take decisions to benefit the users of that environment based on real-time information gathered and historical data accumulated (Augusto, 2008; Weber et al., 2005). AmI is the sub-category of IoT technology specializing in relations between people and the environment. The occupant data is collected through various sensors and devices and transmitted to a middleware. An artificial intelligence reasoning supported by a decision-making system analysis evaluated the occupant's changing conditions and reaction and behavior by actuators. The resulting workplace environment maximizes and maintains the workers' comfort and wellbeing. Furthermore, the collected data specific to a knowledge worker by AmI could be stored in the cloud server and transferred to another smart building to allow the same workplace quality and services for the knowledge workers.

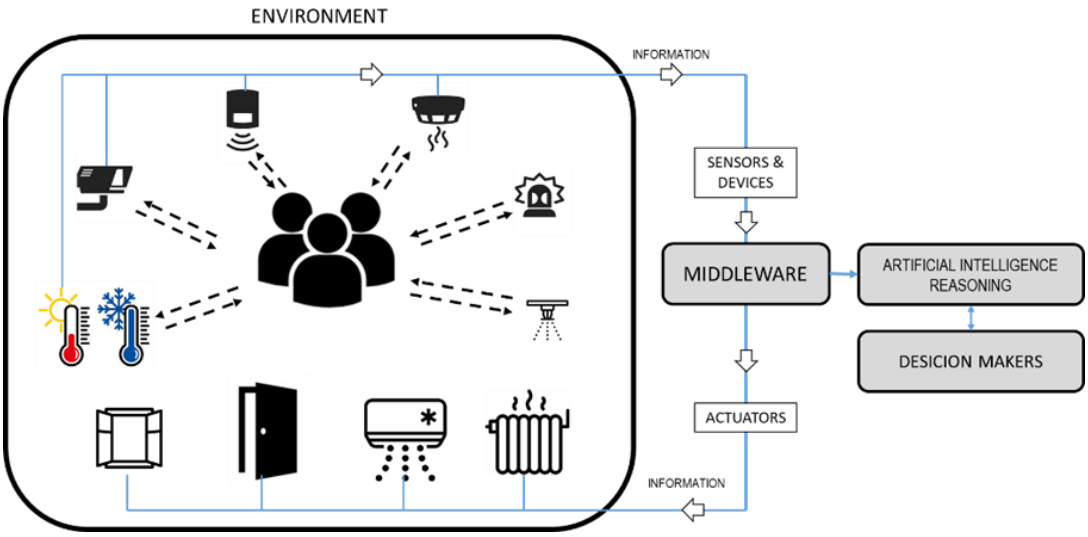

Figure 2-8. Diagrammatic expression of an ambient intelligence framework.

The co-working concept emerged in San Francisco in 2005, incorporating a standard work-life within a traditional, well-delimited workplace in a community-like environment and an independent work-life as a freelancer. The co-working reflects freedom and independence, where the worker is isolated at home (Gandini, 2015; Ivaldi et al., 2018). The emergence of the creative class in the knowledge and creative industries presented a demand to work in a community, sharing the know-how, skills, and physical space (Durante & Turvani, 2018). Co-working spaces are shared workplaces comprising open space desks and other facilities and services offered and organized by co-working businesses run by co-working managers, providers, or proprietors (Durante & Turvani, 2018).

Co-working integrates different elements of the home-office concepts, office communities, telecenters, telework, virtual work, virtual teams, incubators, and communities of practices but specifically offers a cross-sectoral working community with more flexibility, autonomy, and opportunities for social interaction (R. B. Bouncken & Reuschl, 2018). Co-working spaces provide infrastructure and dedicated space to facilitate professional and social interaction, enabling knowledge exchange, creativity, and innovation (Gou, 2016). The common social spaces of cafeterias, lounges, and bars of co-working space expedite serendipitous networking, knowledge exchange, collaboration, innovation, and individual work satisfaction (Gou, 2016). Some co-working spaces have more space dedicated to common, joint, and open offices, while others concentrate on single offices, event spaces, or community areas (R. Bouncken et al., 2020).

Figure 2-9. A coworking space in Medellin. (Co-Work Latam - Medellin, 2017)

- **Workplace, Workspace, and Work Environment**

A workplace is a place where people do their jobs (Cambridge Dictionary, 2023a). On the other hand, a workspace is related to describing the tool or equipment, such as the office, desk, computer, etc., where the people work (Cambridge Dictionary, 2023b). A working environment comprehends a broader term than a workplace and workspace. Thus, a work environment is the sum of the interrelationships between the employee and employer and the environment around the employees, including the technical, human, and organizational features (Oludeyi, 2015).

The technical features cover the workplace's tools, equipment, technological infrastructure and other physical or technical elements. The human environment is related to the network of formal and informal interaction among colleagues, teams, and boss-subordinate relationships within the framework of organizations. The organizational environment includes systems, procedures, practices, values, and philosophies that operate under management's control (Opperman, 2002).

Regarding the aforementioned definitions of workplace, workspace, and work environment, in this study, the workplace is preferred to be used to be configured by

the knowledge worker. This is because the author considers limiting the workplace configuration and customization opportunities within the technical features of the work environment.

- **Business Type and Work Pattern**

The offices in the early 1900s were used for manufacturing light items and products. Therefore, the workers of the office workplaces were dominated by blue collars. On the other hand, the increase in knowledge and involvement of PCs in the 1970s made the office workplaces an area for dealing with and managing knowledge and data. The same transformation had started to be observed in worker types. The dominance of the blue collars was replaced by white collars, which could use PCs and other office equipment and devices.

The structuralist and up-to-down hierarchy among workers has started to disappear. The comfort of the office environment was re-designed to increase the performance and productivity of the workers. Thus, headquarters of organizations replaced manufacturing and production environments in office environments. Furthermore, the office environment has started to include spaces for meeting the social and communal needs of the workers.

Much involvement of ICT in business practices has allowed physical office workplaces to become virtual and electronic workplaces where users can be connected from anytime and anywhere. Thus, the necessity to physically exist in an office environment has been eliminated. Virtual and electronic workplaces have become an inseparable part of firms working globally.

- **Organizational Scale and Size**

Although the involvement of PCs in the 1970s has increased workers' productivity, the required number of staff in an organization to complete regular tasks compared to PC-less working was notably decreased. The same productivity has continued in parallel with the advances and participation of ICT in the business industry. These business types and working pattern transformations make the organization’s size

smaller. Medium-sized firms replaced large firms after the introduction of the PC, and small and even micro-sized firms replaced medium-sized firms. Individual entrepreneurs and freelancers have taken an essential ratio in the business world.

The change in organizational scale has also changed the contractual considerations and office workplace service provisions. A large-sized company occupies a particular area to provide an office workplace, while a medium-sized and small-sized company occupies a medium-sized and small-sized area. The facilities services required for different types of organizations in the same office area or building make the facilities management practices more challenging. Furthermore, micro-sized companies with a single person or a couple of staff have many different requirements than small, medium, and large companies. Especially co-working offices are meeting the expectations of micro-sized companies.

- **Facilities Management Practices and Services**

Shin *et al.* (2018) stated that office building users, mainly corporations, ask for high reliability and performance of facilities to enhance employee productivity (Shin et al., 2018). Furthermore, considering the complexity of the facility, high-rise office buildings are relatively expensive in operation and maintenance, thus requiring professional knowledge and skills. Moreover, since the financial markets have developed, many office buildings have become commercial properties owned by financial investors for investment purposes. It is expected from the investment that the office building will generate a profit either from capital gains or rental income. Although some corporations own the office buildings they occupy, an investor generally owns the office building and collects rent from each tenant. Owners of office buildings expect an increase in their rental income and capital gains by effective facility management.

Facility management is the tools and services supporting the functionality, safety, and sustainability of buildings, grounds, infrastructure, and real estate (IBM, 2021). Facility management includes the following aspects: (a) lease management, including lease administration and accounting, (b) capital project planning and

management, (c) maintenance and operations, (d) energy management, (e) occupancy and space management, (f) employee and occupant experience (g) emergency management and business continuity, (h) real estate management (IBM, 2021). The impact of these aspects changes regarding the building type and functions.

Shin *et al.* (2018) identified critical success factors of effective facility management of office buildings regarding the literature, case study examination, and interviews (Shin et al., 2018). Fourteen critical success factors were retrieved from these studies under five categories, as depicted in Figures 2-10 and 2-11. Furthermore, experts and professionals at office building facility management practices claimed that 5 of these 14 critical success factors are more important than others. These are the reliability and performance of the facility in terms of functionality, emergency preparedness, and safety of tenants in terms of safety and satisfaction of tenants.

DIMENSIONS	CRITICAL SUCCESS FACTORS
Functionality	Reliability of Facility
	Life-Span Extension of Facility
	Performance of Facility
	Upgrading of Facility
Safety	Safety of Tenants
	Emergency Preparedness
	Security of Tenants
Satisfaction	Satisfaction of Tenants
	Responsiveness to Complaints
	Comfort of Environment
Profitability	Cost Saving
	Energy Saving
Environment	Environmental Friendliness
Organization	Development of Staff Competency

Figure 2-10. Critical success factors of office building facility management.
Retrieved from: (Shin et al., 2018)

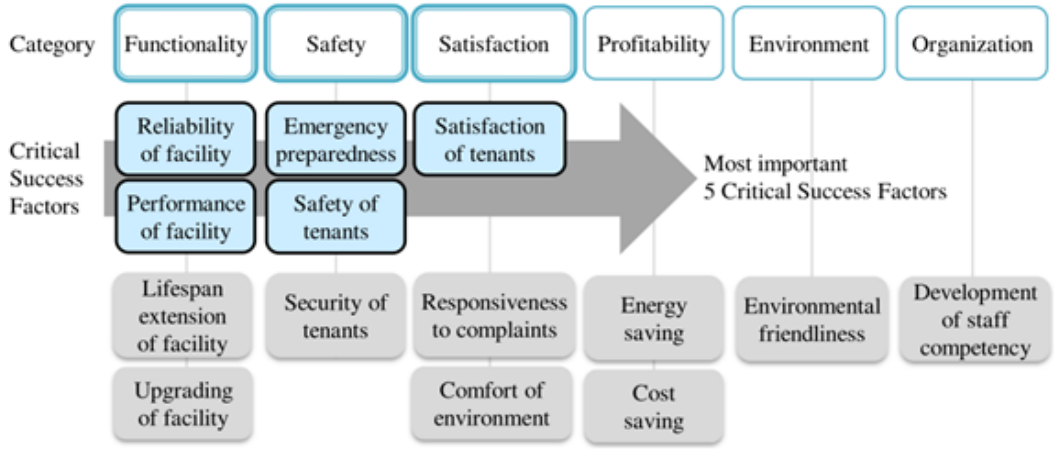

Figure 2-11. Categorized critical success factors and the five most important of them regarding the survey and interview conducted by (Shin et al., 2018) in South Korea.

As stakeholders and relations between them are illustrated in Figures 2-12 and 2-13, the major stakeholders of office building facility management practices are the facility manager, landlord, and tenant (Shin et al., 2018). Both tenant and facility manager have contractual relationships with the landlord for leasing the facility and providing facility management services, respectively. The tenant uses the office building and runs the enterprise based on the space and services provided by the office building and facility manager.

The role and responsibilities of the tenant to the facility manager and the facility manager to the tenant are depicted in the facility management agreement. The landlord earns profit from both rental income and capital gain. The landlord bears the operation and maintenance costs and the facility management service fee (Shin et al., 2018).

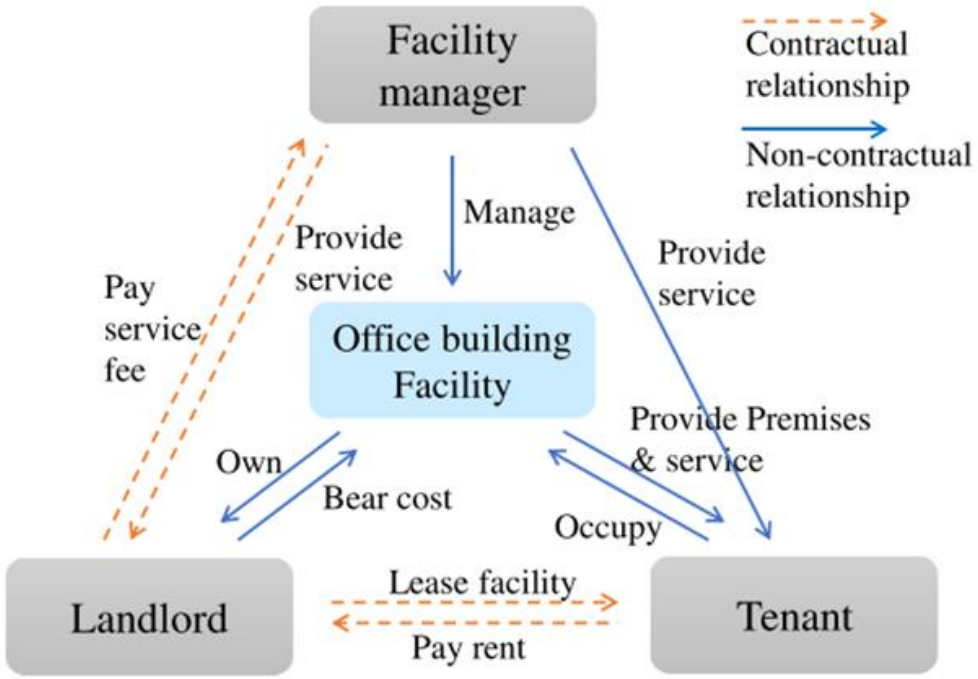

Figure 2-12. Facility Management Stakeholders and their relationships. Retrieved from: (Shin et al., 2018)

Stakeholders	Roles	Responsibilities
Landlord	Owner of facility	To own facility
	Lessor by lease agreement	To lease
	Client by FM service agreement	To order service and pay service fee
Tenant	Occupant of facility	To occupy facility
	Lessee by lease agreement	To pay rent
	No contractual relationship with FM	—
Facility manager	Contractor by FM service agreement	To provide FM service and get service fee
	No contractual relationship with tenant	

Figure 2-13. Office building facility management stakeholders, their roles and responsibilities. Retrieved from: (Shin et al., 2018)

- **Workplace Services in Current Practices:**

The existing practices of workplace services in literature could be divided into two categories: the centralized office concept and the co-working concept.

The centralized office concept is the prevailing office workplace service in business. The office buildings are in the cities' central business and commercial districts. The exterior and interior architectural design have been formalized and reflected with particular architectural forms, construction materials, furniture, devices, and equipment. Organizations in various scales hire the workplace from the landlord without delivering interior architectural finishes for an annual or more contract period. Before the occupation, the organization invested in interior design and construction of the office workplaces. The organizational perspective, corporate culture, unique identity, employee comfort, and productivity are the targets of workplace design and decoration, and the organization makes the decisions about these parameters.

The office building in the centralized office concept includes many tenants. To achieve better building operation, the landlord hires a facility manager to give facilities services to the tenants. Thus, the organization provides an operation cost to the facility manager and the real estate. The facilities services are presented to organizations as standard services with maintaining particular quality.

The occupation ratio of the organizations in the centralized office concept is 70% of the total usable area (Hirst, 2011; Kleeman, 1992). The remaining ones are preserved for future expansions and deviations in work patterns. This means that 30% of the office area is vacant. The shared office concept is based upon efficiently using the vacant office area by decreasing the desk number of offices to lower than the required staff.

Co-working is the commercialized idea of a shared office concept developed for giving office workplace services to micro-scale companies and entrepreneurs. The workplace design allows diverse working and activity environments reflecting

particular ambiances. The service provider gives office workplace services to tenants. Therefore, the tenants lease the workplace from a service provider considering both leasing duration and workplace services. The leasing durations are more flexible than the centralized office concept by allowing monthly, weekly, daily, and hour-based occupation of workplaces. The workplace services are provided in various content with diverse costs. Some commercialized versions of co-working are hot-desking, hot-hoteling, private space, fixed desk, co-working, and virtual office.

Many co-working companies enable membership, where tenants create their account on the company's web site. Following the booking and appointment of the desired workplace type and services, the service provider prepares the workplace, and the tenant uses the reserved workplace, considering the designated services at the designated time. Furthermore, some co-working companies allow take of workplace services in any branch of the company. For example, a member registered and taking workplace services in Ankara can use the same services in the İstanbul branch.

2.2 Workplace Comfort and Wellbeing Parameters

Occupancy comfort has a significant impact on business productivity and worker's wellbeing. Since employees spend a particular amount of time in a workplace, literature presents numerous studies to detect occupancy comfort parameters. The available findings are listed in Table 2-1. They could be categorized as (i) indoor environmental quality (IEQ), (ii) interior use of space, (iii) indoor facilities, (iv) workspaces, (v) support areas, (vi) facility management services, and (vii) information technologies and communication systems.

Table 2-1. Workplace comfort and wellbeing parameters.

Category	Parameters	Source
Visual comfort	• Illuminance • Circadian Lighting Design • Uniformity of illuminance • Illuminance of the immediate surrounding areas • Percentage of the task area meeting the required illuminance	(Franke & Nadler, 2020; Hashemi et al., 2021; ISHRAE, 2019; Moezzi & Goins, 2011; Riratanaphong & Chaiprasien, 2020; USGBC, 2014)
Windows	• Window-to-wall ratio • Size of the window • Operability • Position & Location • Proximity to Window	(Kwon & Remøy, 2019; Moezzi & Goins, 2011; USGBC, 2014)
Furniture	• Ergonomic • Comfort • Type • Quality • Material	(Franke & Nadler, 2020; Hashemi et al., 2021; Moezzi & Goins, 2011; USGBC, 2014)
Acoustic comfort	• Noise Criteria • Reverberation Time • Speech Transmission Index	(Franke & Nadler, 2020; Hashemi et al., 2021; ISHRAE, 2019; Moezzi & Goins, 2011; Riratanaphong & Chaiprasien, 2020; USGBC, 2014)
Indoor Air Quality	• Carbon dioxide • PM 2.5 • PM 10 • Carbon Monoxide • Total Volatile Organic Compounds • Formaldehyde • Sulfur dioxide • Ozone • Total microbial count	(Franke & Nadler, 2020; Hashemi et al., 2021; ISHRAE, 2019; Moezzi & Goins, 2011; Riratanaphong & Chaiprasien, 2020; USGBC, 2014)
Thermal Comfort	• Air temperature • Vertical air temperature difference • Operative temperature • Radiant temperature asymmetry • Floor surface temperature • Air speed	(Franke & Nadler, 2020; Hashemi et al., 2021; ISHRAE, 2019; Moezzi & Goins, 2011; USGBC, 2014)
General office layout	• Size of the area • Height of the space • Location of workplace components • Required equipment, furniture, and devices. • Color, texture, material, and floor, wall, and ceiling finish quality.	(Agha-Hossein et al., 2013; Franke & Nadler, 2020; Hassanain et al., 2018; Kwon et al., 2019; Riratanaphong & Chaiprasien, 2020)
Workplace	• Size of the workplace • Color, texture, and quality of material • Orientation • Location	(Agha-Hossein et al., 2013; Riratanaphong & Chaiprasien, 2020)
Filling and storage space	• Availability • Size • Capacity	(Agha-Hossein et al., 2013; Riratanaphong & Chaiprasien, 2020)
Cycling facilities	• Amount and period of cycling	(Agha-Hossein et al., 2013)
Shower facilities	• Availability • Type	(Agha-Hossein et al., 2013)
Toilet facilities	• Availability	(Agha-Hossein et al., 2013)
Kitchen facilities	• Availability	(Agha-Hossein et al., 2013)

Table 2-1 *continued*

Canteen facilities	• Availability	(Agha-Hossein et al., 2013)
Office Building	• The exterior design of the building • The interior design of the building • Overall quality, color, and material of interior finishing	(Hassanain et al., 2018; Moezzi & Goins, 2011)
Workstation	• General layout • Appearance • Size • Comfort and ergonomic • Location at workplace • Orientation at workplace	(Hassanain et al., 2018)
Accessibility	• Transportation options to the facility • Compliance with universal design principles	(Riratanaphong & Chaiprasien, 2020)
Type of work performed.	• There are various types of workplaces defined such as hive, cell, den, and club by Duffy et al. (1992)	(Hashemi et al., 2021)
Duration of work	• Time	(Hashemi et al., 2021)
Meeting room	• Availability, Capacity, Type, Function, and other specific conditions	(Hassanain et al., 2018)
Dining area	• Availability, Capacity, Type, Function, and other specific conditions	(Moezzi & Goins, 2011; Riratanaphong & Chaiprasien, 2020)
Pantry	• Availability, Capacity, Type, Function, and other specific conditions	(Riratanaphong & Chaiprasien, 2020)
Parking spaces	• Availability, Capacity, Type, Function, and other specific conditions	(Moezzi & Goins, 2011; Riratanaphong & Chaiprasien, 2020)
Resting Area	• Availability, Napping or Sleeping	(PANG, 2017; Smith, 2010)
Smoking area	• Availability & proximity	(Riratanaphong & Chaiprasien, 2020)
Cleaning	• Cleanliness level: high, medium, low	(Franke & Nadler, 2020; Hashemi et al., 2021; Moezzi & Goins, 2011; Riratanaphong & Chaiprasien, 2020)
Safety & Security	• Required security level: high, medium, low	(Moezzi & Goins, 2011; Riratanaphong & Chaiprasien, 2020)
Maintenance	• Necessity • Required frequency	(Hashemi et al., 2021; Moezzi & Goins, 2011; Riratanaphong & Chaiprasien, 2020)
Communicability with Facility Manager (FM)	• In case of any problem conflict, accessibility to FM: Easy access, No access,	(Moezzi & Goins, 2011)
Vertical circulation (elevators)	• Vibration • Noise • Acceleration/ Deceleration Impact • Comfort	(Moezzi & Goins, 2011; Schindler, 2020; Szydło et al., 2020)
Network	• Wired / Wireless • Required performance	(Hassanain et al., 2018)
Audio-visual systems	• Comfort and performance requirements of speakers and video conferencing	(Hassanain et al., 2018)
Modern technologies	• Need for additional affordances, easy plug, etc.	(Hassanain et al., 2018)

2.3 The User – Workplace Matching System

The proposed workplace service provision model maximizes occupancy comfort and wellbeing by allowing a personalized and customized workplace environment for the knowledge worker. This target requires a particular match of the occupant and workplace. This section expresses the available methods in the literature. These are (i) archetypes and stereotypes and (ii) personas.

2.3.1 Archetypes & Stereotypes

An archetype is a standard representation of some aspect of humanity, while a stereotype is a negative and more recently developed image of a particular type of person (Baxter, Michelle, 2014). When a character is modeled after a stereotype or an archetype, the character possesses traits that make him or her easily identifiable (Baxter, Michelle, 2014). Therefore, archetypes and stereotypes are sample characters illustrating certain aspects of humans and culture. Archetypes and stereotypes are used for user-centered-design (UCD) studies. However, due to their higher level of generalization about characters, later studies focus on the development of personas where the character definition is far more specific than archetype and stereotype. Therefore, archetypes and stereotypes are used in global and intercultural sectors and studies such as movies and advertisements.

2.3.2 Personas

The UCD, also known as “human-centered design and customer-centered design,” represents a general philosophy toward design that brings the users or consumers into the design process (Miaskiewicz & Kozar, 2011). The UCD is used in websites, systems, and many product designs and substantially improves user satisfaction. Personas represent target users with common behavioral characteristics, such as hypothetical archetypes of actual users (Miaskiewicz & Kozar, 2011).

Personas are abstractions of groups of real consumers who share common characteristics and needs (Pruitt & Adlin, 2006). A persona is represented through a fictional individual, representing a group of real consumers with similar characteristics (Pruitt & Adlin, 2006; Turner & Turner, 2010). A persona is described in narrative form. This narrative has two goals: (1) to make the persona seem like a real person and (2) to provide a vivid story concerning the persona's needs in the context of the product being designed. The narrative of a persona starts with a description of the type of individual the persona is, likes and dislikes, occupation, and so forth. This narrative part brings the persona to life (Cooper, 1999; Grudin & Pruitt, 2002). Then, the persona's specific needs and personal goals are described in the context of the product being designed. This narrative segment helps inform the resulting design decisions (Manning et al., 2003; Pruitt & Adlin, 2006). These are the exact needs that one would find in a standard requirements document but are now written in the context of the narrative describing a specific persona (Miaskiewicz & Kozar, 2011).

The significant benefits of persona use are (i) the establishment of better communication between the user and design team, (ii) enabling focusing on a specific audience, (iii) making the user needs more explicit and better engagement of the design team to more clarified needs and requirements of target and (iv) target user are much more known by design team that would facilitate more determined future directions and decisions about product and services (Miaskiewicz & Kozar, 2011).

2.4 Occupant Data Collection Methods

Collecting occupant data to detect the employees' comfort and wellbeing conditions is challenging for professionals and academics. There are a couple of methods representing different occupant data collection characteristics. These are surveys, in-field observation, test rooms, and immersive virtual environments (IVE) (Heydarian & Becerik-Gerber, 2017).

2.4.1 Survey-Based Study

Survey-based studies, in general, were performed during the post-occupancy phase. The researchers collect occupant comfort data quickly at a low cost and a known level of accuracy (Forza, 2002; Rea & Parker, 2014). The following findings were presented by using a survey-based study: (i) identifying the correlations between occupant behavior variables and energy consumption habits (Guerra-Santin & Itard, 2010), collecting information about occupant preferences such as lighting, outside view, etc. (Van Den Wymelenberg, 2012), understanding occupants' interactions with different building systems (Moore et al., 2003), and identifying different sources of discomfort (Haldi & Robinson, 2008).

The accuracy and validity of the findings could easily be manipulated by participants either intentionally or unintentionally. Since the feelings are presented, participants' sense of a comfort parameter and actual behavior may differ. Moreover, the participants may wish to present positive feelings about a parameter since the survey-based study does not validate the participant's statement. Furthermore, the content of a survey-based study to improve the performance of the concept would remain limited when compared with other techniques because no additional information would be added about the physical environment. On the other hand, when questions did not address any subjective issues, the validity and reliability of the results could be increased (Heydarian & Becerik-Gerber, 2017).

2.4.2 In-Field Observation

In-field experiments allow researchers to gather occupant comfort data by observing subjects in a real environment. The environment may be workplaces (Castaldo et al., 2018; Lassen et al., 2020), residential (Lai et al., 2009), or educational (Palacios Temprano et al., 2020) buildings and/or semi-open transitional urban spaces (Han et al., 2016; Madigan et al., 2021; Zhou et al., 2020). On the other hand, it is not allowed to control the environmental parameters of the investigated space directly. Thus, in

order to understand human comfort and related occupancy behavior, a cause-effect relationship is required to be established by researchers (Pisello et al., 2021). In other words, field monitoring enables data collection about occupancy behavior and human comfort in a non-controlled environment.

This approach limits the researcher to investigate extremity and border of comfort conditions for the subject. Furthermore, it is not likely to find the best and optimum conditions for the occupant. These obstacles can be overcome by experiments in controlled environments where the desired physical boundaries can be determined and replicated so that different subjects can be exposed to the same stimuli and the influence of subjective factors elucidated (Torresin et al., 2018). Moreover, gathering physiological signals from human subjects is common when a researcher makes laboratory experiments to make a detailed investigation (Pisello et al., 2021).

2.4.3 Test Room

A test room is an enclosed space, environmentally controlled and properly instrumented, where human-centric comfort studies can be performed through actual occupants' presence and monitoring. There has been a rising interest in better understanding human comfort. Therefore, many research institutions have built environmentally controlled experimental facilities to perform human comfort-related experiments worldwide and throughout the years. According to Pisello *et al.* (2021), there are 187 different test rooms located in 126 research institutes around the world, most of which were constructed in the last decades. Each facility has been designed to achieve specific research goals, thus presenting different dimensions, internal layouts, envelope characteristics, energy systems, and monitoring setups. Different equipment types are also included depending on the final aim of an experimental campaign targeting a specific comfort domain.

Several test rooms are located in diverse countries and regions, giving services for measuring various IEQ parameters (Pisello et al., 2021). However, these test rooms

provide services for localized needs. For example, test rooms in European regions measure the thermal comfort and air quality of occupants to detect comfortable conditions for employees, whereas Asian and American-originated test rooms measure lighting, acoustic, and air quality. Some examples of measuring occupancy comfort parameters are presented in Figure 3-36.

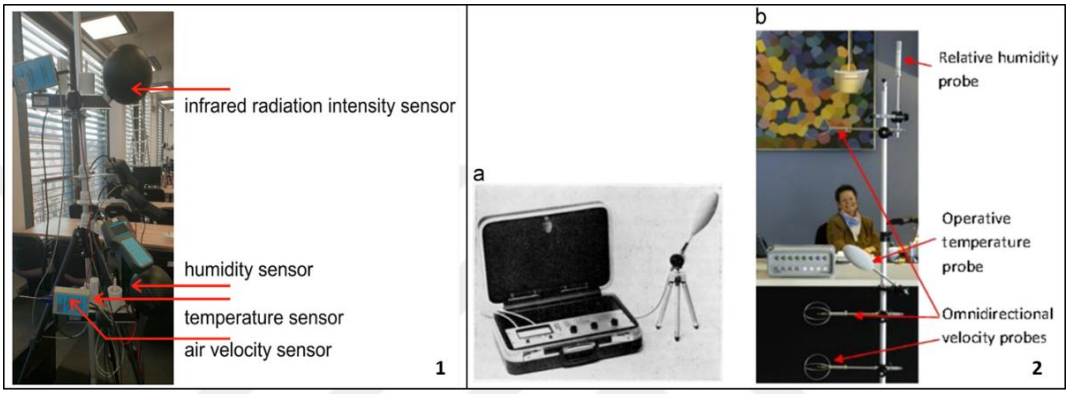

Figure 2-14. Some tools for measuring occupancy comfort. 1) thermal comfort is detected by use of infrared radiation intensity, humidity, temperature, and air velocity (Piasecki et al., 2019). 2) Comfort meter measuring relative humidity, operative temperature, and velocity (Korsgaard & Lund Madsen, 1973)

2.4.4 Immersive Virtual Environment (IVE)

IVE refers to virtual reality (VR) environments, where the users are fully immersed in a realistic, 1:1 scaled environment, where they can interact and visualize simulations of real-life events and scenarios (Niu et al., 2016). IVE technologies seek to reproduce reality more convincingly by offering participants a virtual sensation that is both more inclusive and perceptually richer (Birenboim et al., 2019). The simulated environments typically surround the participant through the use of, for example, VR glasses (head-mounted display) or a virtual display on the walls around the participants in a room-sized cube (cave automatic virtual environment; CAVE), and a dynamic display enables a direct coupling between the participant's motor actions and the simulation. IVEs are capable of delivering visual (sight), auditory

(hearing), haptic (touch), olfactory (smell), and gustatory (taste) sensations to the participant's senses, as well as stimulating the vestibular (balance) and proprioception (relative position) senses.

IVE-based experimental studies have been increased since last years. IVEs were used for spatial perception of occupants (Paes et al., 2017), observation and data collection for building energy simulation studies (Saeidi et al., 2018), consumer perception of purchase behavior (Lombart et al., 2020a), interactive education and clinical research (Oigara, 2019; Persky & McBride, 2009), visual perception and wayfinding (Schrom-Feiertag et al., 2017), controlling construction projects, team collaboration and education (Elghaish et al., 2020), project management (Dodevska & Mihić, 2018), decisions on occupant lighting preferences (Heydarian et al., 2017; Mahmoudzadeh et al., 2021), data collection method for occupant behavior on energy consumption (Heydarian & Becerik-Gerber, 2017; Niu et al., 2016; Zhu et al., 2018), occupant spatial and environmental presence and preference (Birenboim et al., 2019), analyzing human thermal experience (Saeidi et al., 2021), and understanding occupant perceptional space for physiological studies (Holth & Schnabel, 2017). The variety of IVE use in research fields increases the validity and reliability of IVE to be used as a data collection method in this study.

Using various sensors, the behavior of the user's body could be transferred to an avatar and virtual environment, as stated in Figure 2-15. Building Information Modeling (BIM) allows the creation of a virtual model of a natural environment to enable immersion in a virtual environment, as illustrated in 2-16. Users can also interact with digital objects in virtual environments by changing or moving, as Figure 2-17 depicts. Figure 2-18 illustrates an experiment measuring occupant-specific lighting conditions in a virtual office environment. The user can also change the lighting conditions using a navigation bar.

In addition to data collection practices, the current literature presents plenty of examples to demonstrate the applicability of IVE in the business world. The pandemic has accelerated the use of IVE in virtual and electronic office systems

where the users have the opportunity to work remotely (Lombart et al., 2020b; Pollard et al., 2020; Prabhakaran et al., 2020; Saeidi et al., 2021; Tea et al., 2021; Y. Zhang et al., 2019)

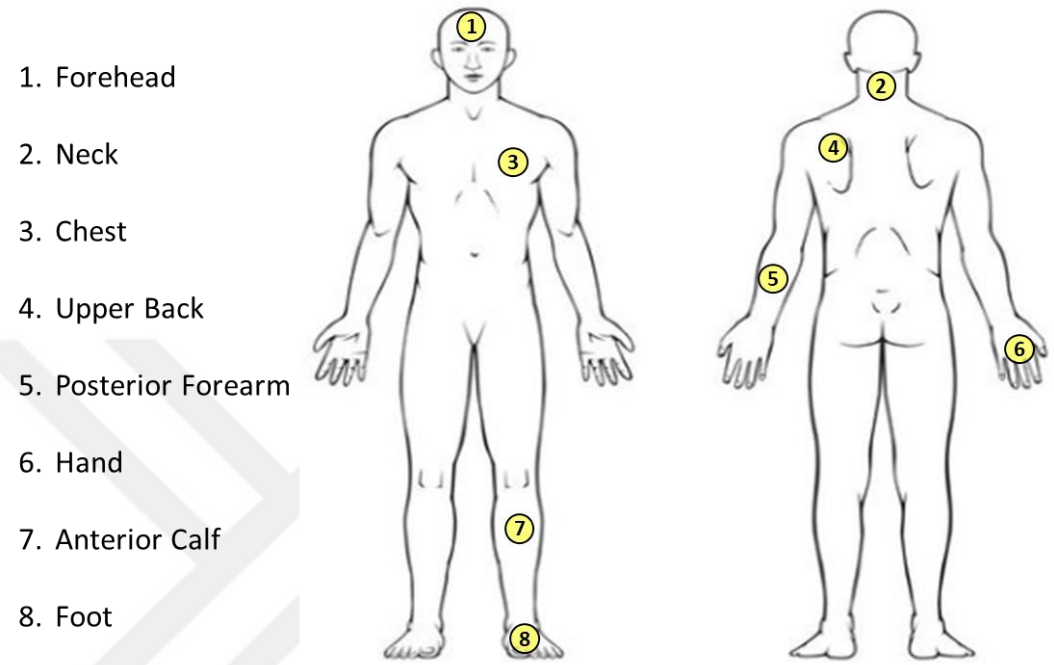

Figure 2-15. Body sensors collect data and transfer the data to an avatar in the virtual environment. Retrieved from: (Saeidi et al., 2021)

Figure 2-16. Real environment versus virtual environment for immersion. Retrieved from: (Saeidi et al., 2021)

Figure 2-17. Users can interact with digital objects in the virtual environment. Retrieved from: (Prabhakaran et al., 2020)

Figure 2-18. Measuring the illuminance of the virtual environment. 1: Participate in the experiment. 2: Virtual office environment. 3: User interface for adjusting the lighting level within the IVE. Retrieved from: (Mahmoudzadeh et al., 2021)

2.5 Ambient Intelligence

The internet of things (IoT) that emerged in the early 2000s has manifested through a network of interconnected ‘things’, of which sensors and sensor-equipped devices constitute a major subset (Louis & Dunston, 2018). The things here include people, location of objects, time information of objects, and condition of objects (Salazar, 2019). The IoT aims to connect things anytime, anywhere, with anyone, ideally using any path/network and service (Salazar, 2019). The data is collected from the things and then utilized for further evaluation through analytics. When supported by a decision-making algorithm, the IoT would react to the changing conditions of things via actuators.

Smart building, as a term, is strongly borne upon IoT infrastructure. The smart building concept is facilitated by a Building Management System (BMS), which could manage various crucial components of the buildings such as heating, ventilating, and air conditioning (HVAC), gas, lighting, security system, and fire system, and it can communicate with the IoT devices (Guvenc et al., 2015). The IoT sensing devices enable data collection of things in various categories. Utilization of IoT in building management systems, then specialized in Ambient Intelligence in the following years.

Ambient Intelligence (AmI) is a system establishing a relationship between people and the environment by gathering data by use of sensors and devices interconnected through a network to take decisions to benefit the users of that environment based on real-time information gathered and historical data accumulated (Augusto, 2008; Weber et al., 2005). The occupant data is collected through various sensors and devices and transmitted to a middleware. An artificial intelligence reasoning supported by a decision-making system analysis evaluated the occupant's changing conditions and reaction and behavior by actuators. An AmI system can be established by following the below steps (Augusto, 2008; Weber et al., 2005):

- The sensors and devices must surround the occupants of an environment that can provide accurate feedback to the system in different contexts.
- The information collected has to be transmitted by a network and pre-processed by what is called middleware.
- A higher-level level of reasoning will accomplish diagnosis and advice or assist other humans with the final responsibility for the system's operation to make decision-making easier and more beneficial to the environment's occupants.

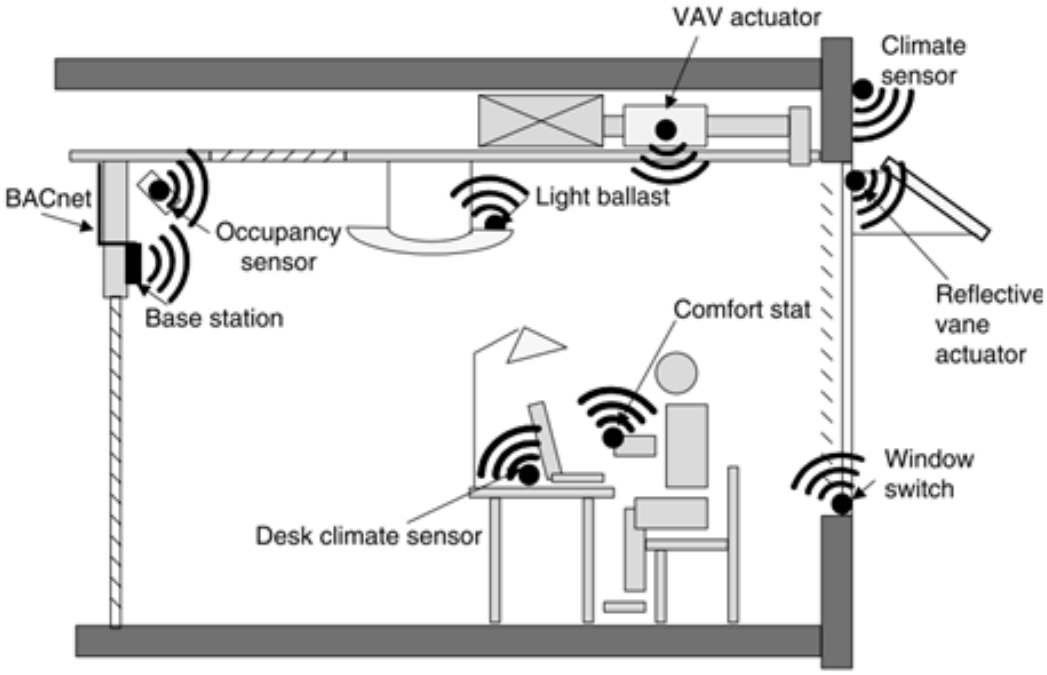

Figure 2-19. An AmI application diagram shows the location and sensor types at an office workplace. Retrieved from: (Weber et al., 2005)

An AmI application in an office workplace is presented in Figure 2-19. The available sensors in the sample diagram are on walls, windows, lights, blinds, furniture, exterior, HVAC system, and occupant. The data collected from sensors are transferred by an open-source building automation protocol to the building energy

management system from a base station functioning as a gateway. As an actuator, the comfort stat – a remote controller could control the lights, or the variable-air-volume diffuser in the ceiling could be located. As depicted in Figure 2-19, regarding the indoor air quality, temperature status, and lighting glare and degree, window switches and reflective vane actuators could be activated to arrange according to the occupant's pre-determined indoor air quality, temperature, and lighting conditions.

Another example is presented in Figure 2-20 to illustrate the arrangement of wireless control hardware, which will be facilitated for indoor lighting according to occupant needs and requirements. Integrating AmI with the building energy management system has substantial opportunities to provide smart occupancy comfort in various aspects, as depicted in Figure 2-21.

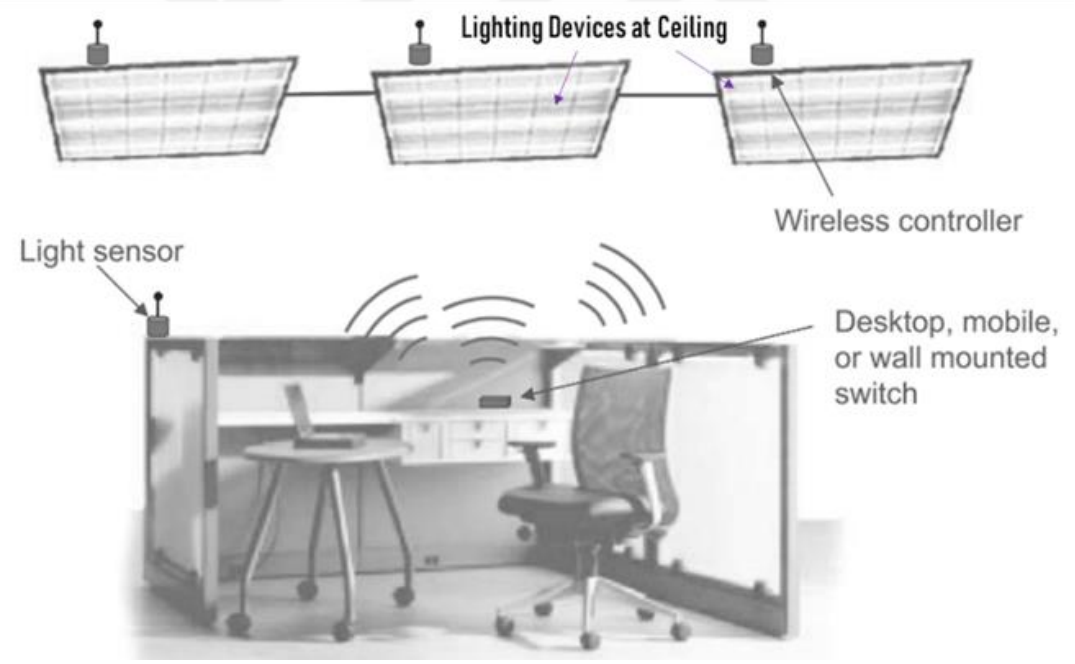

Figure 2-20. Arrangement of wireless control hardware to set indoor lighting for occupants according to occupant needs and requirements. Retrieved from: (Weber et al., 2005)

The digital twin is the 3-dimensional representation of a building with its assets by allowing bi-directional data flow between the physical and digital assets (Jiang et al., 2021). From this perspective, the digital twin is defined as a comprehensive digital representation of a physical asset that includes the properties, conditions, and behavior of such an asset in terms of models and data (Haag & Anderl, 2018) where simulation, prediction, and optimization of physical systems and process could be achieved (Lee et al., 2015; Uhlemann et al., 2017). The emerging research and practices presented diverse integration of BIM, AmI, and digital twin to allow occupant-specific facilities management practices (Götz et al., 2022; Kang & Mo, 2024; Voordijk et al., 2023; Yoon, 2023; A. Zhang et al., 2023).

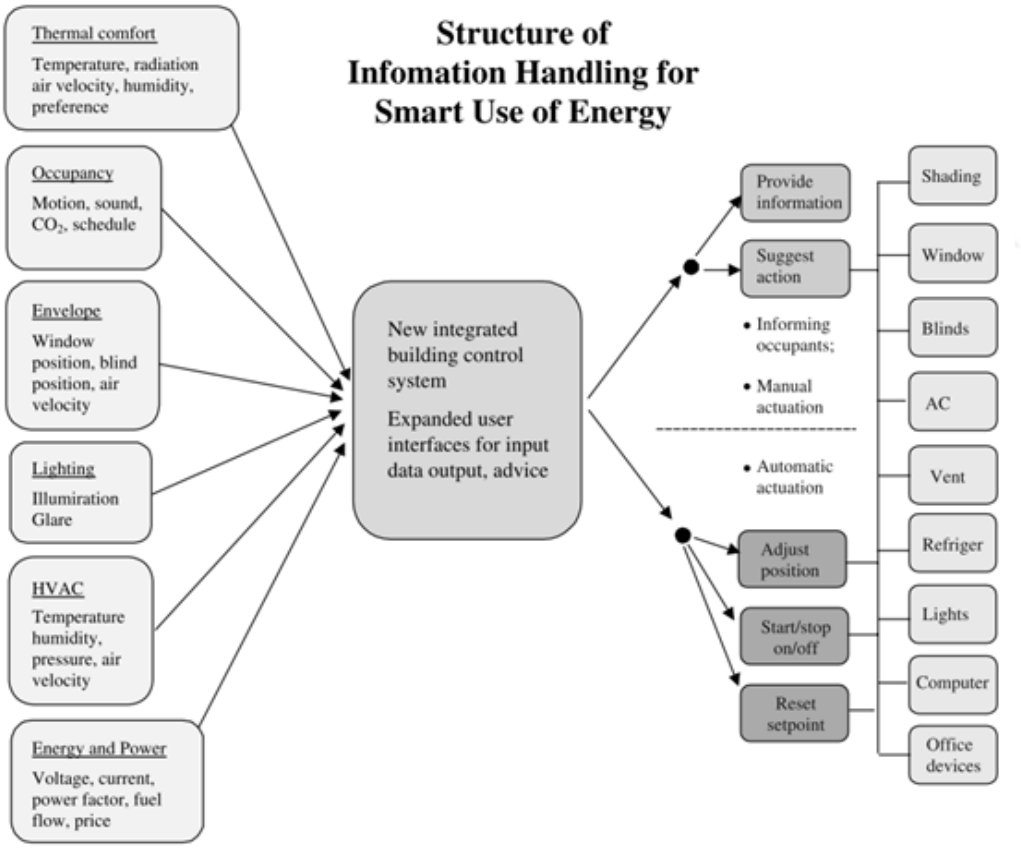

Figure 2-21. Integration of available control functions in a building using a wireless building control system. Retrieved from: (Weber et al., 2005).

The illustrated figures and diagrams in this section state that using AmI can enable occupant-specific behavior and act of building systems contributing to occupant comfort at workplaces. When the required set of occupants for comfort parameters are defined and introduced to AmI and digital twin-integrated building energy management systems, creating an environment specifically set for a particular person is possible.

2.6 Blockchain and Smart Contract

Blockchain is a technology that enables the creation of a community of users to record transactions in a shared ledger within that community, such that under normal operation of the blockchain network, no transaction can be changed once published (Yaga et al., 2019). Thus, there is no need for central authority and central repository to verify and validate the transactions. Although the idea originated in the 1990s, the initial proposal for using blockchain for electronic cash schemes was dated in 2009, titled “Bitcoin: Peer-to-Peer Electronic Cash System” (Yaga et al., 2019). Since then, literature and professionals have given significant attention to adopting and using blockchain technology in various fields.

Smart contracts are agreements in software code implemented on the Blockchain platform, ensuring smart contract terms' autonomy and self-executive nature based on a predetermined set of factors (Herian, 2021; Savelyev, 2017; Yin et al., 2020). From the definition, it can be revealed that a smart contract contains a blockchain platform, a predetermined set of factors, and software codes. Smart contracts are not only formed online, but their performances are guaranteed by a network of decentralized, cooperating computer nodes known as blockchains (Mik, 2017).

Smart contracts reduce transaction costs by eliminating intermediaries and simplifying enforcement (Herian, 2021; Mik, 2017; Yin et al., 2020). This is achieved by removing the need for protection from traditional legal institutions such as courts. Bankers and judges are authorities protecting the traditional contract

process. However, their decisions and behavior are considered fallible and untrustworthy (Mik, 2017). Computers, conversely, are objective, infallible, and trustworthy due to the substantial execution of pre-determined codes and regulations. Therefore, it can be revealed that the idea behind the smart contract is based upon the elimination of human judgment, reduction of dependence on financial intermediaries, and detachment from the legal system (Mik, 2017).

The growing digitalization of the business world since last century presents a commercial practice that eliminates human involvement. Decreasing the human involvement, central authority, and repository enables the automatization of stakeholder transactions. When a proper system for real estate of workplace areas can be established, the time and cost for leasing would be eliminated, and thus, the process would be completed and executed in a much-uninterrupted manner by smart contract applications.

The smart contract has the following applications:

- **Document preservation and accessibility:** Patents and copyrights are verifiable and foolproof since a smart contract's timestamps cannot be altered. Files are easily accessed. Documents exist on various computers on the network. Document validity can be checked easily (Dilmegani, 2023; Geroni, 2021; Goodness, 2022; HEDERA, 2023; Kot, 2023; Pacheco, 2022; J. Zhang, 2023)
- **Administrative payments and billing**: Payrolls, taxation, pensions, insurance, and bill payments (Dilmegani, 2023; Geroni, 2021; Goodness, 2022; HEDERA, 2023; Kot, 2023; Pacheco, 2022; J. Zhang, 2023)
- **Statistics collation:** Improved accuracy of results, reduced cost of elections, trusted results due to process transparency, and fewer resources needed for the collating of data (Dilmegani, 2023; Geroni, 2021; Goodness, 2022; HEDERA, 2023; Kot, 2023; Pacheco, 2022; J. Zhang, 2023)
- **Health and agricultural supply chains:** Proof of existence can be easily accessed, the location of a commodity can be traced and updated

seamlessly, and matchmaking is more accessible and can be done on a global scale (Dilmegani, 2023; Geroni, 2021; Goodness, 2022; HEDERA, 2023; Kot, 2023; Pacheco, 2022; J. Zhang, 2023)

- **Real estate and crowdfunding**: Ease of use, tokenization of more tangible goods, open, timeless markets, flexible global economy (Dilmegani, 2023; Geroni, 2021; Goodness, 2022; HEDERA, 2023; Kot, 2023; Pacheco, 2022; J. Zhang, 2023)
- **Identity management**: Identity safety, the user chooses the data they give out, easier KYC verification (Dilmegani, 2023; Geroni, 2021; Goodness, 2022; HEDERA, 2023; Kot, 2023; Pacheco, 2022; J. Zhang, 2023)

The workplace comfort and wellbeing parameters could be stored and transferred in the blockchain. The parameters could be transformed into provisions, and payment could be executed in the smart contract environment by taking advantage of the aforementioned benefits of the blockchain and smart contract. Furthermore, the self-executive nature of the smart contract could eliminate potential conflicts and claims in services and payments.

2.7 Semantic Web Applications and Web Ontology Models

The World Wide Web (WWW) is primarily composed of documents written in "Hyper Text Markup Language" (HTML), used for publishing information. (Cardoso & Sheth, 2006; Patel & Jain, 2021). HTML is a set of markup symbols stored in a web page displayed on a web browser. HTML was used for reading and understanding humans in the first two decades of its existence. The computers were used for displaying the information on the web. However, there is a way that the computer can use the information on the web for interoperability and integration between systems and applications by using the knowledge representation formalism. The new web approach is called the "Semantic Web."

The web was originally a vast set of static web pages linked together (Cardoso & Sheth, 2006; Patel & Jain, 2021). As depicted in the left image of Figure 2-22, the resources are linked together, forming the Web. There is no distinction between resources or the links that connect resources. The new standards and languages bring semantics to the web resources or the links that connect resources so that machine-readable descriptions are allowed to the data and documents on the web. These language rules and descriptive information characterize the type of resources individually and precisely on the web and the relationships between resources as illustrated in the right image of Figure 2-22.

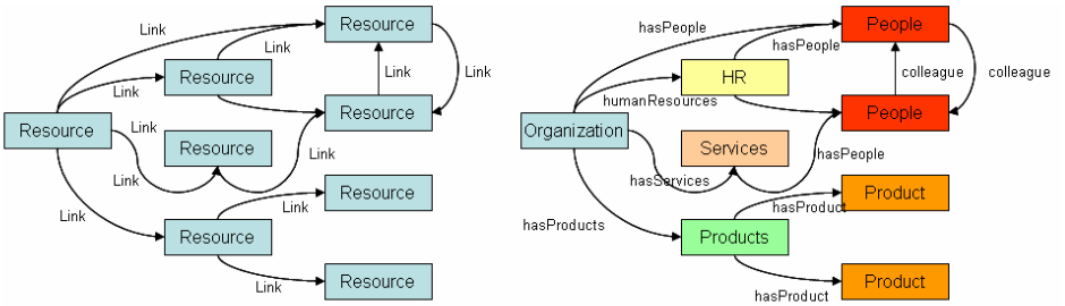

Figure 2-22. Evolution of the Web. Retrieved from: (Cardoso & Sheth, 2006)

The Resource Description Framework (RDF) and the Web Ontology Language (OWL) are standards that enable the Web to be a reliable infrastructure for sharing documents and data. RDF shares a unified model and provides a framework for developing web applications that deal with data and semantics. OWL provides a language for defining structured web-based ontologies, allowing a richer integration and data interoperability among communities and domains.

Ontologies are the heart of the linked data since the linked data provides large-scale data integration and reasoning on the data using technologies such as SPARQL, RDF, and OWL. The ontologies allow users to search a schematic model of all data within the applications. The ontologies classify the parts of the data and permit

communications between the data available in distinct formats. The data are stored in the form of ontologies in the semantic web.

There are two significant behaviors of semantic web technologies. Firstly, it allows understanding of the web queries and resources structured and organized at background by ontologies. Secondly, the semantic web technologies enable looking into the organized datasets and knowledge bases of the semantic web as an alternative to the present web. Therefore, semantic web technologies benefit other domains such as sensor networks, big data, cloud computing, the IoT, and so on (Patel & Jain, 2021).

Web applications were improved to present personalized products and services to clients. A customer can customize some properties of a service or a product by making preferences on the website of the service or product provider. After the purchase process, the customer takes the customized services and products. The following list presents and explains similar services in the literature:

- **Personalized Car**: Similar to other car manufacturers, Volkswagen presents a car configurator as a web application *(https://www.vw.com/en/builder.html)* allowing customers to make selections for the car type, hardware style, engine type, engine power, the color of the car, fabric color, wheel, and rim type and other similar options. Following the recipe of the car configurator, the car is manufactured and then could be delivered by any local seller to the customer.
- **FitMyFoot Uses Technology to Build Custom Shoes:** Customers use an app to take pictures of their feet, which FitMyFoot then uses to take measurements and build a digital map of each person's footbed. Each person's 3D-printed file is unique, even down to their left and right feet. Those files create custom insoles and sandals; customers can customize the design and color (Baker, 2020; Morgan, 2021).
- **Care/of Personalizes Vitamins** (Baker, 2020; Morgan, 2021): Users take a short quiz about their diet, energy, stress, and overall health, and then Care/of builds a personalized plan of vitamins and supplements. Customers get a daily pack with

all their vitamins and names printed clearly on top. The plans change over time as customers meet health goals.

- **Tesla Creates Detailed Driver Profiles** (Morgan, 2021): Tesla takes car personalization to the next level with an individual profile for each driver. The car remembers each driver's preference for the seat, steering wheel, mirror location, suspension, braking, radio presets, and even driving style. The seamless integration of driver profiles into the Tesla experience makes the car an extension of the driver and allows each person to drive the car the way they want, which is most comfortable for them.
- **MTailor Uses Smartphone Scans for Custom Clothes** (Baker, 2020; Brooks, 2022; Morgan, 2021): MTailor uses a personalized, AI-driven approach that creates perfect sizing that is 20% more accurate than a tailor. Customers choose from several shirts, pants, or suit options and then upload a photo and short video of themselves to the app. MTailor's algorithm then takes 16 measurements to create personalized clothing that fits each customer perfectly.
- **The function of Beauty** (Baker, 2020; Brooks, 2022; Morgan, 2021): allows customers to create personalized shampoo, conditioner, and body wash based on their needs and preferences. Customers take a four-question quiz about their hair needs to unlock a personalized formula to help their hair be healthy and beautiful. Customers can then choose the color and scent of their shampoo and conditioner for a truly personalized product.

Semantic web applications could be used as an interface among stakeholders to configure and purchase workplace services. Semantic web applications can integrate diverse systems and platforms to establish an ecosystem. Once the system's ontology has been established, semantic web applications could facilitate the web ontology models. The methodology to establish the web ontology model was expressed in the following chapter.

CHAPTER 3

MATERIAL AND METHOD

A new workplace service provision model is established, formalized, and represented as a web ontology model. A domain ontology can represent the concepts belonging to a realm of the world reflecting domain-specific definitions of the terms (W3C, 2012). Since the new workplace service provision model aims to make the knowledge worker the decision maker of the workplace configuration, the model uses the workplace configurable parameters as the ontology domain, as illustrated in Figure 3-1. This is achieved by presenting a domain-specific knowledge base by integrating and allowing direct interaction with the knowledge worker and service provider / facility manager, as depicted in Figure 3-2.

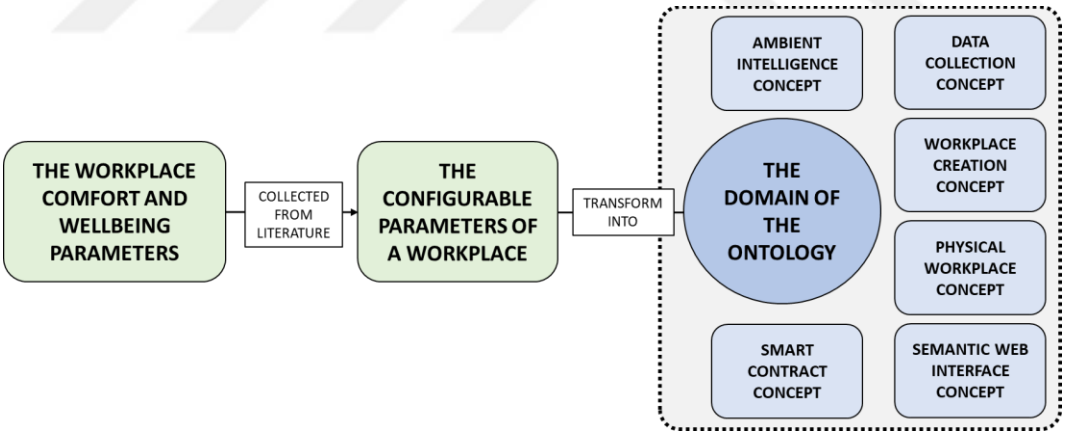

Figure 3-1. The domain of and its usage in the ontology.

Web ontology models establish the knowledge base for a domain-specific model or part of the world. It describes and represents the particular meanings of terms as they apply to that domain. Furthermore, the modeled ontologies allow the further

discovery of the potential relations and associations between or among the concepts. The personalization and customization opportunities for the knowledge workers are limited or not available in the current practices. Modeling the ontology of a workplace service provision system that allows workplace configuration and servicing specific to the knowledge worker can represent all possible activities, relationships, entities, and attributes.

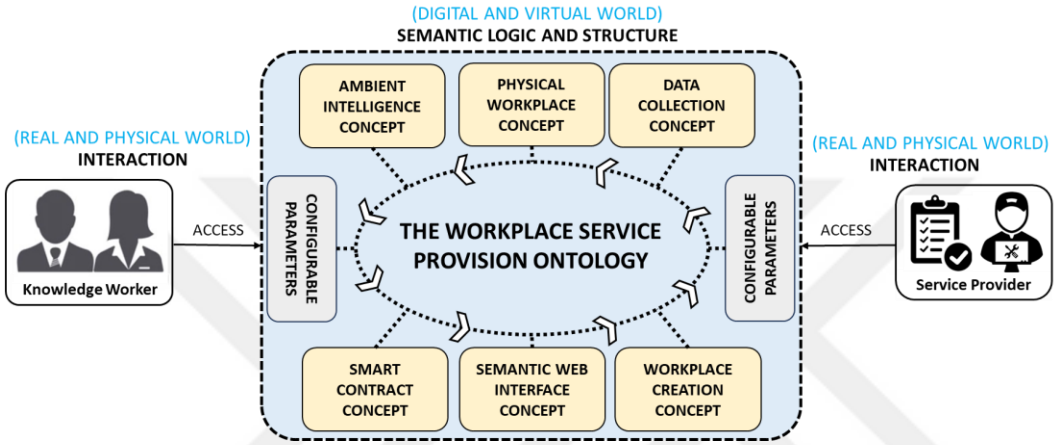

Figure 3-2. Interaction of the user with the ontology model and concepts

3.1 Methods for the Web Ontology Model

Each web ontology model requires particular methods for development and evaluation, although they use the same techniques and tools. The following sub-sections express modeling techniques, evaluation tools, and methods.

3.2 Modeling an Ontology and Ontology Editors

There are various open-source ontology editors developed for specific purposes in diverse research fields, such as Protégé (Stanford University, 2020), NeOn Toolkit (NeOn Foundation, 2014), Vitro (Lyrasis, 2023) and VocBench (ART Group, 2023) released to be used by researchers. Protégé is an open-source platform and editor to construct domain models and knowledge-based applications with ontologies (Musen

et al., 1987). It has a pluggable architecture and allows plugins for different functionalities (GitHub, 2023; Stanford University, 2020; W3C, 2009). The frameworks built in Protégé could be used in intelligent systems (Stanford University, 2020). The OWL-based workplace comfort model ontology is modeled and edited using Protégé to define its classes, relationships, and axioms.

3.3 Evaluation Methods

Evaluation of the ontology model is depicted as the technical review of the ontology content regarding a frame of reference during every phase, between phases, or at the last phases of their lifecycle (Lovrenčić & Čubrilo, 2008; Poveda-Villalón et al., 2012). A frame of reference could be requirements, specifications, competency questions, real-world, etc. No commonly accepted and unique method is agreed upon by scholars (Bilgin et al., 2014). Thus, no best practice has been proposed by scholars (Patrick & Florian, 2010). Each proposed ontology is evaluated by specific evaluation tools representing a variety of characteristics.

On the other hand, it is possible to categorize the ontology evaluation into two parts. These are verification and validation. Verification is defined as building the ontology correctly to ensure that its definitions implement the requirements of ontology and competency questions correctly or function correctly in real-world (Lovrenčić & Čubrilo, 2008; Poveda-Villalón et al., 2012). Conversely, validation refers to matching and complying ontology definitions with the real world for which the ontology was created. In other words, validation is proof that the world model is compliant with the world modeled formally (Lovrenčić & Čubrilo, 2008; Poveda-Villalón et al., 2012).

The literature represents a variety of ontology evaluation methods regarding its measures (Gangemi et al., 2006), property (Fernandez-Breis et al., 2009; Netzer et al., 2009), the process of ontology creation (Bachir Bouiadjra & Benslimane, 2011), based of ontology construction (Bolotnikova et al., 2011; Brewster et al., 2004;

Daelemans & Reinberger, 2004; Patrick & Florian, 2010; Zouaq & Nkambou, 2009) and characteristic of available ontology evaluation tools (Hartmann et al., 2005; Jain & Prasad, 2016). Furthermore, the latest studies illustrated that existing ontology creation tools had gained particular opportunity to verify and check for inconsistency of the created ontology models by use of external reasoners as a plugin such as ELK (Kazakov et al., 2012), HermiT (Glimm et al., 2014), Mastro (De Giacomo et al., 2012), Ontop (Bagosi et al., 2014), Pellet (Sirin et al., 2007), jcel (Mendez, 2012) and Ontodebug (Schekotihin et al., 2019).

Protégé can use HermiT, Mastro, Pellet, ELK, Jcel, Ontop, and a couple more reasoners to check the consistency of the ontology. Each reasoner has focused on a specific reasoning field. HermiT performs object and data property reasoning tasks and SPARQL query answering (Glimm et al., 2014). SPARQL is the standard query language and protocol that allows users and developers to extract information from databases or data sources (Sirin & Parsia, 2007). Mastro evaluates the DL-Lite family of description logic (DL) (De Giacomo et al., 2012). Pellet is used for reasoning individuals, user-defined datatypes, and debugging ontologies (Sirin et al., 2007). ELK is specialized for reasoning lightweight ontology language (Kazakov et al., 2012). Jcel is performed for the description logic EL+ using a rule-based completion algorithm (Mendez, 2012). Ontop allows querying relational data sources by conceptualizing the domain of interest (Bagosi et al., 2014).

3.4 Validation Studies in Literature and Critics

Although verification tasks could be achieved using plugins or tools, the validation task requires particular approaches that are unique and specific for each ontology. Therefore, similar validation approaches in the literature were investigated to develop a proper validation methodology.

Fortineau *et al.* (2015) established an OWL-based ontology to present the modeling choices required to build a domain knowledge model. Two folds studied the

validation. Firstly, the ontology population on a set of business rules is large enough and various enough to prove the completeness of the model since industrial users built the set based on their experience. So far, no semantic limit or difficulty has been raised during the population process. Secondly, the reduction of the modeling commitment was measured by the quantity of inferred information (number of triples that need to be explicitly modeled vs. the inferred ones) to estimate it when the population of the set of rules is finished. The test results indicated that it is possible to get inferred information with very little explicit knowledge (Fortineau et al., 2015).

Hagedorn *et al.* (2019) developed a framework to provide an Integrated Framework for Additively Manufactured Products (IFAMP). IFAMP is a shared top-level ontology. Rule-based semantic reasoning and a knowledge base query were facilitated to validate ontology to provide an ontological representation of the design, intended manufacturing processes, usability, and innovation (Hagedorn et al., 2019). Besides, the reasoning study does not represent any inconsistency. The core framework comprises 2535 classes, 266 properties, and 3915 logical axioms. The knowledge base was queried to identify instances to find products or instances used to fix objects in place reversibly.

Shreyas *et al.* (2020) developed a genome mapping ontology by considering 60 primary classes and four properties (Shreyas et al., 2020). The model was evaluated by use of two methods. The quantitative evaluation study presented a 0.8 reuse ratio, 48 – Count of Subclasses, 1.52 – average depth of inheritance, and 5 – maximum depth of inheritance, making the ontology a conceptual ontology. Furthermore, the ontology was appraised by 80 domain experts using the semiotics method. Eight metrics were used for assessment: relevance, clarity, accuracy, comprehensiveness, consistency, interpretability, richness, and lawfulness.

Tiwari and Abraham (2020) developed a smart healthcare ontology (SHCO) for healthcare information and IoT devices. Various assessment tools were used to evaluate the ontology. Themis and TDDonto tools verify the test cases, while Protégé

and OOPs validate modeled knowledge in the ontology (Tiwari & Abraham, 2020). The ontology has been assured that all attributes were expressed in a consistent model with their classes, data types, and properties. No unspecified terms are used in the proposed ontology, and it does not have unsatisfiable classes. It is consistent when combined with data and describes every class, data type, and property.

Ye *et al.* (2011) developed a top-level ontology to model and reason on domain knowledge precisely and traceably, serving as a conceptual backbone for developing domain and application ontologies for smart environments (Ye et al., 2011). The top-level ontology includes all layers of domain knowledge, such as concepts, contexts, and activities. All ontology layers were modeled and fully implemented in the real world, starting from concepts for domain ontology and context and activities for application ontology. The model is applied and tested in a "living laboratory" to demonstrate the validity of the ontology.

The set of business rules used in the OWL-based ontology developed by Fortineau *et al.* (2015) was built on the experiences of industrial users. Hagedorn *et al.* (2019) utilized a knowledge base query to validate the ontology. All ontology layers were modeled and fully implemented in the real world in the Ye *et al.* (2011) study. Tiwari and Abraham (2020) developed test cases to check the validity of the modeled ontology.

The proposed ontology in this dissertation has not yet been fully implemented in the real world nor built by the experiences of the industrial users. Furthermore, the data query method cannot be implemented since the modeled ontology cannot be assured to include all possible real-world practices and necessary extensions. On the other hand, the test cases developed by Tiwari and Abraham (2020) could be used to check the validity of the modeled ontology.

3.5 Development of the Evaluation Method

Each ontology includes particular domain knowledge, characteristics, associations, and entities requiring the development of unique evaluation methods. The evaluation of the proposed model consists of literature and in-field-based evaluation techniques, as demonstrated in Figure 3-3. The verification method includes the use of HermiT and OntoDebug, which are the plugins of the Protégé. HermiT facilitates the reasoning tasks in the ontology hierarchy to detect faults, whereas OntoDebug identifies the inconsistencies and incoherencies in the ontology structure.

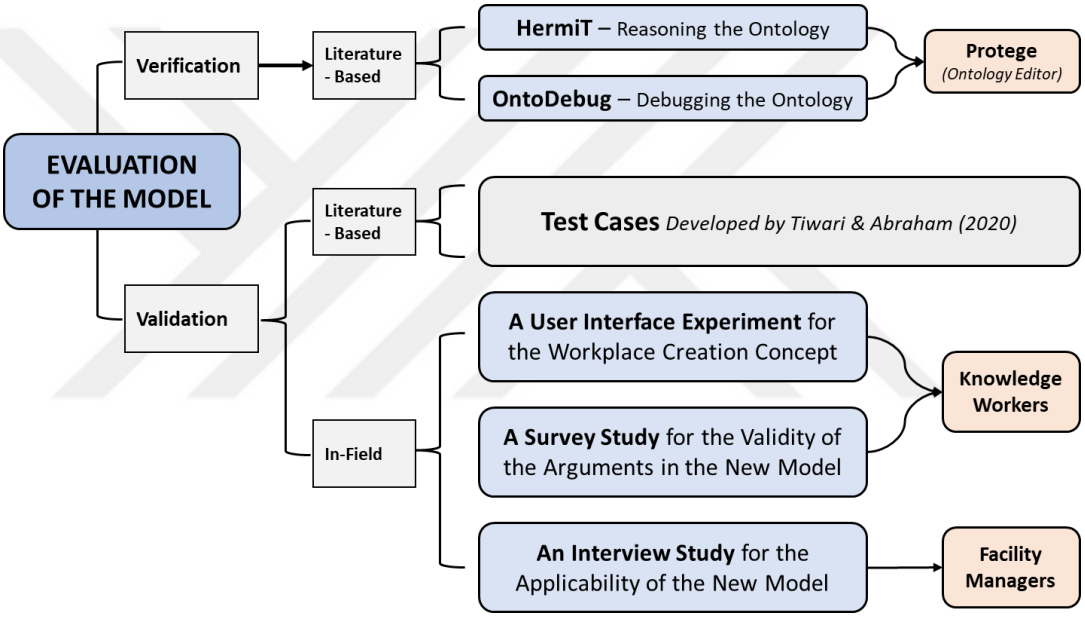

Figure 3-3. The evaluation method was developed to verify and validate the dissertation.

Validation methods facilitate literature–based cases and in-field studies. The test cases developed by Tiwari & Abraham (2020) were adopted and used for the synthetic validation of the model. On the other hand, actual validation relies on in–field studies, including a survey, user interface demo, and interviews with the knowledge workers and the facility managers. The research methods applied in in-field studies are explained as follows:

3.5.1 Pairwise Comparison Study

A survey is a data collection method directing structured questions for the participants to gather information from a sample of individuals (Scheuren, 2004). Verbal surveys are often known as interviews, and written surveys are questionnaires (Glasow, 2006). Survey studies have many forms and types to be implemented. Cross-sectional surveys are carried out to present a snapshot of what is happening in that group at that particular time (Mathers et al., 2009). On the other hand, longitudinal surveys take time to draw a picture of events or attitudes over time.

Pairwise comparison is a method where a judge is presented with a pair of objects and asked to state that they possess more of a specified attribute. The study aims to find the most preferred entities. Therefore, applying a pairwise comparison study presents the benefits of cross-surveying and listing the preferred entities. It turns qualitative information like opinions, quotes, or images into quantitative data that can be measured and ranked.

3.5.2 User Interface Demo

Using Microsoft PowerPoint, a user interface demo is prepared to demonstrate and experience the workplace creation concept. The study allows participants to configure a workplace regarding several selection parameters. Each parameter is supported with a proper image. At the end of the selection process, the application directs the user to a 3-D virtual environment reflecting the user selections. The users can navigate inside the 3-D virtual environment; thus, rather than a static image, a stereo environment is provided to the user to increase the perception of their selections. The 3-D virtual environment is created in Autodesk Revit and then rendered and stored in Autodesk cloud server. The Autodesk cloud server enables an access link to the third-party user to access the 3-D rendered environment. A particular workplace scene is created and presented to the user for each potential user

configuration. The link is attached to the PowerPoint application so that at the end of the selection process, the user can navigate inside the virtual scene.

3.5.3 Interview Study

The workplace configuration by the knowledge worker is a unique idea. Thus, the workability and applicability of the concept in the real world regarding the facilities management practices and approaches need to be clarified. The knowledge workers' personalization and customization of the workplace are conceptualized in a couple of narrative explanations and directed to the facility managers of the office workplaces. Their comments and approaches are the primary data to identify the handicaps, address the application-based problems, discover the proposal's advantages, and overcome the potential risks.

CHAPTER 4

THE NEW WORKPLACE SERVICE PROVISION MODEL

This Chapter explains the development of the new workplace service provision model. The Chapter is structured as follows: A user-workplace matching system specific to this study is established by criticizing the available options. Occupant data collection methods are identified to be used in the new model. A detailed scenario is expressed to describe the entities and narrate the working procedure of the new model. The domain and concepts of the new model are introduced. Formal representation and the process maps of each concept are described. The ontology is modeled in an ontology editor. Smart contract and workplace creation concepts are implemented following the ontology's modeling. The changing conditions, new roles, and responsibilities of facilities management practices are presented.

4.1 A User – Workplace Matching System

The proposed workplace service provision model maximizes occupancy comfort and wellbeing by allowing a personalized and customized workplace environment for the knowledge worker. This target requires a particular match of user and workplace services. The available method in the literature categorizes people by their commonly shared characteristics, reflecting "one size fit for certain persons." Indeed, as illustrated in Figure 4-1, the required personalization specification for this dissertation study on the individual scale cannot be assured by the available methods.

Some industries developed a method that each person has their account, personality, or character definition described by fulfillment of certain forms reflecting a person's character by his/her expressions. An example is presented in Figure 4-2, where

detailed information about a persona is described with key characteristics. These persona forms express the persona's necessary characters and information for a target reader. A similar approach can be used for this study in which each knowledge worker may have a persona file indicating his/her specific choices about workplaces.

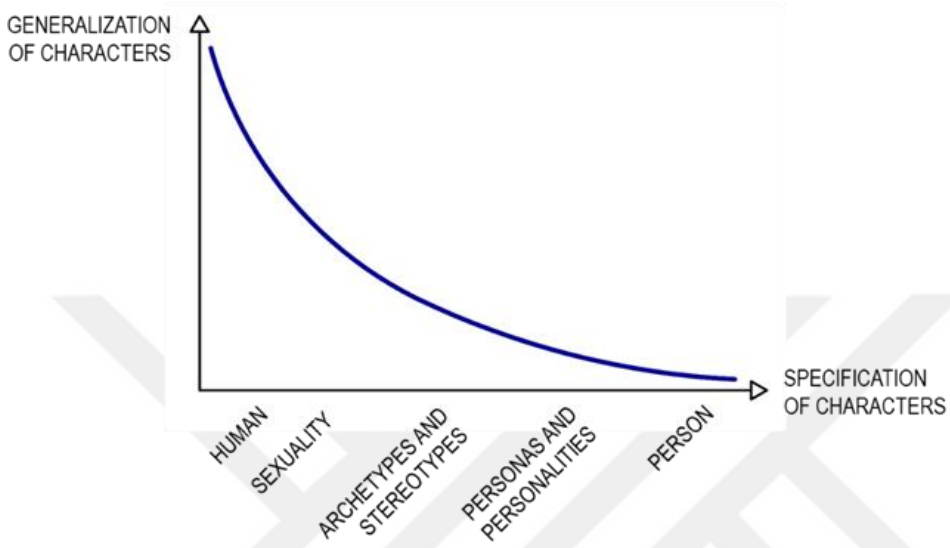

Figure 4-1. The personality types and their specialization level

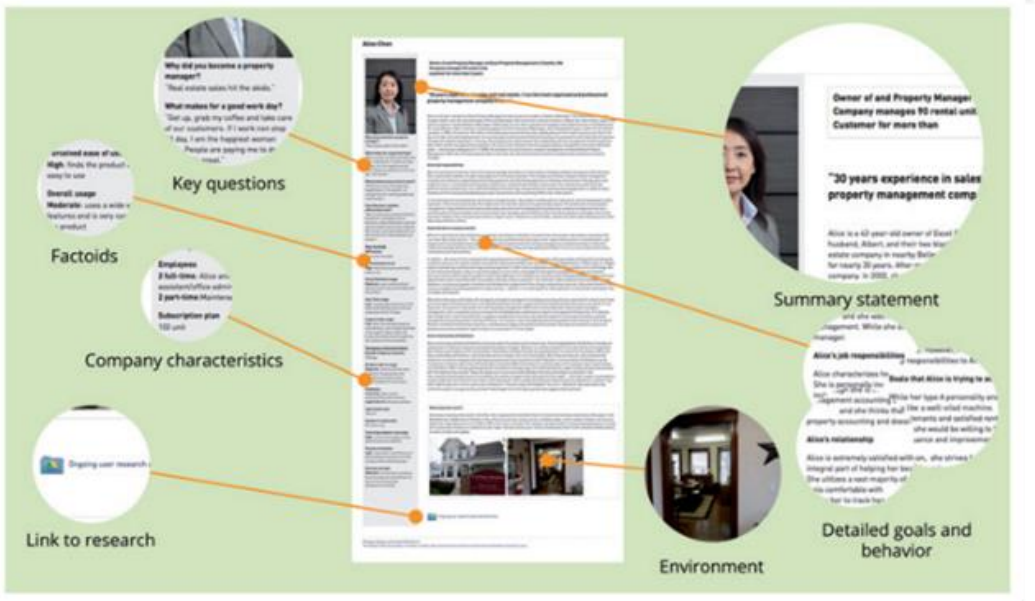

Figure 4-2. Detailed information of a persona. Retrieved from: (Miaskiewicz & Luxmoore, 2018)

4.2 Collecting Personalized Workplace Data

Describing an individual's persona requires data collection from the individual. The available data collection methods are in-field monitoring, survey, test room, and IVE. In-field monitoring requires observation of the occupant in his/her living environment. Thus, it is not proper for this study since the proposed model presents new workplace comfort and wellbeing parameters that could not exist in the workers' current environment. On the other hand, remaining data collection methods could be used.

Regarding their capability, each data collection method is matched with a parameter as depicted in Table 4-1. The workplace comfort and wellbeing parameters are neither constant nor permanent. When adding a new parameter, the most suitable method could be matched among the available occupant data collection methods. As a result of the matching study, the majority of the parameters were matched with the test room and IVE, while the minority of them were matched with the survey-based data collection method.

Table 4-1. Match of data collection methods and workplace comfort and wellbeing parameters.

Category	Parameters	Measurement Method
Visual comfort	• Illuminance	Testing Room
	• Circadian Lighting Design	Testing Room
	• Uniformity of illuminance	Testing Room
	• Illuminance of the immediate surrounding areas	Testing Room
	• Percentage of the task area meeting the required illuminance	Testing Room
Windows	• Window-to-wall ratio	Immersive Virtual Environment
	• Size of the window	Immersive Virtual Environment
	• Operability	Immersive Virtual Environment
	• Position & Location	Immersive Virtual Environment
	• Proximity to Window	Immersive Virtual Environment
Furniture	• Ergonomic	Testing Room
	• Comfort	Testing Room
	• Type	Testing Room
	• Quality	Testing Room
	• Material	Testing Room
	• Noise Criteria	Testing Room

Table 4-1 *continued*

Acoustic comfort	• Reverberation Time	Testing Room
	• Speech Transmission Index	Testing Room
Indoor Air Quality	• Carbon dioxide	Testing Room
	• PM 2.5	Testing Room
	• PM 10	Testing Room
	• Carbon Monoxide	Testing Room
	• Total Volatile Organic Compounds	Testing Room
	• Formaldehyde	Testing Room
	• Sulfur dioxide	Testing Room
	• Ozone	Testing Room
	• Total microbial count	Testing Room
Thermal Comfort	• Air temperature	Testing Room
	• Vertical air temperature difference	Testing Room
	• Operative temperature	Testing Room
	• Radiant temperature asymmetry	Testing Room
	• Floor surface temperature	Testing Room
	• Air speed	Testing Room
General office layout	• Size of the area	Immersive Virtual Environment
	• Height of the space	Immersive Virtual Environment
	• Location of workplace components	Immersive Virtual Environment
	• Required equipment, furniture, and devices	Immersive Virtual Environment
	• Color, texture, material, and quality of floor, wall, and ceiling finishes	Immersive Virtual Environment
Workplace	• Size of the workplace	Immersive Virtual Environment
	• Color, texture, and quality of material	Immersive Virtual Environment
	• Orientation	Immersive Virtual Environment
	• Location	Immersive Virtual Environment
Filling and storage space	• Availability	Immersive Virtual Environment
	• Size	Immersive Virtual Environment
	• Capacity	Immersive Virtual Environment
Cycling facilities	• Amount and period of cycling	Survey-based
Shower facilities	• Availability	Survey-based
	• Type	Survey-based
Toilet facilities	• Availability	Survey-based
Kitchen facilities	• Availability	Survey-based
Canteen facilities	• Availability	Survey-based
Office Building	• The exterior design of the building	Immersive Virtual Environment
	• The interior design of the building	Immersive Virtual Environment
	• Overall quality, color, and material of interior finishing	Immersive Virtual Environment
Workstation	• General layout	Immersive Virtual Environment
	• Appearance	Immersive Virtual Environment
	• Size	Immersive Virtual Environment
	• Comfort and ergonomic	Immersive Virtual Environment
	• Location at workplace	Immersive Virtual Environment
	• Orientation at workplace	Immersive Virtual Environment
Accessibility	• Transportation options to the facility	Survey-based
	• Compliance with universal design principles	Survey-based
Type of work performed.	• There are various types of workplaces defined such as hive, cell, den, and club by Duffy et al. (1992)	Survey-based
Duration of work	• Time	Survey-based
Meeting room	• Availability, Capacity, Type, Function, and other specific conditions	Survey-based

Table 4-1 *continued*

Dining area	• Availability, Capacity, Type, Function, and other specific conditions	Survey-based
Resting Area	• Availability, Napping or Sleeping	Survey-based
Pantry	• Availability, Capacity, Type, Function, and other specific conditions	Survey-based
Parking spaces	• Availability, Capacity, Type, Function, and other specific conditions	Survey-based
Smoking area	• Availability & proximity	Survey-based
Cleaning	• Cleanliness level: high, medium, low	Survey-based
Safety & Security	• Required security level: high, medium, low	Survey-based
Maintenance	• Necessity • Required frequency	Survey-based
Communicability with Facility Manager (FM)	• In case of any problem conflict, accessibility to FM: Easy access, No access,	Survey-based
Vertical circulation (elevators & stairs)	• Comfort	Immersive Virtual Environment
	• Quality	Immersive Virtual Environment
	• Appearance	Immersive Virtual Environment
Network	• Wired / Wireless	Survey Based
	• Required performance	Survey Based
Audio-visual systems	• Comfort and performance requirements of speakers and video conferencing	Testing Room
Modern technologies	• Need for additional affordances, easy plug, etc	Survey Based

4.3 Entities of the Model

The entities facilitated in the proposed model are expressed as follows:

- **Knowledge Worker:** The user of the workplace services.
- **Service Provider:** The facility manager of the physical workplace gives workplace services to the knowledge worker.
- **Data Collector:** The data collector has two roles. Firstly, the data collector collects workplace comfort and wellbeing parameter data specific and personalized to the knowledge worker in the data collection lab. Then, the collected data is delivered to the knowledge worker. Secondly, the data collector inspects the physical workplace, detects the workplace service range for the service provider, and then delivers the service range data to be published in the semantic web interface.

- **Data Collection Lab:** A facility or an environment presenting data collection opportunities for data collectors upon the service provider's knowledge worker and physical workplace.
- **Physical Workplace:** A built environment with particular workplace service opportunities for the knowledge worker.
- **Semantic Web Interface:** A web application presenting personal accounts for knowledge worker and service provider, a digital marketplace for knowledge worker and service provider, an agreement environment for the workplace services between the knowledge worker and service provider, a service finder to find proper workplace services, a booking and an appointment environment to book, appoint and schedule the physical workplace of service provider and workplace services of knowledge worker and a digital in-purchase environment to buy and sell workplace services.
- **Workplace Set:** A specific workplace design including a user-defined amount of workplace comfort and wellbeing parameters and depicting user-specific comfort data.
- **Workplace Service Range:** A service range for a physical workplace's specific comfort and wellbeing parameters.
- **Smart Contract:** The workplace services agreed upon by the knowledge worker and service provider are delivered by the semantic web interface to the smart contract application, and then these services are transformed into service provisions. The payments are transected upon smart contract application.
- **Ambient Intelligence (AmI):** AmI consists of various sensors and actuators for collecting instant data from the knowledge worker and setting the indoor environmental parameters to the knowledge worker's workplace configurations. Once the smart contract is executed, the service provisions are delivered to AmI. During the occupation of the workplace environment, AmI continuously monitors both the knowledge worker and the indoor environment to ensure that the knowledge worker’s workplace configuration

is executed. The knowledge worker can give instant feedback to the service provider, and service provisions could be updated to maintain the comfort and wellbeing of the knowledge worker.

- **Workplace Comfort and Wellbeing Parameters:** It lists many comfort and wellbeing parameters and conditions for the knowledge worker. The list could be varied and changed regarding the needs and requirements of the knowledge worker.

4.4 Scenario Development

This section expresses the process, relation, and association among the entities of the proposed model by composing the entities in a narrative scenario. The scenario was divided into seven phases to describe the role of each entity in detail.

4.4.1 Identify the Workplace Services

When the service provider first gets involved in the new system, capabilities and service range of the physical workplace regarding the workplace comfort and wellbeing parameters must be inspected and measured by the data collector. The data collector may use special devices and equipment to define the service range of the parameters. The data collected at the end of the study will describe a range that service providers could give workplace services for the workplace setting when the workplace setting is identified within the range of the workplace service of the physical workplace. At the end of the study, the data collector delivers a log file to the service provider listing the specific workplace comfort and wellbeing parameter data in the semantic web environment.

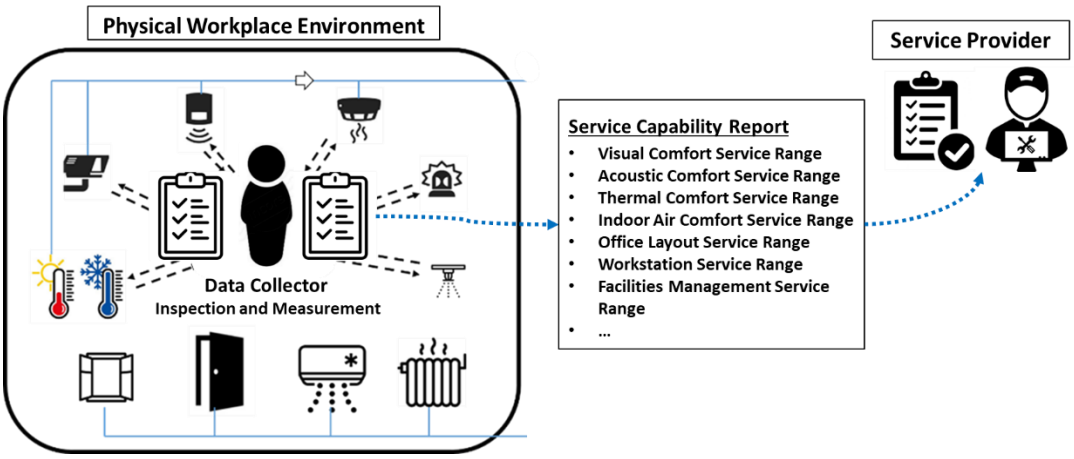

Figure 4-3. The data collector inspects and measures the physical workplace environment, and the data collector submits a service capability report to the service provider.

4.4.2 Identify the Personal Comfort Settings

When the knowledge worker gets involved in the new system, the data collector must initially inspect, and measure personalized and customized workplace comfort and wellbeing parameters. The data collector collects data in the data collection lab specific and personalized to the knowledge worker, ensuring that these data are comfortable for the knowledge worker. At the end of the study, the data collector delivers a log file to the knowledge worker listing the specific parameter data in the semantic web environment.

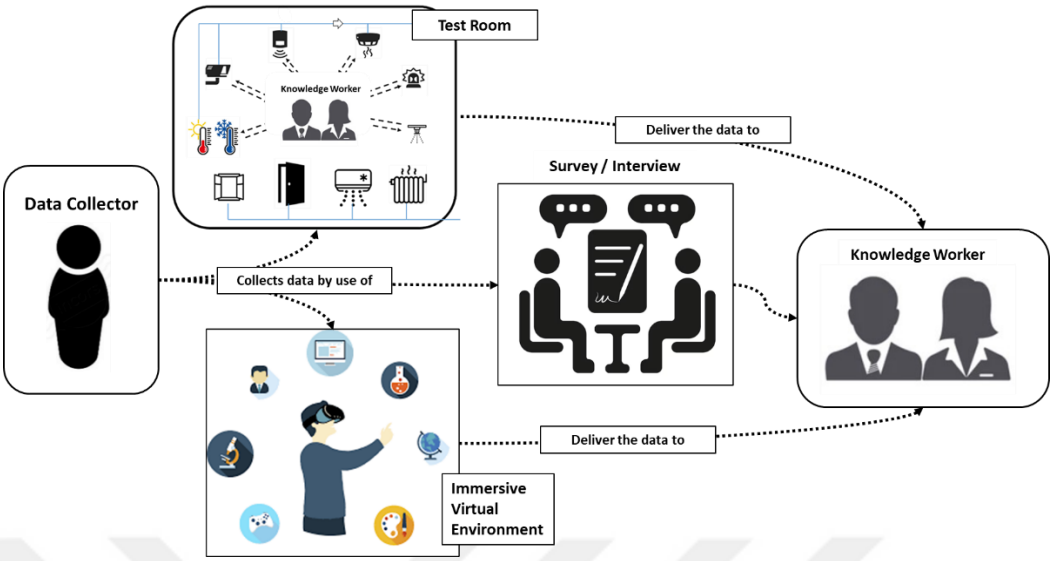

Figure 4-4. The data collector uses occupant data collection methods to gather workplace comfort and wellbeing data from the knowledge worker.

4.4.3 Describe the Workplace Needs and Requirements

Both knowledge workers and service providers could do the description of the workplace types. The knowledge worker describes a workplace for a specific purpose that would be used for a particular time. For example, a meeting workplace will include a couple of indoor environmental quality parameters and will be used for 2 hours. Another example could be a concentrated study area with many indoor environmental quality parameters requiring specific architectural finishings and furniture. The workplace would be used for 3 hours in the working days. Thus, the required workplace types could be decided by knowledge workers regarding the needs and requirements of knowledge workers on the semantic web applications.

The service provider could present various workplace service types regarding the capability of the physical workplace. For example, a co-working space including a couple of workplace comfort and wellbeing parameters could be published in the semantic web application to find potential knowledge workers to give workplace services. Another example could be a meeting space consisting of particular comfort and wellbeing parameters and could be occupied within certain periods.

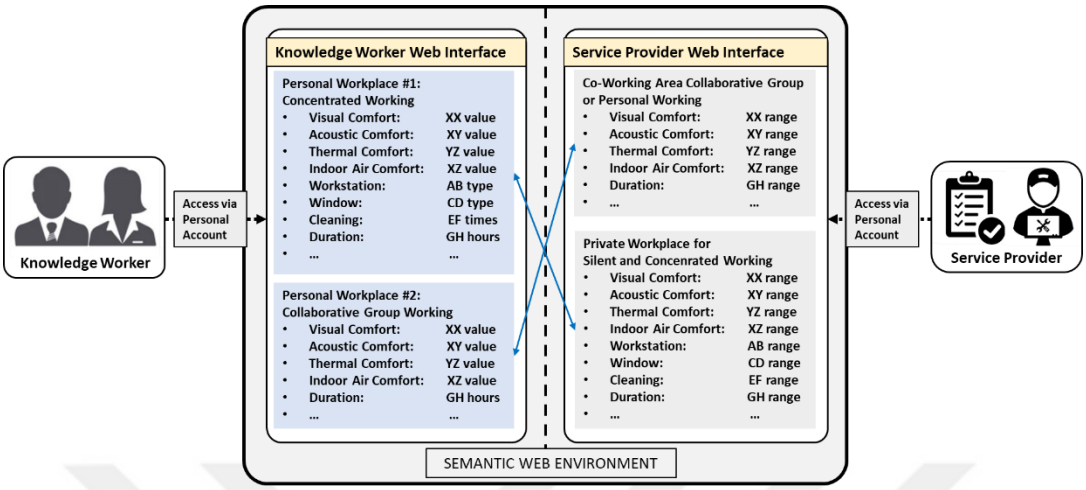

Figure 4-5. Description of workplace needs and requirements for the services by knowledge worker and service provider.

4.4.4 Find a Proper Service Provider and Knowledge Worker

Since the semantic web application presents a digital marketplace opportunity, the service provider and the knowledge worker could publish their workplace desires as ads. The semantic web application can match these ads to find the best compliant and relevant ads and list them to the users.

4.4.5 Deal on a Smart Contract

The semantic web application directs the user to the smart contract application after selecting the proper knowledge worker for the service provider or service provider for the knowledge worker. Furthermore, the workplace comfort and wellbeing parameters depicted and desired by the users transform into service provisions. When the users confirm the provisions, the semantic web application transfers the service provisions to the AmI system of the service provider.

4.4.6 Prepare the Workplace for the Knowledge Worker

Regarding the workplace service provisions, the physical workplace must be prepared for the knowledge worker to occupy and use the desired workplace within the desired time interval. If the workplace provisions require the establishment of specific devices or the construction of particular materials, then the crew of the service provider should prepare the required environment before the knowledge worker uses the workplace.

4.4.7 Use the Workplace and Evaluate the Services

When the booking time has come, and the reserved area is ready, the knowledge worker could use and occupy the workplace. The AmI system of the service provider instantly tracks and monitors the knowledge worker and sets the environment regarding the service provisions. Regarding the in-use feedback of the knowledge worker, the service provider can change the provisions and re-set the workplace environment. Following the finish of the workplace services, the knowledge worker can evaluate the workplace services, and the service provider can evaluate the workplace set of the knowledge worker.

4.5 Domain and Concepts of the Model

A domain is a class having RDF statement property and a range of its value (W3C, 2023). Thus, a domain in knowledge representation techniques indicates a particular field of subject consisting of concepts, attributes, and relation between concepts and their attributes (Milutinovic & Tomazic, 2001).

A concept is an entity of consciousness perceived as an action, task, function, strategy, or reasoning process expressed implicitly or explicitly (Xiaojia et al., 2007). The implicit concept exists in a text and is extracted using the natural language processing (NLP) method, while explicit concepts exist in simulated knowledge,

description logic, and concept maps (Milutinovic & Tomazic, 2001). The concepts are interpreted with graphic techniques such as conceptual graphs and concept maps.

The conceptual graphs express the basic expressions using symbols associated with and directed to linking lines. On the other hand, the concept map describes the complex and detailed composition of concepts constituting a meaningful structure, as depicted in Figure 4-6. The concepts in the concept map are linked with words or phrases specifying the relations between two concepts.

Various concepts would have existed in a domain. Classes, properties, relations, attributes, rules and restrictions, and realms with instances and individuals describe the concepts. The classes are the assets of the concepts and are organized by a structured hierarchy. The relations are the interactions between concepts and their attributes. The properties identify the associations between classes and their individuals and instances. The rules and restrictions are the limitations for the ranges or regulations for the descriptions. Instances and individuals are the realm of the particular classes reflecting the properties and relations.

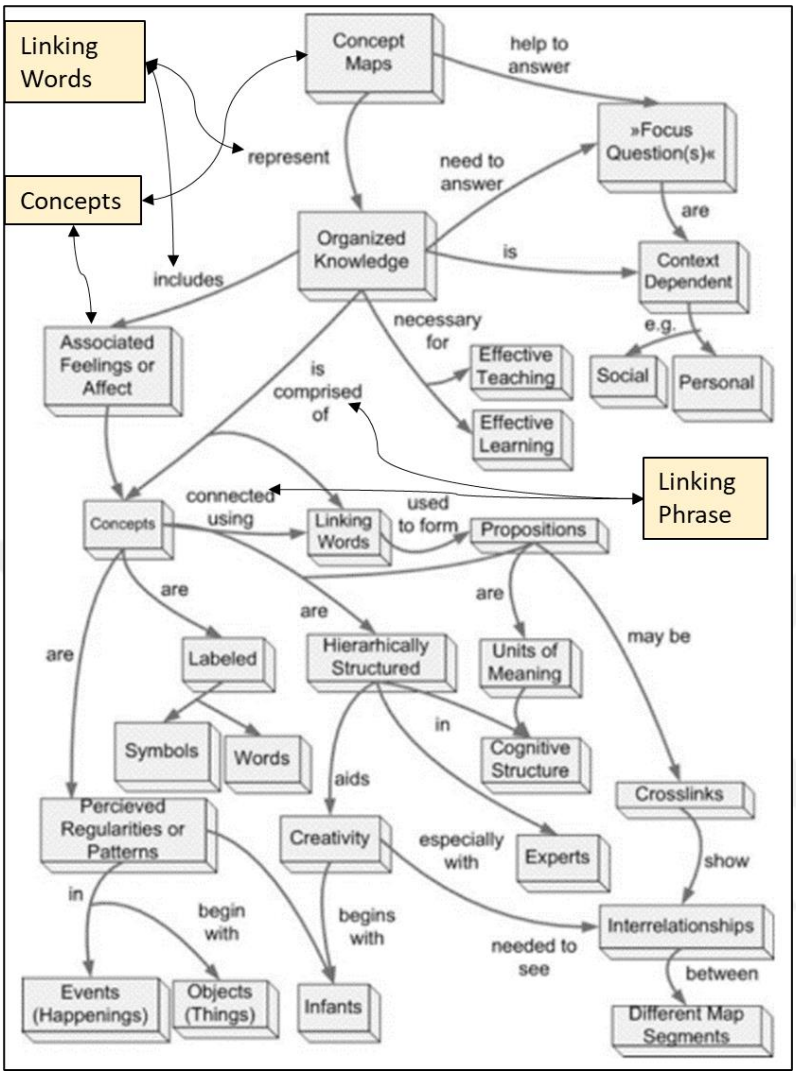

Figure 4-6. A concept map. Retrieved from: (Milutinovic & Tomazic, 2001)

4.5.1 The Domain of the Model

The ontologies are established on a particular knowledge domain. The knowledge domain of the proposed model is the workplace comfort and wellbeing parameters because the concepts are established on the population of the particular parameters, and the knowledge worker-specific parameter data will be shared and reused among the concepts.

As illustrated in Figure 4-7, a domain of a specific parameter is represented in a triple hierarchy. A couple of customized data in either integer or string format could exist in various values and descriptions. A service range may cover many of these values and descriptions. A domain of the parameter, on the other hand, includes all of these varieties in the data and ranges.

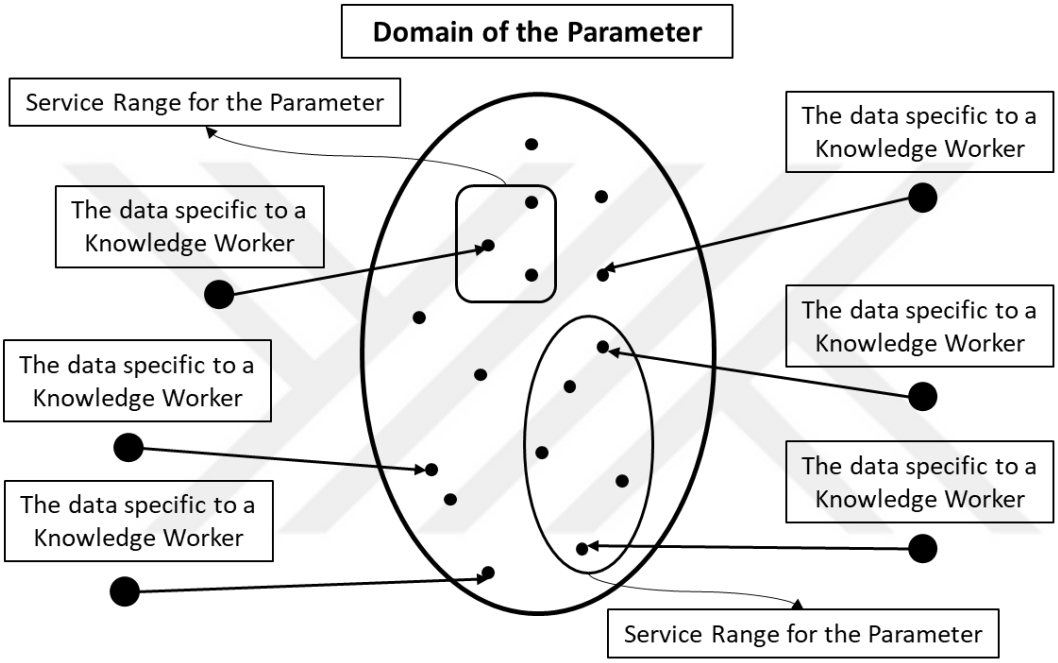

Figure 4-7. Relation among service range, workplace set, and domain for a workplace service parameter.

The workplace comfort and wellbeing parameters were collected and listed in the initial chapter. The parameters in the list are disorganized, thus requiring categorization and classification. A classification method similar to the Uniformat of Construction Specification Institutes (CSI) is adopted and presented in Table 4-2. Thirteen groups were established under six classes, and the parameters were listed under these thirteen groups.

Table 4-2. Classification of the workplace comfort and wellbeing parameters

Classes	Sub-Classes	Parameters
A. Duration of Booking	A10. Duration of Booking	A101. Duration of Booking
B. Occupancy Comfort	B10. Visual Comfort	B101. Illuminance
		B102. Circadian Lighting Design
		B103. Uniformity of illuminance
		B104. Illuminance of the immediate surrounding areas
		B105. Percentage of the task area meeting the required illuminance
	B20. Acoustic Comfort	B201. Noise Criteria
		B202. Reverberation Time
		B203. Speech Transmission Index
	B30. Thermal Comfort	B301. Air temperature
		B302. Vertical air temperature difference
		B303. Operative temperature
		B304. Radiant temperature asymmetry
		B305. Floor surface temperature
		B306. Air speed
	B40. Indoor Air Quality	B401. Carbon dioxide
		B402. PM 2.5
		B403. PM 10
		B404. Carbon Monoxide
		B405. Total Volatile Organic Compounds
		B406. Formaldehyde
		B407. Sulfur dioxide
		B408. Ozone
		B409. Total microbial count
C. Office Interior	C10. Office Layout	C101. Size of the Area
		C102. Height of the space
		C103. Location of workplace components
		C104. Required equipment, furniture, and devices
		C105. Color, texture, material, and quality of floor finishing
		C106. Color, texture, material, and quality of wall finishing
		C107. Color, texture, material, and quality of ceiling finishing
	C20. Workstation	C201. Size of the workspace
		C202. Color, texture, and quality of material
		C203. Orientation
		C204. Location
	C30. Window	C301. Window-to-Wall ratio
		C302. Size of the window
		C303. Operability of window
		C304. Position of window
		C305. Location of window
		C306. Proximity of workstation
D. Office Building	D10. Accessibility	D101. Transportation options to the facility
		D102. Compliance with universal design principles

Table 4-2 *continued*

	D20. Vertical Circulation	D201. Vibration
		D202. Noise
		D203. Acceleration/ Deceleration Impact
		D204. Comfort
	D30. Building Exterior	D301. Exterior Material & Finishing
		D302. Building Type
E. Facility Management Services	E10. Facility Management Services	E101. Resting Need and Capacity
		E102. Shower Need and Capacity
		E103. WC Need and Capacity
		E104. Kitchen
		E105. Canteen
		E106. Meeting Room Need and Capacity
		E107. Dining Area Need and Capacity
		E108. Pantry
		E109. Parking Space Need and Capacity
		E110. Smoking Area Need and Capacity
		E111. Cleaning
		E112. Safety & Security
		E113. Maintenance
		E114. Communication with FM
		E115. Network Type and Capacity
		E116. Audio Visual Systems Needs and Capacity
		E117. Modern Technologies
F. Reserved for Future Needs	F10. Reserved for Future Needs	

4.5.2 The Concepts of the Model

The concepts of the proposed model, regarding the narrated scenario, were described as data collection concepts, workplace creation concepts, physical workplace concepts, web interface concepts, smart contract concepts, and ambient intelligence concepts.

4.6 Formal Representation and the Processes of the Concepts

Each concept of the proposed model is explained in the following sub-sections.

4.6.1 Data Collection Concept

- **The Data Collection for the Knowledge Worker**

Workplace comfort and wellbeing parameters could be grouped according to the workplace type and duration of work. However, various office workplace types are specialized for specific tasks; four types of workplaces were depicted, as stated in Figure 4-8. These are (i) hive for routine work, (ii) cell for specific and concentrated work, (iii) den for teamwork, and (iv) club for complex and multi-task work. Furthermore, three types of contractual relations could be matched with these four types of workplaces, as demonstrated in Figure 4-9. These are long-term use, short-term use, and very short-term use.

Before measurement by the data collector, the knowledge worker must decide the workplace type and contractual duration. This is because the duration and type of work affect the work environment and, thus, the content of workplace comfort and wellbeing parameters. Thus, a study presenting the matrix of workplace type and contractual duration is presented in Figure 4-9. Four workplace types could be matched with three work durations and present twelve workplaces performing different business and contractual relations.

After selecting the workplace type, the knowledge worker and data collector decide the required workplace comfort and wellbeing parameters. Then, as depicted in Figure 4-10, the data collector measures and collects knowledge of worker's specific comfort and wellbeing data regarding the selected workplace type. As depicted in Figure 4-11, at the end of the study, the data collector prepares a workplace comfort set or configuration specific for the user regarding the selected work type and duration. Afterward, the measured and collected workplace set could be uploaded to the Knowledge Worker's account in a semantic web interface.

The concept map graphical representation is presented in Figure 4-12. The concept map illustrates relations between entities of the concept and parameters of the domain in detail by referencing the behavior of the entities during the process.

Workspace Types	Used For	Classification	Source
Hive	Routine work	Business Operation	(Laing et al., 1998)
Cell	Specific and concentration work		
Den	Team work		
Club	Complex and multi-task work		
Core Space	Long-Term Use	Contractual	(GIBSON & LIZIERI, 2000)
First Periphery Space	Short-Term Use		
Second Periphery Space	Very Short Term Use		

Figure 4-8. Workplace types

	Core Space	First Periphery	Second Periphery
Hive	Long Term Use – Routine Work	Short Term Use – Routine Work	Very Short Term Use – Routine Work
Cell	Long Term Use – Specific and Concentration Work	Short Term Use – Specific and Concentration Work	Very Short Term Use – Specific and Concentration Work
Den	Long Term Use – Team Work	Short Term Use – Team Work	Very Short Term Use – Team Work
Club	Long Term Use – Complex and Multi-Task Work	Short Term Use – Complex and Multi-Task Work	Very Short Term Use – Complex and Multi-Task Work

Figure 4-9. Workplace type matrix considering business operation and contractual consideration.

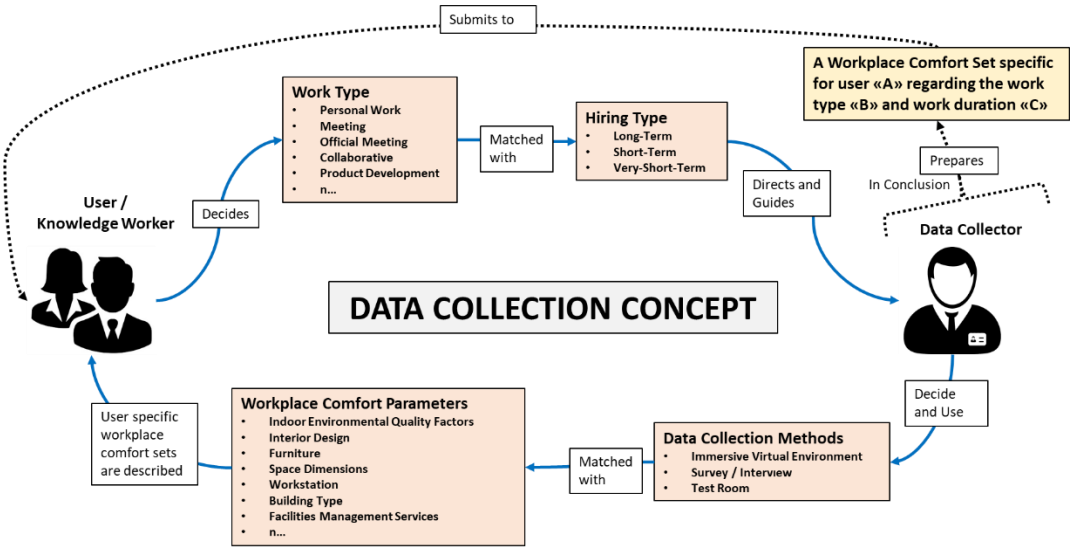

Figure 4-10. Activities and actions between knowledge worker and data collector

WORKPLACE #X		
CODE	COMFORT PARAMETERS	COMFORT DATA
A101	Duration of Booking	2 months
B101	Illuminance	500
B201	Noise Criteria	50
B202	Reverberation Time	0.9
B301	Air temperature	27
B302	Vertical air temperature difference	2
B303	Operative temperature	25
B304	Radiant temperature asymmetry	15
B305	Floor surface temperature	25
B401	Carbon dioxide	2500-3500
B404	Carbon Monoxide	3
B407	Sulphur dioxide	0.9
B408	Ozone	0.015
C101	Size of the Area	3X5
C102	Height of the space	3
C103	Location of workplace components	All of them at above the Desk
C104	Required equipment, furniture and devices	Desk, Printer, 24 inc monitor, office chair, Sketch Pad
C105	Color, texture, material and quality of floor finishing	Laminated Wood, light colors, carpet
C106	Color, texture, material and quality of wall finishing	brutal brick with smooth joint
C107	Color, texture, material and quality of ceiling finishing	No ceiling
C201	Size of the workspace	L shape, 140+180x80 cm
C202	Color, texture and quality of material at workspace	Lake covered, white color
C203	Orientation	East-West
C204	Location of Workstation	South-North Direction
C302	Size of the window	At least 1m x 1m
C303	Operability of window	Awning, Pivot
C304	Position of window	Center of the Wall
C305	Location of window	South Elevation
C306	Proximity of workstation	1 m distance to window
D101	Transportation options to facility	Private Car
D301	Exterior Material & Finishing of Building	Glass Curtain Wall
D302	Building Type	Office Building
E101	Resting Need and Capacity	Single Person Resting
E102	Shower Need and Capacity	Shower, Towel, Shampoo
E103	WC Need and Capacity	built-in reservoir
E106	Meeting Room Need and Capacity	5
E107	Dining Area Need and Capacity	3
E109	Parking Space Need and Capacity	Car Park, 3 Cars
E110	Smoking Area Need and Capacity	5 people smoking
E115	Network Type and Capacity	Wired, 300 mb+
E116	Audio Visual Systems Needs and Capacity	Samsung or Apple, bluetooth, professional

Figure 4-11. The data collector submits a document listing knowledge worker-specific and personalized workplace set to the knowledge worker.

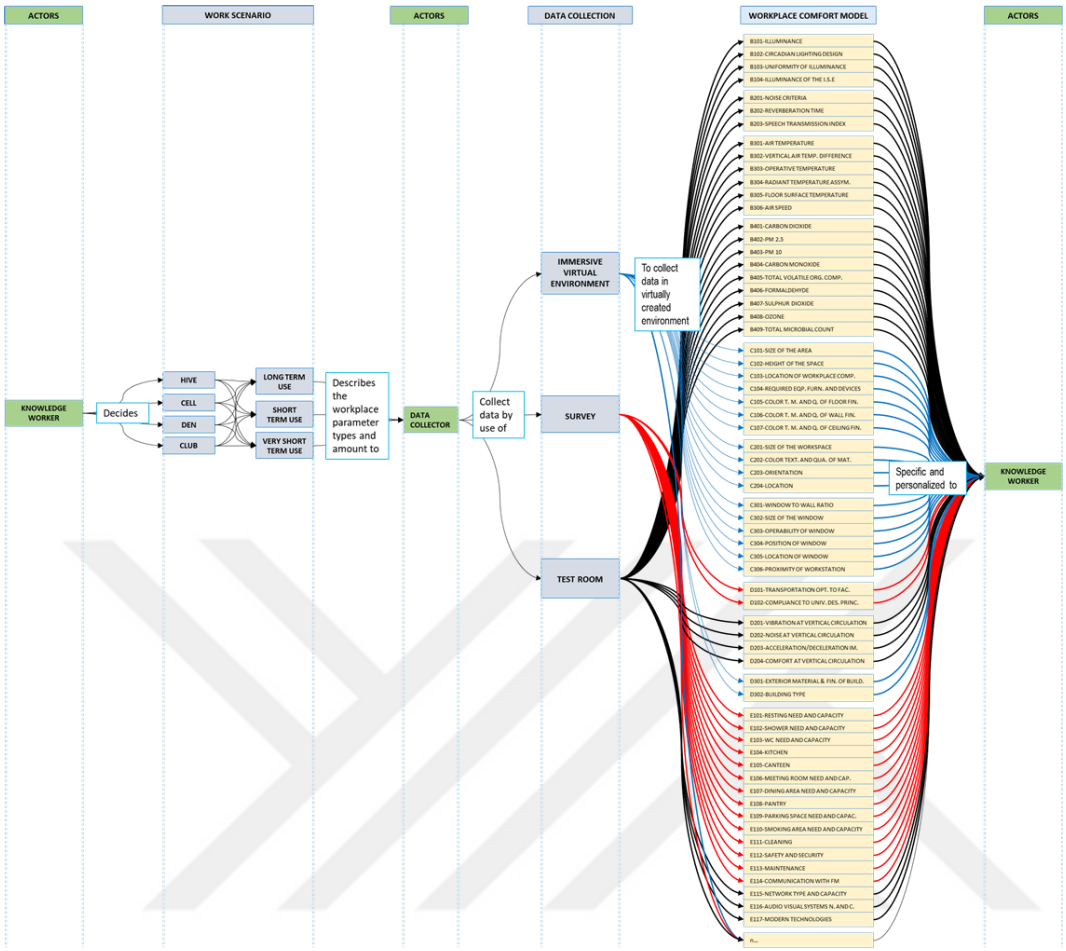

Figure 4-12. Data collection concept map graphical representation

- **The Data Collection for the Service Provider**

Like the knowledge worker, the service provider finds a data collector to inspect and measure the workplace services available in the physical environment. At the end of the inspection and measurement process, the data collector delivers a document listing available workplace service parameters and their service ranges to the service provider.

4.6.2 Workplace Creation Concept

After completing the data collection process, the knowledge worker can create his/her workplace set or configuration in the semantic web interface. After detecting the required workplace type and duration, the desired workplace comfort and wellbeing parameters were identified. Since the knowledge worker is aware of his/her comfort level and range of the workplace comfort and wellbeing parameters, he/she can use or change the parameter data.

The semantic web interface allows the proper visual appearance for the knowledge worker in each selection and decision about the workplace comfort and wellbeing parameters. Furthermore, at the end of the selection and decision process, the application presents a 3-Dimensional virtual environment reflecting the knowledge worker's workplace parameters. After confirmation of the workplace set by the knowledge worker, the semantic web application directs the knowledge worker to a marketplace application to publish an ad for finding a potential service provider.

4.6.3 Physical Workplace Concept

The service provider operates the physical workplace environment and gives facilities services to the knowledge workers. Since the data collector submits the available workplace service parameters and their service ranges, the service provider can create either an ad to give various workplace services in the marketplace of the semantic web application or by uploading the available service parameters and their service ranges, find a compliant workplace set ad to give workplace services. In the first option, the semantic web application matches the proper knowledge worker desiring to take workplace services for the service provider so that the provider can select any knowledge worker. In the second option, the semantic web application browses the relevant match of the workplace set ads to the service provider.

In the first option, the service provider prepares a couple of workplace services as a theme, such as a meeting area, co-working place, or private working room. The

workplace service parameter data are presented as a range. For example, the illuminance value of the meeting area could be between 150 to 500 lux. This means that workplace sets requiring a lux value between 150 and 500 are proper for the meeting area, while a lux value of 600 is not proper, and the semantic web application will not browse out-of-range values. In the second option, the entire list of workplace service parameters was listed again as range, and the semantic web application will browse the workplace setting that the parameter data is between the service range.

4.6.4 Semantic Web Interface Concept

Once the workplace comfort and wellbeing parameters are identified for the knowledge workers and the physical workplace, the process is executed on a semantic web interface. The knowledge worker and the service provider initiate personal accounts in the semantic web interface. The workplace configurations and services are prepared and then published as ads in the marketplace of semantic web applications as separate web pages such as "workplace set ads" and "workplace service ads."

The knowledge worker prepares workplace sets representing the knowledge worker's desires for taking workplace services and then publishes it as a "workplace set ad." When the knowledge worker asks for the semantic web application to browse the compliant service providers, relevant service providers are listed. The listing could be in vertical or horizontal order as column and row or represented on a map.

The application illustrates the availability of a physical workplace for the requested services to the knowledge worker. After selecting the service provider, the semantic web interface transfers the workplace set data to a smart contract application and informs the service provider to participate in the deal. The workplace sets are transformed into service provisions. When the service provider and the knowledge worker confirm the provisions, the semantic web application book the workplace set and appoint the physical workplace regarding the requested duration and time

interval; if they cannot deal with provisions, the semantic web application directs the users to the marketplace application.

The service provider establishes particular workplace services providing specific workable environments. The parameters presented in these workplace services demonstrate service ranges rather than specific data in the workplace sets. Then, the workplace services are published as "workplace service ads." The relevant knowledge workers are listed when the service provider asks for the semantic web application to browse the compliant knowledge workers. The application matches the "workplace service ads" and "workplace set ads." The relevant workplace set ads are listed to the service provider, and the service provider can contact any of them to give workplace services.

When a service provider and knowledge worker deals in services, the web interface directs the users to smart contract applications, and the workplace set of the knowledge worker transforms into service provisions. When the service provider and the knowledge worker confirm the service provisions, the web application book the workplace set and appoint the physical workplace regarding the requested duration and time interval; if they cannot deal with provisions, the semantic web application directs the users to marketplace application.

4.6.5 Smart Contract Concept

The smart contract concept regulates and explains the ability to work on a specific contract. The workplace sets prepared or selected by the knowledge worker are transformed into service provisions. Therefore, each workplace set becomes a specific and unique service contract. The duration, time interval, personalization and customization opportunities, and flexibility provided to the knowledge worker are formalized and become official using the smart contract.

The state-of-the-art smart contracts require the involvement of purchasing phases and processes that must prevent potential conflicts and claims by assuring being self-

executive by the smart contract itself. The purchase process in this study is based on the escrow contracting type by making certain modifications, as depicted by UML diagrams in Figures 4-13, 4-14, and 4-15. The state diagram in Figure 4-13 expresses the conditions or events in the purchasing process. The activity diagram depicted in Figure 4-14 represents entities of the purchasing process as a knowledge worker, data collection, smart contract, and service provider, relations of these entities, and the process flow by mentioning the decisions in each option. The sequence diagram in Figure 4-15 describes the order of the events and acts in the purchasing process by setting the relations in a sequence of order between actors and events.

The purchase process consists of "status" to ensure and inform parties about the purchase process, as depicted in Figure 4-16. The semantic web interface embeds workplace set and service data into the smart contract as provisions. This will change the status to "Workplace set." Then, the knowledge worker initiates the contract, and the status will be changed from "Workplace Set" to "Contract Started." Later, the knowledge worker transfers the deposit amount to the smart contract. This function will take the deposit amount from the knowledge worker account and store it in the blockchain environment.

Furthermore, the status will be changed from "Contract Started" to "Awaiting Payment". Suppose the workplace service provisions are agreed upon. In that case, the service provider approves the contract, and the status is changed from "Awaiting Payment" to "Approved by Service Provider." If the service provider does not approve the provisions, then the knowledge worker is informed and withdrawn from the contract and the deposit amount is returned to the knowledge worker account. After the status is changed to "Approved by Service Provider, the knowledge worker confirms the overall process; then the status will be changed from "Approved by Service Provider to "Complete," and the deposit amount is transferred to the service provider's account.

The smart contract concept map graphical representation is illustrated in Figure 4-17. The relations and sequences of the order in the purchasing process were depicted.

The diagram depicted in Figure 4-17 is an inclusion and holistic application of the state, activity, and sequence diagrams depicted in Figure 4-10, 4-11, 4-12, and 4-13.

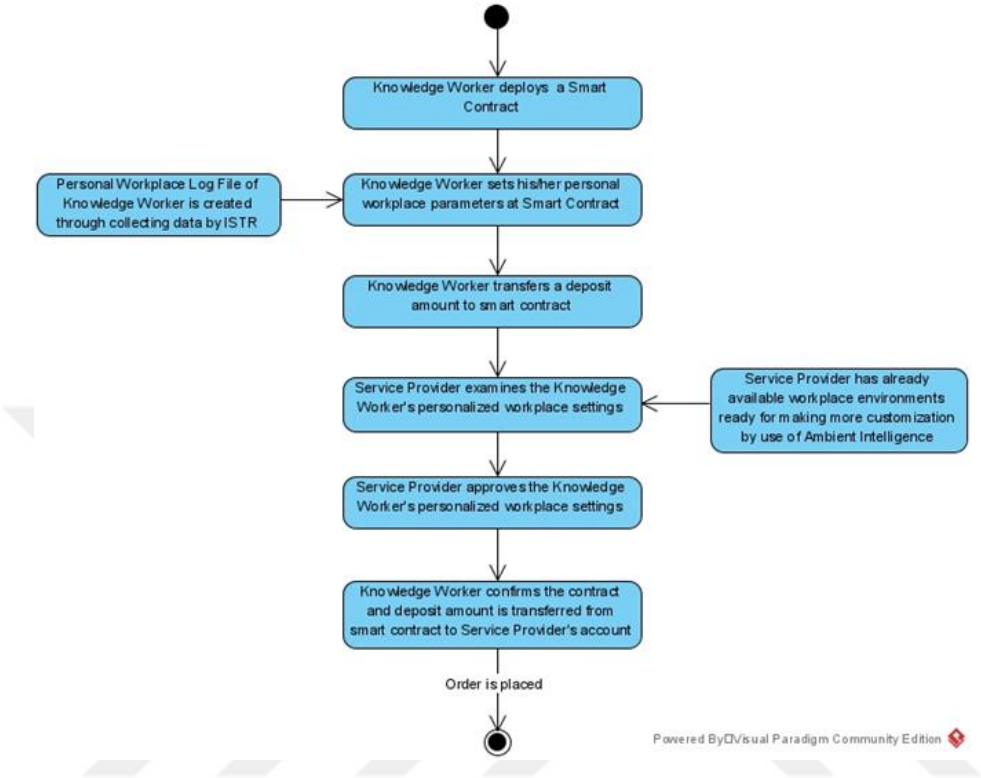

Figure 4-13. The state diagram of the smart contract application.

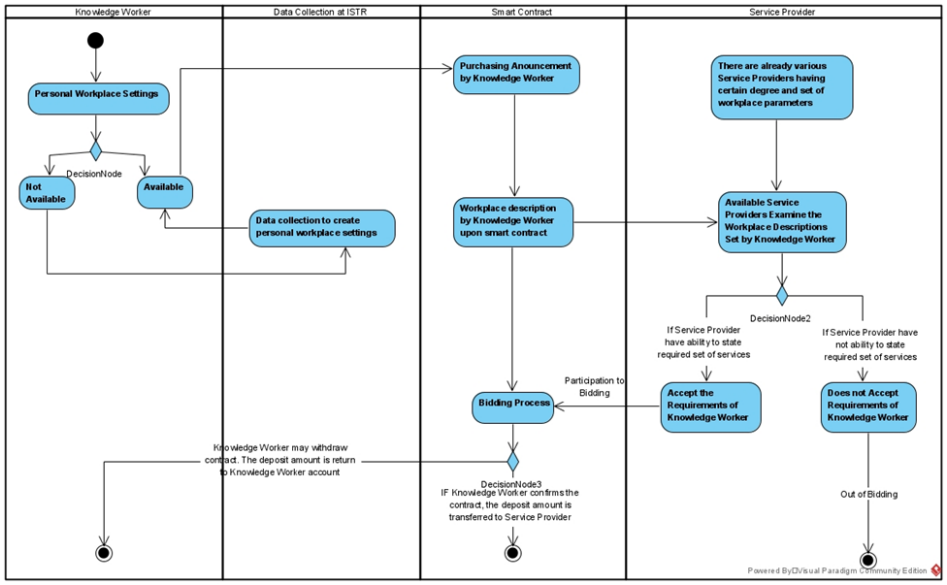

Figure 4-14. The activity diagram of the smart contract application.

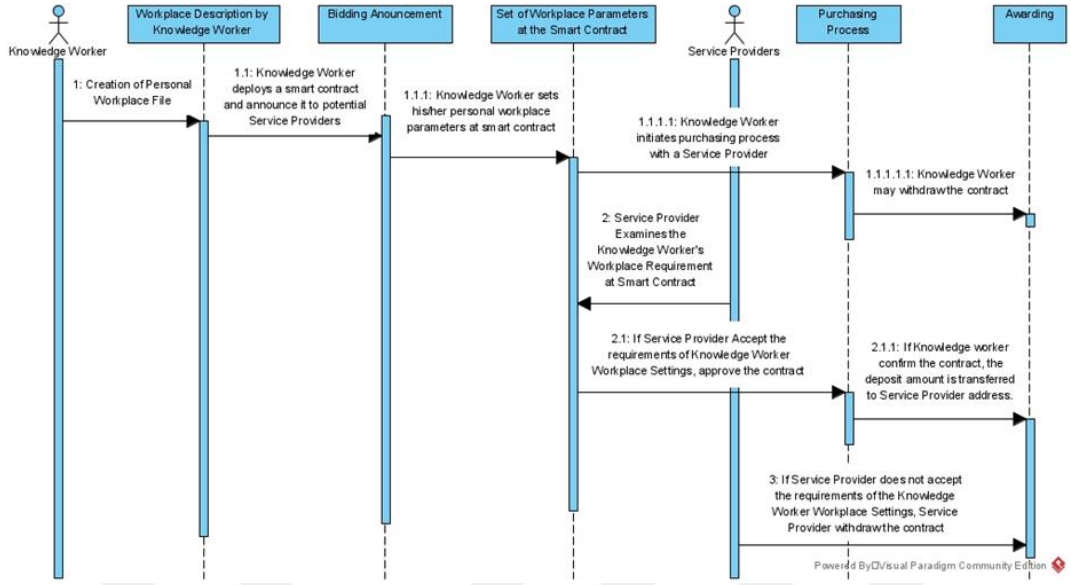

Figure 4-15. The sequence diagram of the smart contract application.

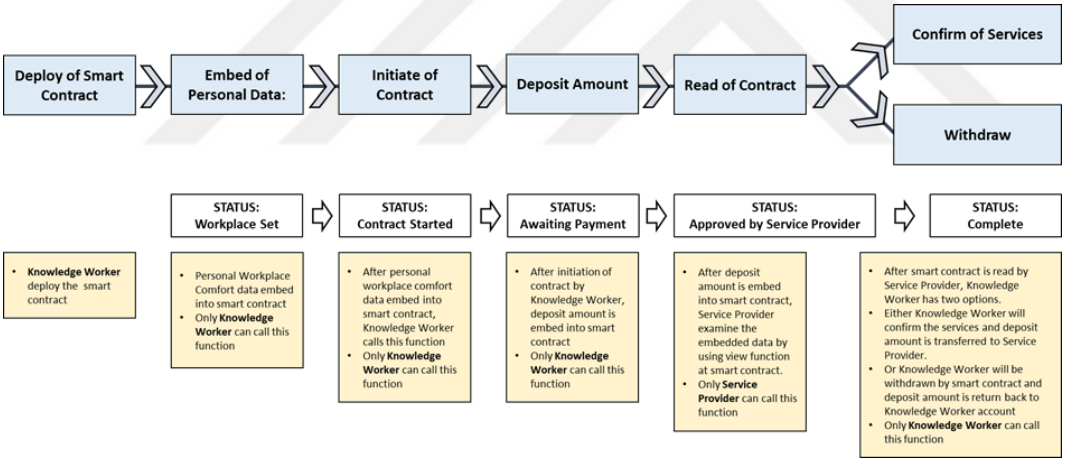

Figure 4-16. The purchase order was designed for this study.

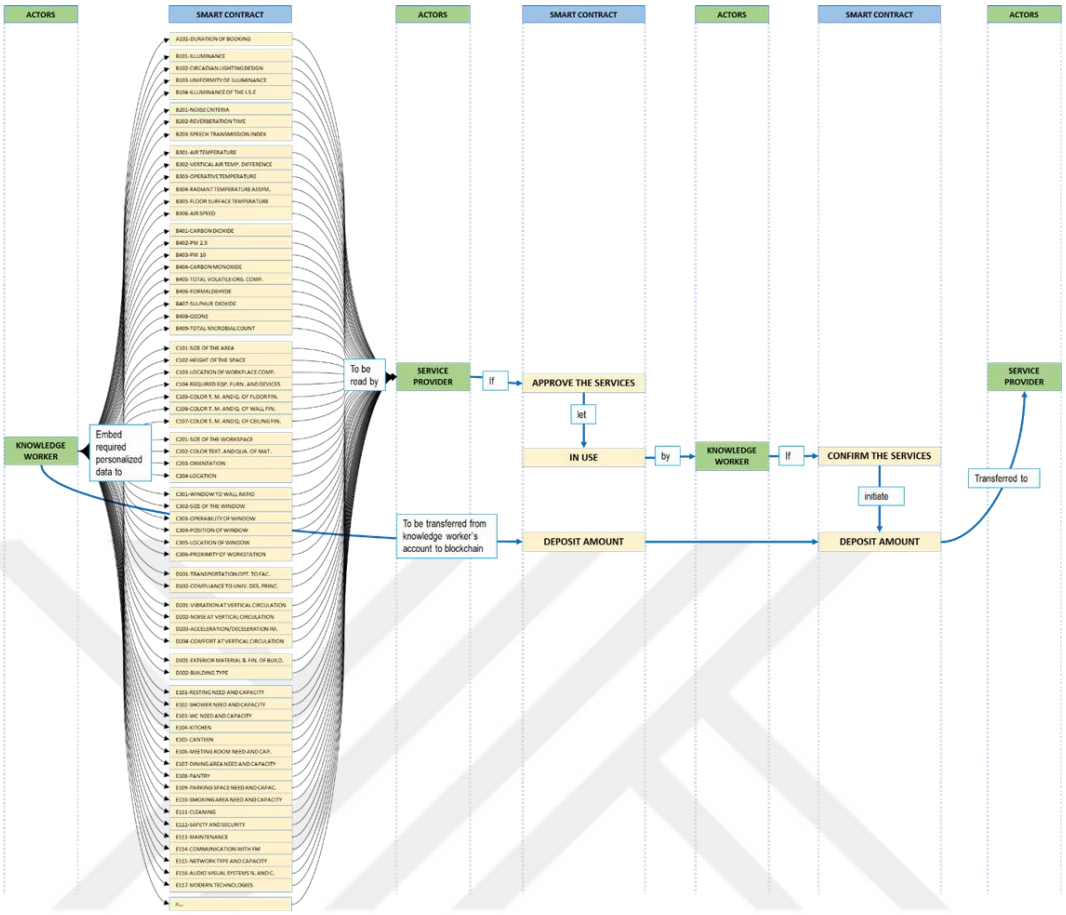

Figure 4-17. The smart contract concept map graphical representation.

4.6.6 Ambient Intelligence Concept

Unlike the other concepts, the ambient intelligence concept facilitates relations and events between indoor environmental quality (IEQ) parameters by using sensors and actuators monitored and controlled by computers as decision-makers, as depicted in Figure 4-18. The ambient intelligence concept consists of two states as IEQ, and actions occur at these IEQ parameters during the in-use conditions. The in-use conditions are facilitated by sensors collecting knowledge worker body data and workspace data and actuators to act changing conditions that may occur upon the workplace environment or knowledge worker's body.

The semantic web interface transfers workplace service provision data to the AmI system of the service provider. However, the IEQ parameters are especially useful for the AmI system. During the workplace occupation by the knowledge worker, the sensors collect instant IEQ data by using a variety of sensors and transfer them to the computer from both the knowledge worker's body and the workplace environment. The computer continuously checks the sensed data and compares it with provision data. In case of change detection in compared data, the computer uses actuators to balance the changing condition. During this process, the computer still monitors the data sensed by the sensors, and when the changed condition returns to its original status, the computer stops the actuators. These events are continuously repeated regarding the change tracked by computers not only in the workplace but also in the body of the knowledge worker in order to balance the changing condition to the original or intended status.

During the occupation, the knowledge worker can monitor the instant status of IEQ parameters; in case of necessity, he/she can increase or decrease the data or stop the operation. This opportunity enables in-service evaluation of the knowledge worker.

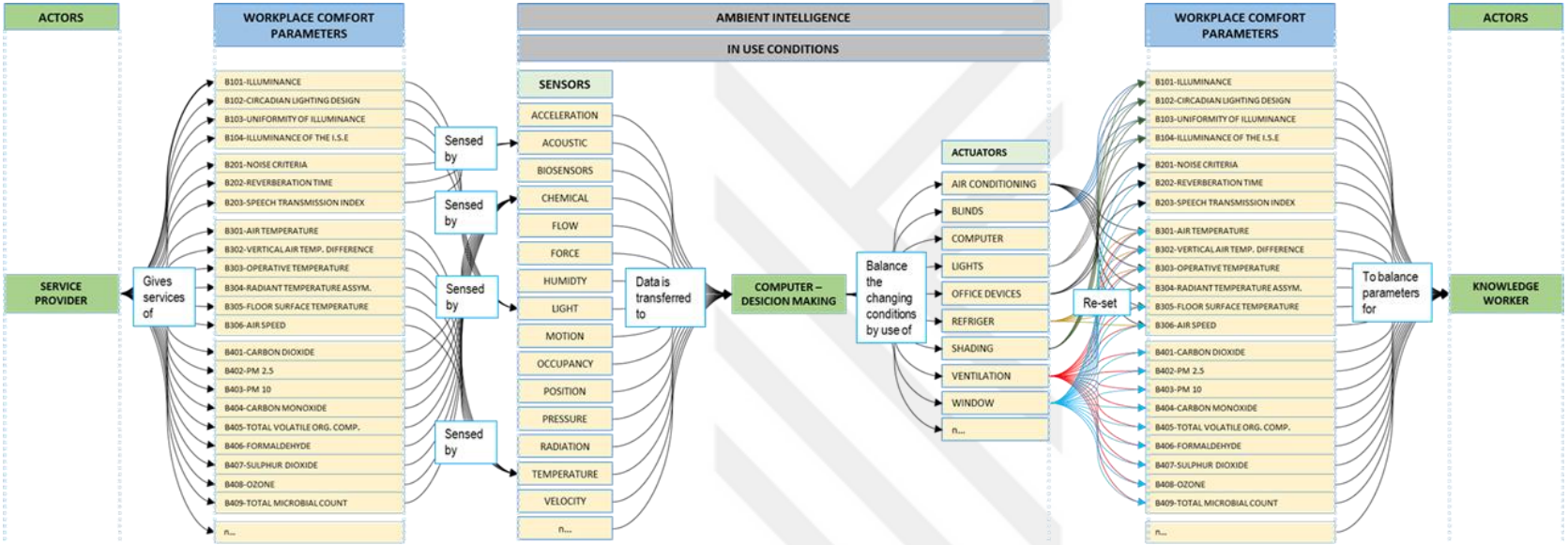

Figure 4-18. Ambient Intelligence concept map graphical representation

4.7 Modeling the Ontology in the Ontology Editor

The protégé has a user-friendly interface to model and edit the web ontology models. The modeling process includes establishing class hierarchies, describing object and data properties, and creating individuals and instances. The class hierarchies and object properties were depicted in Figure 4-19, whereas the data properties were illustrated in Figure 4-20. Individuals and instances were created after presenting class hierarchies, objects, and data properties. The individuals and instances were referred to a particular class, and object properties depicted relations, while data properties specified the data belonging to the individuals and instances.

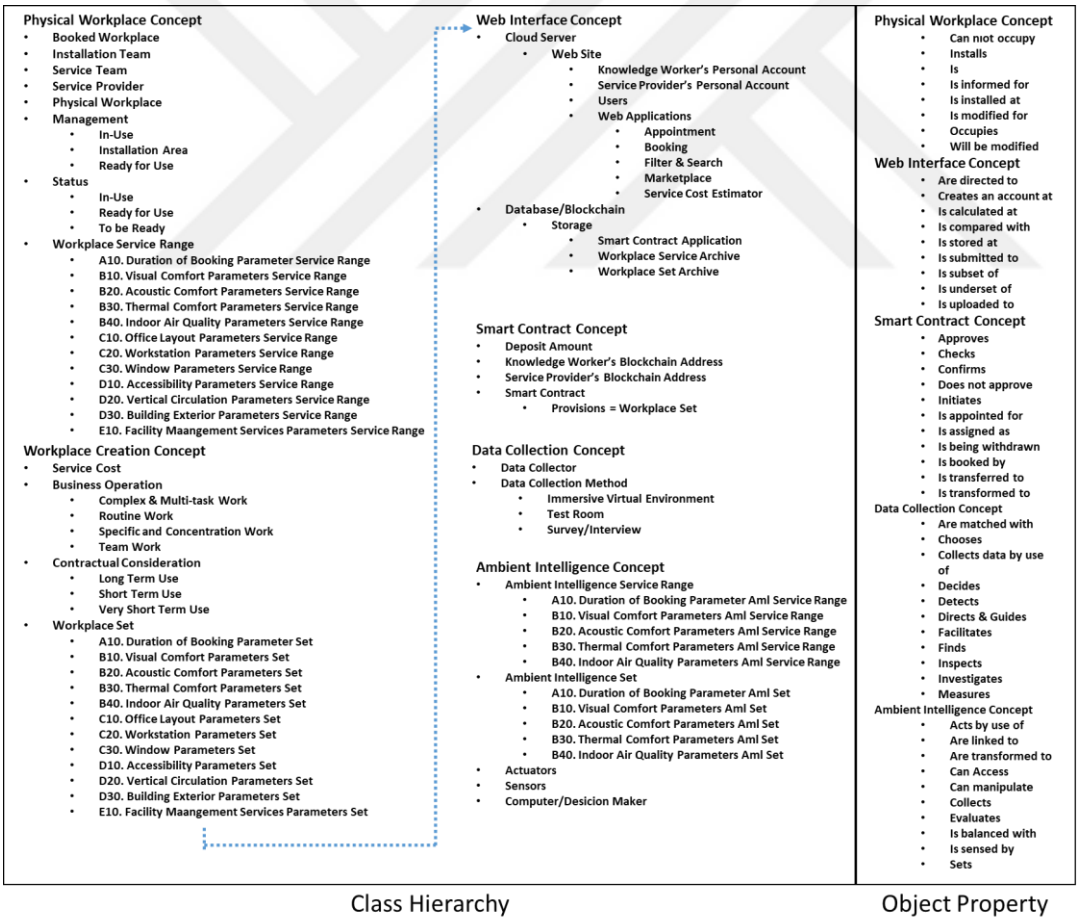

Figure 4-19. Class hierarchy and object properties of the ontology model.

Individual and instance depictions were formalized by presenting each statement as the algorithm. The relations, associations, and attributes within and among the concepts were established during the formal description of the individual and instance statements. The algorithms, object properties, individuals, and instances in the algorithms were illustrated in Figures 4-21, 4-22, 4-23, 4-24, 4-25, and 4-26.

Ambient Intelligence Service Range
- **A10. Duration of Booking Parameter Aml Service Range**
- **B10. Visual Comfort Parameters Aml Service Range**
- **B20. Acoustic Comfort Parameters Aml Service Range**
- **B30. Thermal Comfort Parameters Aml Service Range**
- **B40. Indoor Air Quality Parameters Aml Service Range**

Ambient Intelligence Set
- **A10. Duration of Booking Parameter Aml Set**
- **B10. Visual Comfort Parameters Aml Set**
- **B20. Acoustic Comfort Parameters Aml Set**
- **B30. Thermal Comfort Parameters Aml Set**
- **B40. Indoor Air Quality Parameters Aml Set**

Smart Contract
- **Deposit**

Workplace Service Range
- **A10. Duration of Booking Parameter Service Range**
- **B10. Visual Comfort Parameters Service Range**
- **B20. Acoustic Comfort Parameters Service Range**
- **B30. Thermal Comfort Parameters Service Range**
- **B40. Indoor Air Quality Parameters Service Range**
- **C10. Office Layout Parameters Service Range**
- **C20. Workstation Parameters Service Range**
- **C30. Window Parameters Service Range**
- **D10. Accessibility Parameters Service Range**
- **D20. Vertical Circulation Parameters Service Range**
- **D30. Building Exterior Parameters Service Range**
- **E10. Facility Maangement Services Parameters Service Range**

Workplace Service Set
- **A10. Duration of Booking Parameter Set**
- **B10. Visual Comfort Parameters Set**
- **B20. Acoustic Comfort Parameters Set**
- **B30. Thermal Comfort Parameters Set**
- **B40. Indoor Air Quality Parameters Set**
- **C10. Office Layout Parameters Set**
- **C20. Workstation Parameters Set**
- **C30. Window Parameters Set**
- **D10. Accessibility Parameters Set**
- **D20. Vertical Circulation Parameters Set**
- **D30. Building Exterior Parameters Set**
- **E10. Facility Maangement Services Parameters Set**

Figure 4-20. The data properties of the Ontology Model.

Data Collection Concept		**ALGORITHMS for KNOWLEDGE WORKER**	**Object Properties**	**Individuals**
	1	Knowledge Worker finds a Data Collector	finds	Knowledge Worker, Data Collector
	2	Knowledge Worker decides Business Type	decides	Knowledge Worker, Business Type
	3	Knowledge Worker chooses Contractual Duration	chooses	Knowledge Worker, Contractual Duration
	4	Workplace Type directs and guides Data Collector	directs & guides	Workplace Type, Data Collector
	5	Data Collector facilitates Data Collection Methods	facilitates	Data Collector, Data Collection Methods
	5	Workplace Sets are matched with Data Collection Methods	are matched with	Workplace Sets, Data Collection Methods
	6	Data Collector collects data by use of Data Collection Methods	collects data by use of	Data Collector, Data Collection Methods
	7	Test Room measures about …	measures	Test Rooms, …
	8	Immersive Virtual Environment detects about ….	detects	Immersive Virtual Environment, …
	9	Survey/Interview investigates about ….	investigates	Survey / Interview, …
	10	Workplace Set is submitted to Knowledge Worker	is submitted to	Workplace Set, Knowledge Worker
		ALGORITHMS for SERVICE PROVIDER	**Object Properties**	**Individuals**
	1	Service Provider finds a Data Collector	finds	Service Provider, Data Collector
	2	Data Collector inspects Workplace Service Range	inspects	Data Collector, Workplace Service Range
	3	Workplace Service Range is submitted to Service Provider	is submitted to	Workplace Service Range, Service Provider

Figure 4-21. Algorithms, object properties, individuals, and instances are created for the data collection concept.

Web Interface Concept		ALGORITHMS for KNOWLEDGE WORKER	Object Properties	Individuals
	1	Knowledge Worker creates an account at Web Site	creates an account at	Knowledge Worker, Web Site
	2	Workplace Set is uploaded to Marketplace	is uploaded to	Workplace Set, Marketplace
	3	Workplace Set is stored at Workplace Set Archive	is stored at	Workplace Set, Workplace Set Archive
		ALGORITHMS for SERVICE PROVIDER	**Object Properties**	**Individuals**
	1	Service Provider creates an account at Web Site	creates an account at	Service Provider, Web Site
	2	Workplace Service Range is uploaded to Marketplace	is uploaded to	Workplace Service Range, Marketplace
	3	Workplace Service Range is stored at Workplace Service Archieve	is stored at	Workplace Service Range, Workplace Service Archive
		ALGORITHMS at WEB INTERFACE	**Object Properties**	**Individuals**
	1	Service Cost is calculated at Cost Estimator Apps	is calculated at	Service Cost, Cost Estimator
	2	Workplace Set is compared with Workplace Service Range	is compared with	Workplace Set, Workplace Service Range
	3	If Workplace Set is underset of Workplace Service Range	is underset of	Workplace Set, Workplace Service Range
	4	Workplace Set is submitted to Service Provider	is submitted to	Workplace Set, Service Provider
	6	Users are directed to Provisions	are directed to	Users, Provisions

Figure 4-22. Algorithms, object properties, individuals, and instances are created for the semantic web interface concept.

Smart Contract Concept		ALGORITHMS at SMART CONTRACT	Object Properties	Individuals
	1	Knowledge Worker initiates a Smart Contract	initiates	Knowledge Worker, Smart Contract
	2	Workplace Set is transformed to Service Provisions	is transformed to	Workplace Set, Service Provisions
	3	Service Cost is assigned as Deposit Amount	is assigned as	Service Cost, Deposit Amount
	4	Deposit Amount is stored at Smart Contract App	is stored at	Deposit Amount, Smart Contract App
	5	Service Provider checks the Service Provisions	checks	Service Provider, Service Provisions
	6	If Service Provider approves the Service Provisions	approves	Service Provider, Service Provisions
	7	Service Provision is booked by Booking Apps	is booked by	Workplace Set, Booking App
	8	Physical Workplace is appointed for Knowledge Worker	is appointed for	Physical Workplace, Knowledge Worker
	9	If Service Provider does not approve the Service Provisions	does not approve	Service Provider, Service Provisions
	10	Knowledge Worker is being withdrawn the Smart Contract	is being withdrawn	Knowledge Worker, Smart Contract
	11	Deposit Amount is transferred to Knowledge Worker's Account	is transferred to	Deposit Amount, Knowledge Worker's Account
	12	Users are directed to Marketplace	are directed to	Users, Marketplace
	13	If Knowledge Worker confirms the Smart Contract	confirms	Knowledge Worker, Smart Contract
	14	Deposit Amount is transferred to Service Provider Account	is transferred to	Deposit Amount, Service Provider Account

Figure 4-23. Algorithms, object properties, individuals, and instances are created for the smart contract concept.

Physical Workplace Concept		**ALGORITHMS at PHYSICAL WORKPLACE**	**Object Properties**	**Individuals**
	1	Ambient Intelligence Set is installed at Booked Workplace	is installed at	Ambient Intelligence Set, Booked Workplace
	2	Service Provider is informed for Booked Workplace	is informed for	Service Provider, Booked Workplace
	3	Booked Workplace is appointed for Knowledge Worker	is appointed for	Booked Workplace, Knowledge Worker
	4	If Physical Workplace is Ready for Use,	is	Physical Office Workplace, Ready for Use
	5	Knowledge Worker occupies Booked Workplace	occupies	Knowledge Worker, Booked Workplace
	6	If Physical Workplace is to be Ready	is	Physical Workplace, To be Ready
	7	Physical Workplace is modified for the Workplace Set	is modified for	Physical Workplace, Workplace Set
	8	Installation Team installs to the Installation Area	installs	Installation Team, Workplace Set
	9	If Physical Workplace is In Use,	is	Physical Workplace, In Use
	10	Knowledge Worker can not occupy Booked Workplace	can not occupy	Knowledge Worker, Booked Workplace

Figure 4-24. Algorithms, object properties, individuals, and instances are created for the physical workplace concept.

		ALGORITHMS for AMBIENT INTELLIGENCE	Object Properties	Individuals
Ambient Intelligence Concept	1	Aml Service Range and Sets are linked to Web Interface	is linked to	Aml Service Range, Aml Sets, Web Interface
	2	Service Provisions are transformed to Ambient Intelligence Set	are transformed to	Service Provisions, Ambient Intelligence Set
	3	Service Provider can access Ambiant Intelligence Service Range	can access	Service Provider, Knowledge Worker, Aml Set & Service Range
	4	Knowledge Worker can access Ambiant Intelligence Set	can access	Knowledge Worker, Ambient Intelligence Set
	5	Service Provider can manipulate Ambiant Intelligence Service Range	can manipulate	Service Provider, Ambient Intelligence Service Range
	6	Knowledge Worker can manipulate Ambiant Intelligence Set	can manipulate	Knowledge Worker, Ambient Intelligence Set
	7	Physical Workplace Environment is sensed by Acceleration Sensor	is sensed by	Physical Workplace Environment, Acceleration Sensor
	8	Physical Workplace Environment is sensed by Acoustic Sensor	is sensed by	Physical Workplace Environment, Acoustic Sensor
	9	Physical Workplace Environment is sensed by Biosensor	is sensed by	Physical Workplace Environment, Bio Sensor
	10	Physical Workplace Environment is sensed by Chemical Sensor	is sensed by	Physical Workplace Environment, Chemical Sensor
	11	Physical Workplace Environment is sensed by Flow Sensor	is sensed by	Physical Workplace Environment, Flow Sensor
	12	Physical Workplace Environment is sensed by Force Sensor	is sensed by	Physical Workplace Environment, Force Sensor
	13	Physical Workplace Environment is sensed by Humidity Sensor	is sensed by	Physical Workplace Environment, Humidity Sensor
	14	Physical Workplace Environment is sensed by Light Sensor	is sensed by	Physical Workplace Environment, Light Sensor
	15	Physical Workplace Environment is sensed by Motion Sensor	is sensed by	Physical Workplace Environment, Motion Sensor
	16	Physical Workplace Environment is sensed by Occupancy Sensor	is sensed by	Physical Workplace Environment, Occupancy Sensor
	17	Physical Workplace Environment is sensed by Position Sensor	is sensed by	Physical Workplace Environment, Position Sensor
	18	Physical Workplace Environment is sensed by Pressure Sensor	is sensed by	Physical Workplace Environment, Pressure Sensor
	19	Physical Workplace Environment is sensed by Radiation Sensor	is sensed by	Physical Workplace Environment, Radiation Sensor
	20	Physical Workplace Environment is sensed by Temperature Sensor	is sensed by	Physical Workplace Environment, Temperature Sensor
	21	Physical Workplace Environment is sensed by Velocity Sensor	is sensed by	Physical Workplace Environment, Velocity Sensor
	22	Knowledge Worker's Body is sensed by Acceleration Sensor	is sensed by	Knowledge Worker's Body, Acceleration Sensor
	23	Knowledge Worker's Body is sensed by Acoustic Sensor	is sensed by	Knowledge Worker's Body, Acoustic Sensor
	24	Knowledge Worker's Body is sensed by Biosensor	is sensed by	Knowledge Worker's Body, Bio Sensor
	25	Knowledge Worker's Body is sensed by Chemical Sensor	is sensed by	Knowledge Worker's Body, Chemical Sensor
	26	Knowledge Worker's Body is sensed by Flow Sensor	is sensed by	Knowledge Worker's Body, Flow Sensor
	27	Knowledge Worker's Body is sensed by Force Sensor	is sensed by	Knowledge Worker's Body, Force Sensor
	28	Knowledge Worker's Body is sensed by Humidity Sensor	is sensed by	Knowledge Worker's Body, Humidity Sensor
	29	Knowledge Worker's Body is sensed by Light Sensor	is sensed by	Knowledge Worker's Body, Light Sensor
	30	Knowledge Worker's Body is sensed by Motion Sensor	is sensed by	Knowledge Worker's Body, Motion Sensor
	31	Knowledge Worker's Body is sensed by Occupancy Sensor	is sensed by	Knowledge Worker's Body, Occupancy Sensor
	32	Knowledge Worker's Body is sensed by Position Sensor	is sensed by	Knowledge Worker's Body, Position Sensor
	33	Knowledge Worker's Body is sensed by Pressure Sensor	is sensed by	Knowledge Worker's Body, Pressure Sensor
	34	Knowledge Worker's Body is sensed by Radiation Sensor	is sensed by	Knowledge Worker's Body, Radiation Sensor
	35	Knowledge Worker's Body is sensed by Temperature Sensor	is sensed by	Knowledge Worker's Body, Temperature Sensor
	36	Knowledge Worker's Body is sensed by Velocity Sensor	is sensed by	Knowledge Worker's Body, Velocity Sensor
	37	B101-Illuminance Aml Set is sensed by Light Sensor	is sensed by	B101-Illuminance Aml, Light Sensor
	38	B102-Circadian Lighting Design Aml Set is sensed by Light Sensor	is sensed by	B102-Circadian Lighting Design Aml Set, Light Sensor
	39	B103-Uniformity of Illuminance Aml Set is sensed by Light Sensor	is sensed by	B103-Uniformity of Illuminance Aml Set, Light Sensor
	40	B104-Illuminance of the Immediate Surrounding Areas Aml Set is sensed by Light Sensor	is sensed by	B104-Illum. of the Imm. Surrounding Areas Aml Set, Light Sensor
	41	B105-Perc. of the Task Area Meeting the Req. Illum. Aml Set is sensed by Light Sensor	is sensed by	B105-Perc. of the T. Area Meeting the Req. Illum. Aml Set,Light Sensor
	42	B201-Noise Criteria Aml Set is sensed by Acoustic Sensor	is sensed by	B201-Noise Criteria Aml Set, Acoustic Sensor
	43	B202-Reverberation Time Aml Set is sensed by Acoustic Sensor	is sensed by	B202-Reverberation Time Aml Set, Acoustic Sensor
	44	B203-Speech Transmission Index Aml Set is sensed by Acoustic Sensor	is sensed by	B203-Speech Transmission Index Aml Set, Acoustic Sensor
	45	B301-Air Temperature Aml Set is sensed by Temperature Sensor	is sensed by	B301-Air Temperature Aml Set, Temperature Sensor
	46	B302-Vertical Air Temperature Difference Aml Set is sensed by Temperature Sensor	is sensed by	B302-Vertical Air Temperature Difference Aml Set, Temperature Sensor
	47	B303-Operative Temperature Aml Set is sensed by Temperature Sensor	is sensed by	B303-Operative Temperature Aml Set, Temperature Sensor
	48	B304-Radiant Temperature Asymmetry Aml Set is sensed by Temperature Sensor	is sensed by	B304-Radiant Temperature Asymmetry Aml Set, Temperature Sensor
	49	B305-Floor Surface Temperature Aml Set is sensed by Temperature Sensor	is sensed by	B305-Floor Surface Temperature Aml Set, Temperature Sensor
	50	B306-Air Speed Aml Set is sensed by Temperature Sensor	is sensed by	B306-Air Speed Aml Set, Temperature Sensor
	51	B401-Carbon Dioxide Aml Set is sensed by Chemical Sensor	is sensed by	B401-Carbon Dioxide Aml Set, Chemical Sensor
	52	B402-PM 2.5 Aml Set is sensed by Chemical Sensor	is sensed by	B402-PM 2.5 Aml Set, Chemical Sensor
	53	B403-PM 10 Aml Set is sensed by Chemical Sensor	is sensed by	B403-PM 10 Aml Set, Chemical Sensor
	54	B404-Carbon Monoxide Aml Set is sensed by Chemical Sensor	is sensed by	B404-Carbon Monoxide Aml Set, Chemical Sensor
	55	B405-Total Volatile Organic Compounds Aml Set is sensed by Chemical Sensor	is sensed by	B405-Total Volatile Organic Compounds Aml Set, Chemical Sensor
	56	B406-Formaldehyde Aml Set is sensed by Chemical Sensor	is sensed by	B406-Formaldehyde Aml Set, Chemical Sensor
	57	B407-Sulphur Dioxide Aml Set is sensed by Chemical Sensor	is sensed by	B407-Sulphur Dioxide Aml Set, Chemical Sensor
	58	B408-Ozone Aml Set is sensed by Chemical Sensor	is sensed by	B408-Ozone Aml Set, Chemical Sensor
	59	B409-Total Microbial Count Aml Set is sensed by Chemical Sensor	is sensed by	B409-Total Microbial Count Aml Set, Chemical Sensor
	60	Sensed data is transferred to Computer/Desicion Maker	is transferred to	Sensed data, Computer/Desicion Maker
	61	Sensed data is compared with Ambient Intelligence Set	is compared with	Sensed data, Ambient Intelligence Set
	62	Computer/Desicion Maker acts by use of Actuators	acts by use of	Computer/Desicion Maker, Actuators
	63	Air Conditioning sets B301-Air Temperature Aml Set	sets	Air Conditioning, B301-Air Temperature Aml Set
	64	Air Conditioning sets B302-Vertical Air Temperature Difference Aml Set	sets	Air Conditioning, B302-Vertical Air Temperature Difference Aml Set
	65	Air Conditioning sets B303-Operative Temperature Aml Set	sets	Air Conditioning, B303-Operative Temperature Aml Set
	66	Air Conditioning sets B304-Radiant Temperature Asymmetry Aml Set	sets	Air Conditioning, B304-Radiant Temperature Asymmetry Aml Set
	67	Air Conditioning sets B305-Floor Surface Temperature Aml Set	sets	Air Conditioning, B305-Floor Surface Temperature Aml Set
	68	Air Conditioning sets B306-Air Speed Aml Set	sets	Air Conditioning, B306-Air Speed Aml Set
	69	Air Conditioning sets Knowledge Worker's Body	sets	Air Conditioning, Knowledge Worker's Body
	70	Air Conditioning sets Physical Office Workplace	sets	Air Conditioning, Physical Office Workplace
	71	Blinds set B101-Illuminance Aml Set	sets	Blinds, B101-Illuminance Aml Set
	72	Blinds set B102-Circadian Lighting Design Aml Set	sets	Blinds, B102-Circadian Lighting Design Aml Set

Figure 4-25. Algorithms, object properties, individuals, and instances are created for the ambient intelligence concept.

		ALGORITHMS for AMBIENT INTELLIGENCE	Object Properties	Individuals
AMBIENT INTELLIGENCE CONCEPT	73	Blinds set B103-Uniformity of Illuminance Aml Set	sets	Blinds, B103-Uniformity of Illuminance Aml Set
	74	Blinds set B104-Illuminance of the Immediate Surrounding Areas Aml Set	sets	Blinds, B104-Illuminance of the Immediate Surrounding Areas Aml Set
	75	Blinds set B105-Percentage of the Task Area Meeting the Required Illuminance Aml Set	sets	Blinds, B105-Perc.e of the T. Area Meeting the Required Illum. Aml Set
	76	Blinds set Knowledge Worker's Body	sets	Blinds, Knowledge Worker's Body
	77	Blinds set Physical Office Workplace	sets	Blinds, Physical Office Workplace
	78	Computer sets Physical Office Workplace	sets	Computer, Physical Office Workplace
	79	Lights set B101-Illuminance Aml Set	sets	Lights, B101-Illuminance Aml Set
	80	Lights set B102-Circadian Lighting Design Aml Set	sets	Lights, B102-Circadian Lighting Design Aml Set
	81	Lights set B103-Uniformity of Illuminance Aml Set	sets	Lights, B103-Uniformity of Illuminance Aml Set
	82	Lights set B104-Illuminance of the Immediate Surrounding Areas Aml Set	sets	Lights, B104-Illuminance of the Immediate Surrounding Areas Aml Set
	83	Lights set B105-Percentage of the Task Area Meeting the Required Illuminance Aml Set	sets	Lights, B105-Perc. of the T. Area Meeting the Required Illum. Aml Set
	84	Lights set Knowledge Worker's Body	sets	Lights, Knowledge Worker's Body
	85	Lights set Physical Office Workplace	sets	Lights, Physical Office Workplace
	86	Office Devices set B201-Noise Criteria Aml Set	sets	Office Devices, B201-Noise Criteria Aml Set
	87	Office Devices set B202-Reverberation Time Aml Set	sets	Office Devices, B202-Reverberation Time Aml Set
	88	Office Devices set B203-Speech Transmission Index Aml Set	sets	Office Devices, B203-Speech Transmission Index Aml Set
	89	Office Devices set Knowledge Worker's Body	sets	Office Devices, Knowledge Worker's Body
	90	Office Devices set Physical Office Workplace	sets	Office Devices, Physical Office Workplace
	91	Refriger sets B301-Air Temperature Aml Set	sets	Refriger, B301-Air Temperature Aml Set
	92	Refriger sets B302-Vertical Air Temperature Difference Aml Set	sets	Refriger, B302-Vertical Air Temperature Difference Aml Set
	93	Refriger sets B303-Operative Temperature Aml Set	sets	Refriger, B303-Operative Temperature Aml Set
	94	Refriger sets B304-Radiant Temperature Asymmetry Aml Set	sets	Refriger, B304-Radiant Temperature Asymmetry Aml Set
	95	Refriger sets B305-Floor Surface Temperature Aml Set	sets	Refriger, B305-Floor Surface Temperature Aml Set
	96	Refriger sets B306-Air Speed Aml Set	sets	Refriger, B306-Air Speed Aml Set
	97	Refriger sets Knowledge Worker's Body	sets	Refriger, Knowledge Worker's Body
	98	Refriger sets Physical Office Workplace	sets	Refriger, Physical Office Workplace
	99	Shading sets B101-Illuminance Aml Set	sets	Shading, B101-Illuminance Aml Set
	100	Shading sets B102-Circadian Lighting Design Aml Set	sets	Shading, B102-Circadian Lighting Design Aml Set
	101	Shading sets B103-Uniformity of Illuminance Aml Set	sets	Shading, B103-Uniformity of Illuminance Aml Set
	102	Shading sets B104-Illuminance of the Immediate Surrounding Areas Aml Set	sets	Shading, B104-Illuminance of the Immediate Surrounding Areas Aml Set
	103	Shading sets B105-Percentage of the Task Area Meeting the Required Illuminance Aml Set	sets	Shading, B105-Perc.of the Task Area Meeting the Req. Illum. Aml Set
	104	Shading sets Knowledge Worker's Body	sets	Shading, Knowledge Worker's Body
	105	Shading sets Physical Office Workplace	sets	Shading, Physical Office Workplace
	106	Ventilation sets B301-Air Temperature Aml Set	sets	Ventilation, B301-Air Temperature Aml Set
	107	Ventilation sets B302-Vertical Air Temperature Difference Aml Set	sets	Ventilation, B302-Vertical Air Temperature Difference Aml Set
	108	Ventilation sets B303-Operative Temperature Aml Set	sets	Ventilation, B303-Operative Temperature Aml Set
	109	Ventilation sets B304-Radiant Temperature Asymmetry Aml Set	sets	Ventilation, B304-Radiant Temperature Asymmetry Aml Set
	110	Ventilation sets B305-Floor Surface Temperature Aml Set	sets	Ventilation, B305-Floor Surface Temperature Aml Set
	111	Ventilation sets B306-Air Speed Aml Set	sets	Ventilation, B306-Air Speed Aml Set
	112	Ventilation sets B401-Carbon Dioxide Aml Set	sets	Ventilation, B401-Carbon Dioxide Aml Set
	113	Ventilation sets B402-PM 2.5 Aml Set	sets	Ventilation, B402-PM 2.5 Aml Set
	114	Ventilation sets B403-PM 10 Aml Set	sets	Ventilation, B403-PM 10 Aml Set
	115	Ventilation sets B404-Carbon Monoxide Aml Set	sets	Ventilation, B404-Carbon Monoxide Aml Set
	116	Ventilation sets B405-Total Volatile Organic Compounds Aml Set	sets	Ventilation, B405-Total Volatile Organic Compounds Aml Set
	117	Ventilation sets B406-Formaldehyde Aml Set	sets	Ventilation, B406-Formaldehyde Aml Set
	118	Ventilation sets B407-Sulphur Dioxide Aml Set	sets	Ventilation, B407-Sulphur Dioxide Aml Set
	119	Ventilation sets B408-Ozone Aml Set	sets	Ventilation, B408-Ozone Aml Set
	120	Ventilation sets B409-Total Microbial Count Aml Set	sets	Ventilation, B409-Total Microbial Count Aml Set
	121	Ventilation sets Knowledge Worker's Body	sets	Ventilation, Knowledge Worker's Body
	122	Ventilation sets Physical Office Workplace	sets	Ventilation, Physical Office Workplace
	123	Window sets B201-Noise Criteria Aml Set	sets	Window, B201-Noise Criteria Aml Set
	124	Window sets B202-Reverberation Time Aml Set	sets	Window, B202-Reverberation Time Aml Set
	125	Window sets B203-Speech Transmission Index Aml Set	sets	Window, B203-Speech Transmission Index Aml Set
	126	Window sets B301-Air Temperature Aml Set	sets	Window, B301-Air Temperature Aml Set
	127	Window sets B302-Vertical Air Temperature Difference Aml Set	sets	Window, B302-Vertical Air Temperature Difference Aml Set
	128	Window sets B303-Operative Temperature Aml Set	sets	Window, B303-Operative Temperature Aml Set
	129	Window sets B304-Radiant Temperature Asymmetry Aml Set	sets	Window, B304-Radiant Temperature Asymmetry Aml Set
	130	Window sets B305-Floor Surface Temperature Aml Set	sets	Window, B305-Floor Surface Temperature Aml Set
	131	Window sets B306-Air Speed Aml Set	sets	Window, B306-Air Speed Aml Set
	132	Window sets B401-Carbon Dioxide Aml Set	sets	Window, B401-Carbon Dioxide Aml Set
	133	Window sets B402-PM 2.5 Aml Set	sets	Window, B402-PM 2.5 Aml Set
	134	Window sets B403-PM 10 Aml Set	sets	Window, B403-PM 10 Aml Set
	135	Window sets B404-Carbon Monoxide Aml Set	sets	Window, B404-Carbon Monoxide Aml Set
	136	Window sets B405-Total Volatile Organic Compounds Aml Set	sets	Window, B405-Total Volatile Organic Compounds Aml Set
	137	Window sets B406-Formaldehyde Aml Set	sets	Window, B406-Formaldehyde Aml Set
	138	Window sets B407-Sulphur Dioxide Aml Set	sets	Window, B407-Sulphur Dioxide Aml Set
	139	Window sets B408-Ozone Aml Set	sets	Window, B408-Ozone Aml Set
	140	Window sets B409-Total Microbial Count Aml Set	sets	Window, B409-Total Microbial Count Aml Set
	141	Window sets Knowledge Worker's Body	sets	Window, Knowledge Worker's Body
	142	Window sets Physical Office Workplace	sets	Window, Physical Office Workplace
	143	Sensed data is balanced with Ambient Intelligence Set	is balanced with	Sensed Data, Ambient Intelligence Set
	144	Knowledge Worker evaluates Workplace Services	evaluates	Knowledge Worker, Workplace Services

Figure 4-26. Algorithms, object properties, individuals, and instances are created for the ambient intelligence concept.

An axiom created in the ontology model is illustrated in Figure 4-27. “John” as a knowledge worker finds “Jena” as a data collector. The relations of the individuals with other individuals and other relations and associations of the individuals in the ontology model were also presented. These relationships among the individuals and

instances were counted as axioms. As a result of the modeling process, 2216 axioms were created and established.

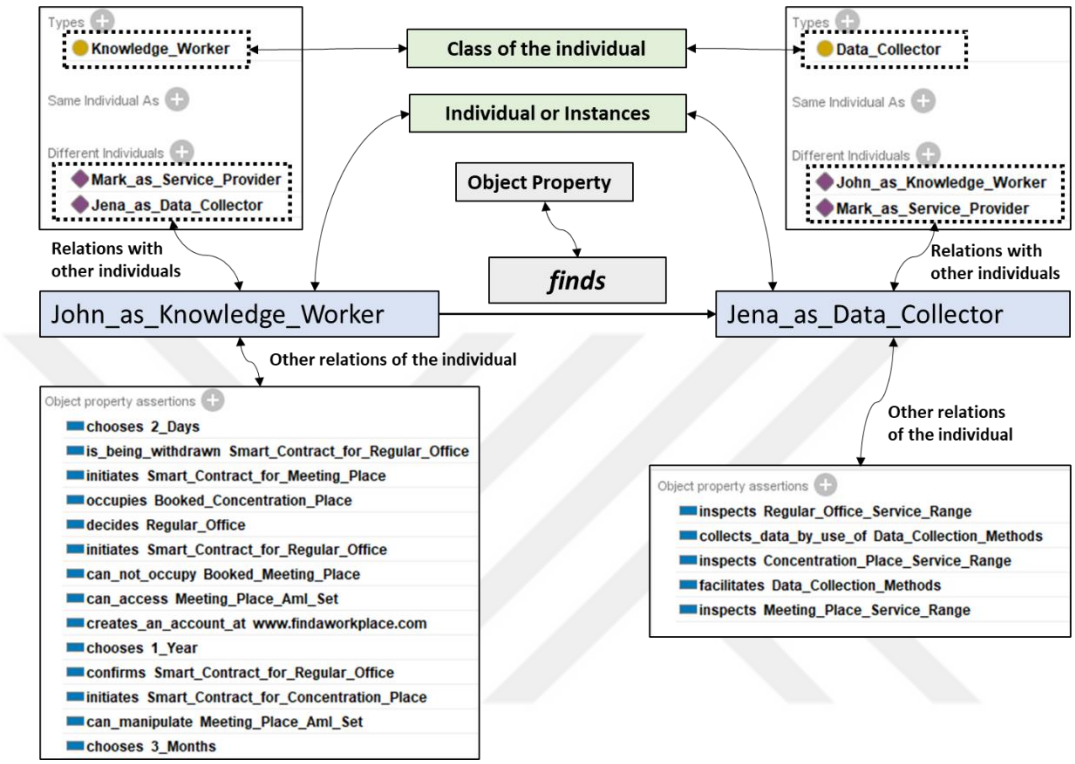

Figure 4-27. An axiom in the ontology model

4.8 Implementation Practices of the Proposed Model

Two concepts could be implemented during this dissertation's study due to their uniqueness and key to facilitating the remaining concepts. These are smart contract and website applications to partially implement workplace creation and semantic web concepts. The following sub-sections explain and illustrate the implementation practices in detail.

4.8.1 Smart Contract Application

A smart contract is a digitalized set of agreements represented in a code and is self-executed by computers once certain conditions are met (Ciotta et al., 2021; Dolgui et al., 2020; Feng et al., 2019; Mik, 2017; Sheth & Subramanian, 2019; Solaiman et al., 2021). The code is stored and replicated in a Blockchain (Dolgui et al., 2020). The computer network can self-execute the contract when the subsequent transactions are stored as a block of data at the end of the Blockchain. Regarding the definition and characteristics of a smart contract, provisions for the services and directives for self-execution must be defined and described. Since the desired contract is used for workplace services, the body of the service provisions are the workplace comfort and wellbeing parameters.

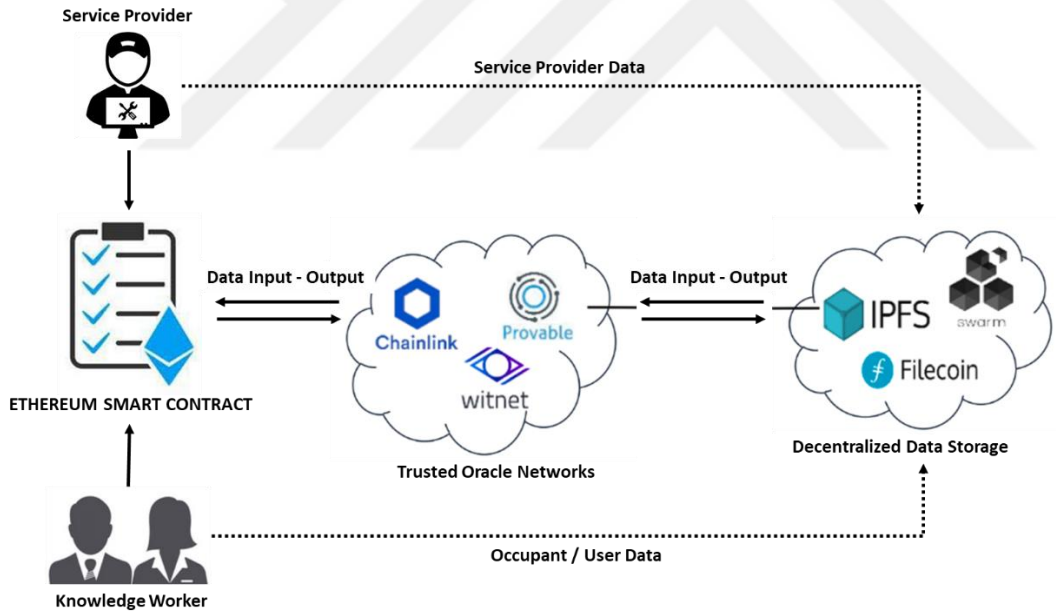

Figure 4-28. Smart contract application procedure in a web interface. Adopted from: (Omar et al., 2021)

Figure 4-28 states that a smart contract application executes the codes stored in a blockchain or database. Since the blockchain is not opened to the web environment, a couple of networks enable the interaction of smart contracts and data in the blockchain. In other words, the smart contract is a function that uses data stored in a blockchain or a database, although its directives and codes are also stored at the same medium and execute the directives regarding the actions and activities of the participants.

- **Code Editing and Establishment of the Smart Contract**

Solidity is an object-oriented, high-level language for implementing smart contracts influenced by C++, Python, and JavaScript and is designed to target the Ethereum Virtual Machine (EVM) (GitHub, 2016). Programming languages utilize Integrated Development Environments (IDE) for code editing. An IDE is a software application that provides a comprehensive environment to computer programmers for software development (Busbee, 2021). An IDE normally consists of a source code editor, build automation tools, and a debugger. Remix IDE is an open-source web and desktop application with modules for testing, debugging, and deploying smart contracts (RemixIDE, 2016). The smart contract application in this research study is coded, deployed, and tested in Remix IDE.

The user interface of common purchase types in Ethereum smart contracts is created in Remix IDE and presented in Figure 4-29. The buttons above the dashed line can input data from users. However, each button could be input regarding the assigned permissions. For example, the seller can only execute the bid button presented at auctions, while the buyer can only execute the withdrawal button. Buttons below the dashed lines can only be used for viewing, such as being informed about the highest bid and bidder, the beneficiary's address, and the remaining time for bidding.

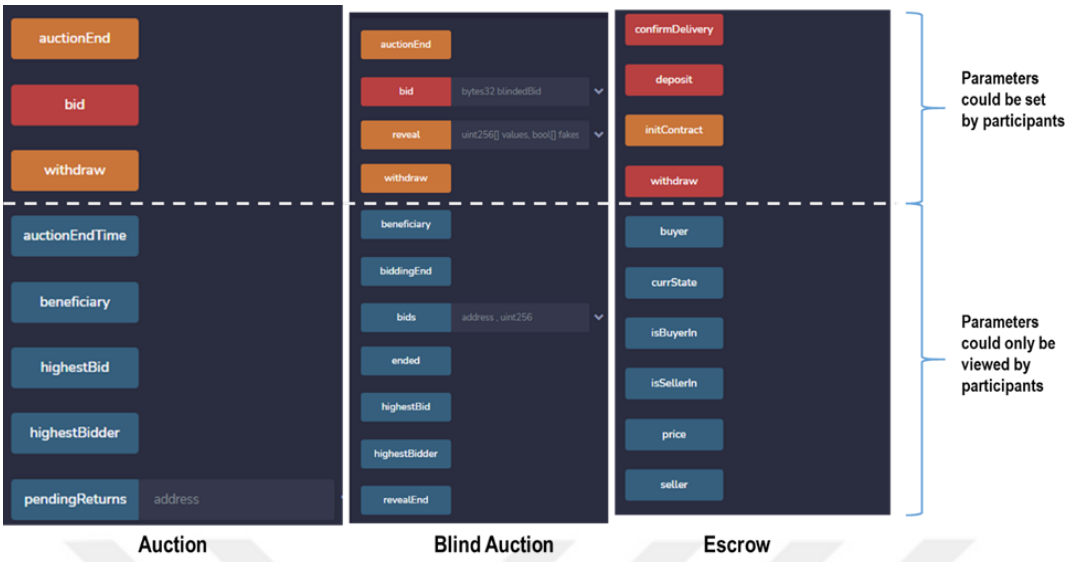

Figure 4-29. The user interface of smart contracts deployed in Remix IDE.

- **The Coding of Ethereum Smart Contract in Remix IDE**

Like other IDEs, Remix IDE also includes certain rules and restrictions to code smart contracts. The solidity language version must be exhibited at the first row of coding. The basic components of smart contract coding are "contract," "constructor," and "function," as presented in Figure 4-30. "Contract" is the first code to be depicted to create a smart contract. Constructor is the first function allowing deploy of the contract. Function, on the other hand, is the basic code enabling contract conditions. This is achieved by embedding data types such as string, integer, or boolean to smart contracts by the user. When "function" is followed by "set," data input by the assigned user is allowed. However, when "function" is followed by "get," embedded data can only be viewed by any user without making changes.

Furthermore, other basic codes such as "enum" and "modifiers" exist. Enum is a function enumerating a list where the listing elements could be referenced in the following codes of the smart contract. The modifier is a function to modify the behavior of a function. For example, "onlyKnowledgeWorker" enables a call of command by only the Knowledge Worker address.

Basic Code	Explanation
CONTRACT	First code to establish smart contract
CONSTRUCTOR	First function allowing deploy of contract
FUNCTION	Set: When function is followed by «set», it enables data input by assigned user
	Get: When function is followed by «get», it enables data view by user without making any change
ENUM	Enum is a function to enumerate a list.
MODIFIER	Modifiers are function to modify the behavior of a function. For example, «onlyKnowledgeWorker» enable execution of commands by only released by Knowledge Worker

Figure 4-30. Basic codes in Remix IDE to establish smart contracts.

Regarding the coding description presented in the above statement, entire workplace comfort parameters are transferred into function, as illustrated in Table 4-3. Each parameter takes "function" and then "set." When the function coded at solidity is followed by "onlyBuyer," only the knowledge worker can enter input to the function where the service provider can only view the embedded data by the knowledge worker. Similarly, when the function is followed by "onlySeller," only the service provider calls the function where the knowledge worker can only view the embedded data.

Table 4-3. Transformation of workplace comfort wellbeing parameters to smart contract code.

Parameters	Remix IDE Code
A101. Duration of Booking	function **set_A101**
B101. Illuminance	function **set_B101**
B102. Circadian Lighting Design	function **set_B102**
B103. Uniformity of illuminance	function **set_B103**
B104. Illuminance of the immediate surrounding areas	function **set_B104**
B105. Percentage of the task area meeting the required illuminance	function **set_B105**
B201. Noise Criteria	function **set_B201**
B202. Reverberation Time	function **set_B202**
B203. Speech Transmission Index	function **set_B203**
B301. Air temperature	function **set_B301**
B302. Vertical air temperature difference	function **set_B302**
B303. Operative temperature	function **set_B303**
B304. Radiant temperature asymmetry	function **set_B304**
B305. Floor surface temperature	function **set_B305**

Table 4-3 *continued*

B306. Air speed	function **set_B306**
B401. Carbon dioxide	function **set_B401**
B402. PM 2.5	function **set_B402**
B403. PM 10	function **set_B403**
B404. Carbon Monoxide	function **set_B404**
B405. Total Volatile Organic Compounds	function **set_B405**
B406. Formaldehyde	function **set_B406**
B407. Sulfur dioxide	function **set_B407**
B408. Ozone	function **set_B408**
B409. Total microbial count	function **set_B409**
C101. Size of the Area	function **set_C101**
C102. Height of the space	function **set_C102**
C103. Location of workplace components	function **set_C103**
C104. Required equipment, furniture, and devices	function **set_C104**
C105. Color, texture, material, and quality of floor finishing	function **set_C105**
C106. Color, texture, material, and quality of wall finishing	function **set_C106**
C107. Color, texture, material, and quality of ceiling finishing	function **set_C107**
C201. Size of the workspace	function **set_C201**
C202. Color, texture, and quality of material in the workspace	function **set_C202**
C203. Orientation	function **set_C203**
C204. Location of Workstation	function **set_C204**
C301. Window-to-Wall ratio	function **set_C301**
C302. Size of the window	function **set_C302**
C303. Operability of window	function **set_C303**
C304. Position of window	function **set_C304**
C305. Location of window	function **set_C305**
C306. Proximity of workstation	function **set_C306**
D101. Transportation options to the facility	function **set_D101**
D102. Compliance with universal design principles	function **set_D102**
D201. Vibration at Vertical Circulation	function **set_D201**
D202. Noise at Vertical Circulation	function **set_D202**
D203. Acceleration/ Deceleration Impact at Vertical Circulation	function **set_D203**
D204. Comfort at Vertical Circulation	function **set_D204**
D301. Exterior Material & Finishing of Building	function **set_D301**
D302. Building Type	function **set_D302**
E101. Resting Need and Capacity	function **set_E101**
E102. Shower Need and Capacity	function **set_E102**
E103. WC Need and Capacity	function **set_E103**
E104. Kitchen	function **set_E104**
E105. Canteen	function **set_E105**
E106. Meeting Room Need and Capacity	function **set_E106**
E107. Dining Area Need and Capacity	function **set_E107**
E108. Pantry	function **set_E108**
E109. Parking Space Need and Capacity	function **set_E109**
E110. Smoking Area Need and Capacity	function **set_E110**
E111. Cleaning	function **set_E111**
E112. Safety & Security	function **set_E112**
E113. Maintenance	function **set_E113**
E114. Communication with the Facility Manager	function **set_E114**
E115. Network Type and Capacity	function **set_E115**
E116. Audio Visual Systems Needs and Capacity	function **set_E116**
E117. Modern Technologies	function **set_E117**

- **Deploy of the Smart Contract**

After the code description is completed, a compile process is required by Remix IDE to check and control compliance of the written codes with the compiler of Remix. Then, the smart contract could be deployed by the knowledge worker. The knowledge worker must enter his/her blockchain address, service provider blockchain address, and deposit price to activate the deploy button, as depicted in Figure 4-31. After the deployment process, the deployed contract is listed below the user interface. Deployed contracts are ready to be used for commercial purposes. On the other hand, the deployed addresses can only enter data regarding their role as knowledge workers or service providers.

The knowledge worker could input data for any parameters presented in Figure 4-32. Two data types are allowed. These are string and integer. The integer data is the value describing the personal comfort of the parameter, while string data specifies literal information. Unlike integers, string data must be written in the user interface between quotation marks such as “white colored desk.” Otherwise, the data is not stored in the database. Soon, workplace comfort sets are embedded in smart contracts; the service provider could see the embedded data by calling the buttons with the same parameter name.

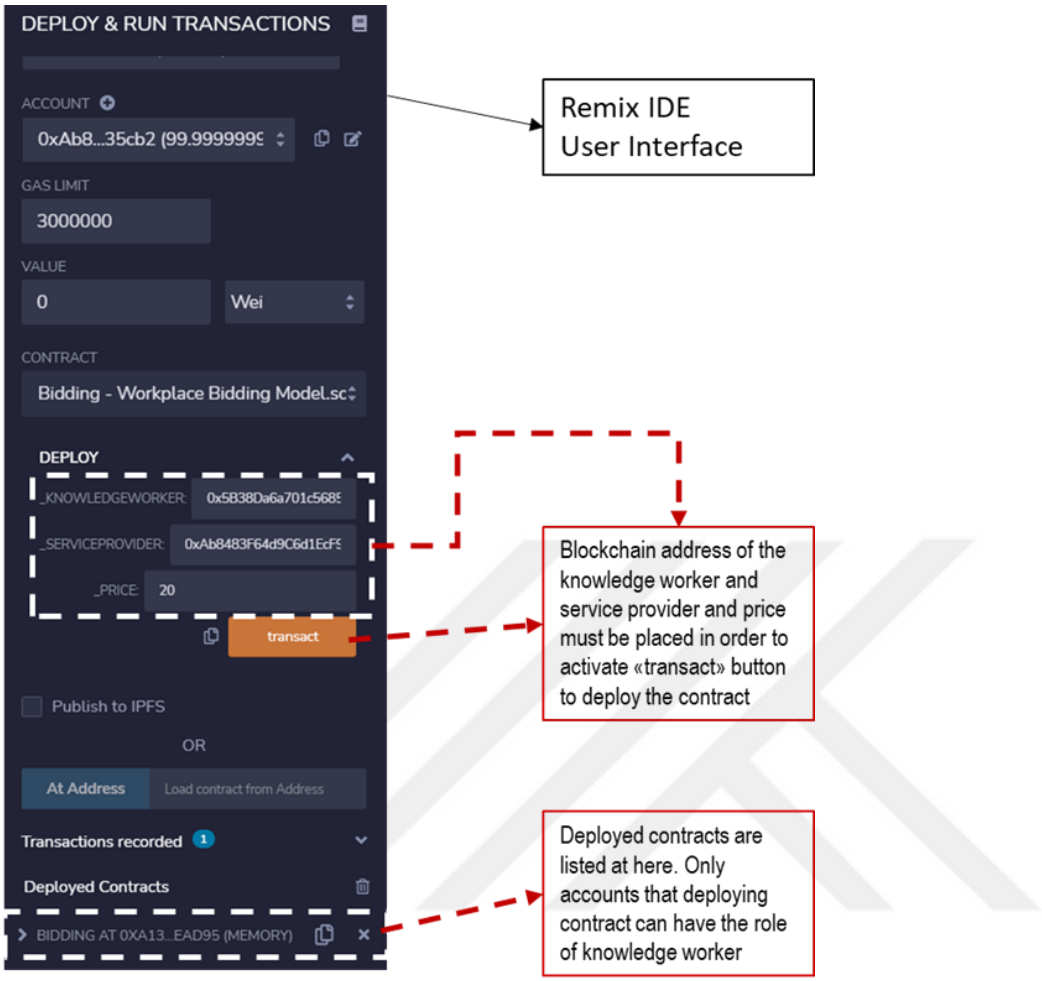

Figure 4-31. The user interface of deployed smart contract in Remix IDE

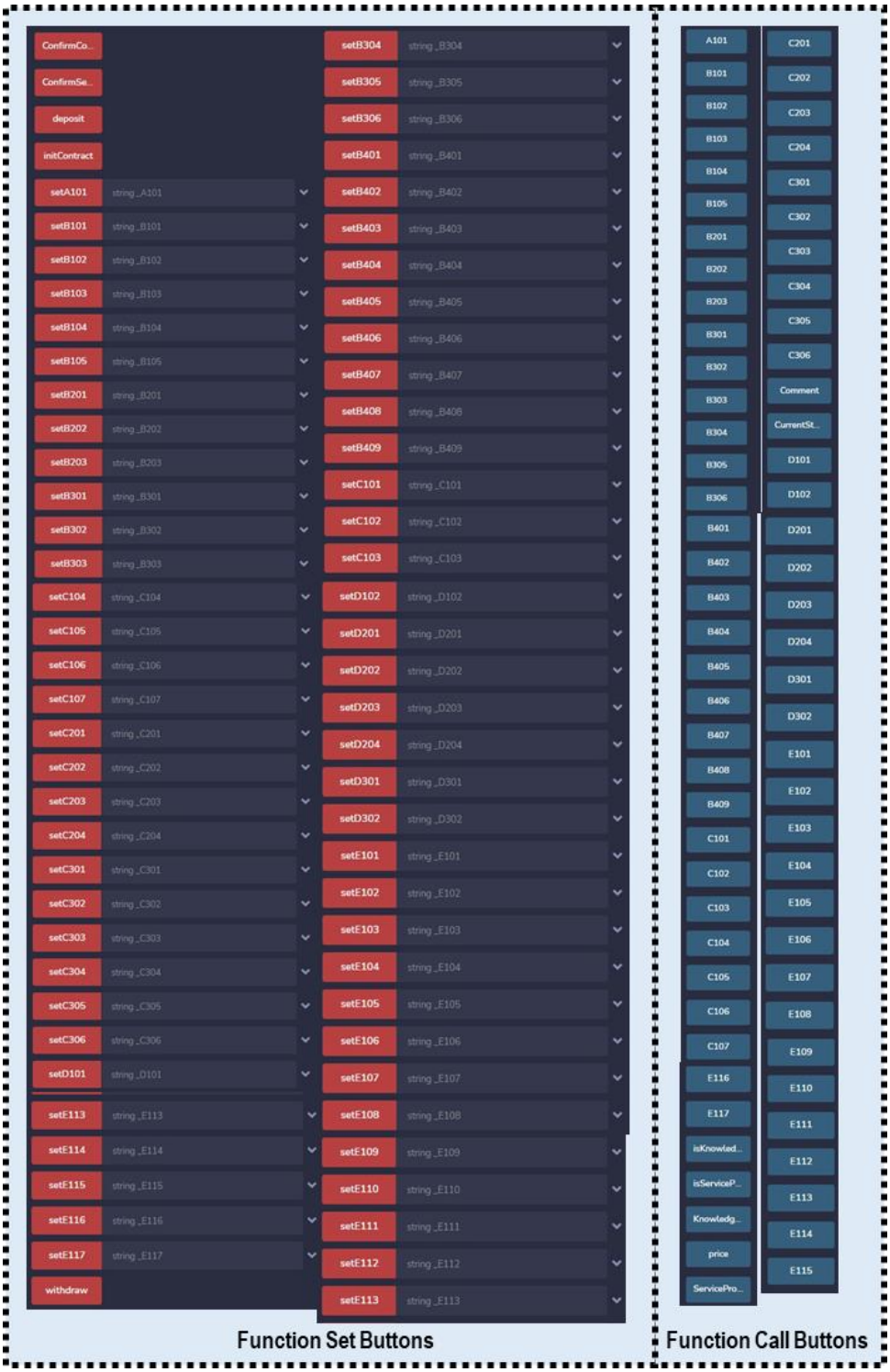

Figure 4-32. The knowledge worker (left) and service provider (right) user interface of deployed smart contract in Remix IDE. The red buttons allow data input by the knowledge worker, while the blue buttons allow only a view of embedded data by the Service Provider.

- **Testing the Smart Contract**

Gas in the Ethereum blockchain refers to the cost necessary to perform a transaction on the network (ethereum.org, 2021; Frankenfield, 2021; Jabbar & Dani, 2020; Zarir et al., 2021). The concept of gas was introduced to maintain a distinct value layer that solely indicates the consumption toward computational expenses on the Ethereum network (Frankenfield, 2021). Gas fees are payments made by users to compensate for the computing energy required to process and validate transactions on the Ethereum blockchain (ethereum.org, 2021; Frankenfield, 2021; Jabbar & Dani, 2020; Zarir et al., 2021). The gas usage depends on the number and type of instructions executed during runtime and the information that must be stored in the blockchain (Zarir et al., 2021). Thus, rather than changing and eliminating instructions, decreasing the amount of data stored in the blockchain is the only applicable method to reduce gas costs in this research study. Therefore, both the applicability of the scenario and the gas cost to execute the scenario were tested and evaluated.

For testing the smart contract, a workplace type is prepared. Workplace #1 includes 43 workplace parameters and is specialized for concentrated work, as shown in Figure 4-33. When these parameters were embedded into the smart contract and followed by the purchasing process, it was demonstrated that the formalized method is successful and applicable in allowing the configuration by only the knowledge worker and reading the embedded data by the service provider.

As illustrated in Figure 4-34, total gas consumption is 9,782,726 units, and 7,442,889 units are spent for contract deployment, which equals 76% of total consumption. Considering that 1 USD Dollar is equals to **218,199,542,974,810 wei** (cryps, 2021)**, 9,800,025 wei** consumption for overall smart contract application is equals to **0.000000044913 USD** dollars which is making a very small amount of money when compared with traditional contracting approaches.

WORKPLACE #1		
A101	Duration of Booking	2 months
B101	Illuminance	500
B201	Noise Criteria	50
B202	Reverberation Time	0.9
B301	Air temperature	27
B302	Vertical air temperature difference	2
B303	Operative temperature	25
B304	Radiant temperature asymmetry	15
B305	Floor surface temperature	25
B401	Carbon dioxide	2500-3500
B404	Carbon Monoxide	3
B407	Sulphur dioxide	0.9
B408	Ozone	0.015
C101	Size of the Area	3X5
C102	Height of the space	3
C103	Location of workplace components	All of them at above the Desk
C104	Required equipment, furniture and devices	Desk, Printer, 24 inc monitor, office chair, Sketch Pad
C105	Color, texture, material and quality of floor finishing	Laminated Wood, light colors, carpet
C106	Color, texture, material and quality of wall finishing	brutal brick with smooth joint
C107	Color, texture, material and quality of ceiling finishing	No ceiling
C201	Size of the workspace	L shape, 140+180x80 cm
C202	Color, texture and quality of material at workspace	Lake covered, white color
C203	Orientation	East-West
C204	Location of Workstation	South-North Direction
C302	Size of the window	At least 1m x 1m
C303	Operability of window	Awning, Pivot
C304	Position of window	Center of the Wall
C305	Location of window	South Elevation
C306	Proximity of workstation	1 m distance to window
D101	Transportation options to facility	Private Car
D301	Exterior Material & Finishing of Building	Glass Curtain Wall
D302	Building Type	Office Building
E101	Resting Need and Capacity	Single Person Resting
E102	Shower Need and Capacity	Shower, Towel, Shampoo
E103	WC Need and Capacity	built-in reservoir
E106	Meeting Room Need and Capacity	5
E107	Dining Area Need and Capacity	3
E109	Parking Space Need and Capacity	Car Park, 3 Cars
E110	Smoking Area Need and Capacity	5 people smoking
E115	Network Type and Capacity	Wired, 300 mb+
E116	Audio Visual Systems Needs and Capacity	Samsung or Apple, bluetooth, professional

Figure 4-33. Workplace Comfort Parameters for Workplace #1

WORKPLACE #1			
			GAS CONSUMPTION (wei)
		Contract Deployment	7,442,061
A101	Duration of Booking	2 months	69,531
B101	Illuminance	500	49,547
B201	Noise Criteria	50	49,558
B202	Reverberation Time	0.9	49,503
B301	Air temperature	27	49,536
B302	Vertical air temperature difference	2	49,500
B303	Operative temperature	25	49,536
B304	Radiant temperature asymmetry	15	49,490
B305	Floor surface temperature	25	49,492
B401	Carbon dioxide	2500-3500	49,576
B404	Carbon Monoxide	3	49,543
B407	Sulphur dioxide	0.9	49,503
B408	Ozone	0.015	49,594
C101	Size of the Area	3X5	49,572
C102	Height of the space	3	49,566
C103	Location of workplace components	All of them at above the Desk	49,882
C104	Required equipment, furniture and devices	Desk, Printer, 24 inc monitor, office chair, Sketch Pad	94,646
C105	Color, texture, material and quality of floor finishing	Laminated Wood, light colors, carpet	94,406
C106	Color, texture, material and quality of wall finishing	brutal brick with smooth joint	49,872
C107	Color, texture, material and quality of ceiling finishing	No ceiling	49,608
C201	Size of the workspace	L shape, 140+180x80 cm	49,776
C202	Color, texture and quality of material at workspace	Lake covered, white color	49,768
C203	Orientation	East-West	49,641
C204	Location of Workstation	South-North Direction	49,710
C302	Size of the window	At least 1m x 1m	49,725
C303	Operability of window	Awning, Pivot	49,690
C304	Position of window	Center of the Wall	49,715
C305	Location of window	South Elevation	49,648
C306	Proximity of workstation	1 m distance to window	49,754
D101	Transportation options to facility	Private Car	49,645
D301	Exterior Material & Finishing of Building	Glass Curtain Wall	49,751
D302	Building Type	Office Building	49,671
E101	Resting Need and Capacity	Single Person Resting	49,741
E102	Shower Need and Capacity	Shower, Towel, Shampoo	49,730
E103	WC Need and Capacity	built-in reservoir	49,748
E106	Meeting Room Need and Capacity	5	49,478
E107	Dining Area Need and Capacity	3	49,544
E109	Parking Space Need and Capacity	Car Park, 3 Cars	49,658
E110	Smoking Area Need and Capacity	5 people smoking	49,748
E115	Network Type and Capacity	Wired, 300 mb+	49,721
E116	Audio Visual Systems Needs and Capacity	Samsung or Apple, bluetooth, professional	94,489
		Initiate_Contract by Knowledge Worker	46,341
		Deposit by Knowledge Worker	48,049
		Read_Contract by Service Worker	31,317
		Confirm Delivery by Knowledge Worker	42,445
		Total Gas Consumption	**9,800,025**

Figure 4-34. Gas consumption for Workplace #1 at smart contract transactions

4.8.2 Web Site Application and Workplace Creation Concept

The semantic web application is assigned to manage complex and multi-layered tasks in the proposed model. Although implementing a semantic web application regarding the roles and responsibilities of the proposed model requires high-level web programming skills and expertise, it is possible to realize the domain of the proposed model as a workplace set and workplace services in a simple website.

The web site is registered as www.findaworkplace.com. The marketplace, booking, and appointment applications were facilitated on the website. The web site enables two posting types under the role of either a service provider or a knowledge worker. The user posts could be viewed in the marketplace under separate post archives as workplace services for posts of service provider and workplace sets for posts of the knowledge worker, as illustrated in Figure 4-35. In order to list the posts in the marketplace, limited information is presented for the users, as depicted in Figure 4-36. Complete post visibility is presented in single posts, as demonstrated in 4-37 and 4-38.

The web site works for service providers and knowledge workers separately. The knowledge workers may create a post describing his/her specific workplace set by fulfilling and defining required workplace comfort and wellbeing parameters as illustrated in Figure 4-39. A service provider may contact a knowledge worker to deal with conditions. On the other hand, the service provider may create a post describing the workplace service range specific to the building or workplace, as depicted in Figure 4-40. A knowledge worker may contact a service provider by sending a workplace set where the parameter's data are within the service range of the service provider. Once knowledge workers and service providers are agreed upon the conditions, they could be directed to smart contract applications. Since the smart contract is coded in solidity, custom cascading style sheets (CSS) tools could execute the smart contract application in a web browser.

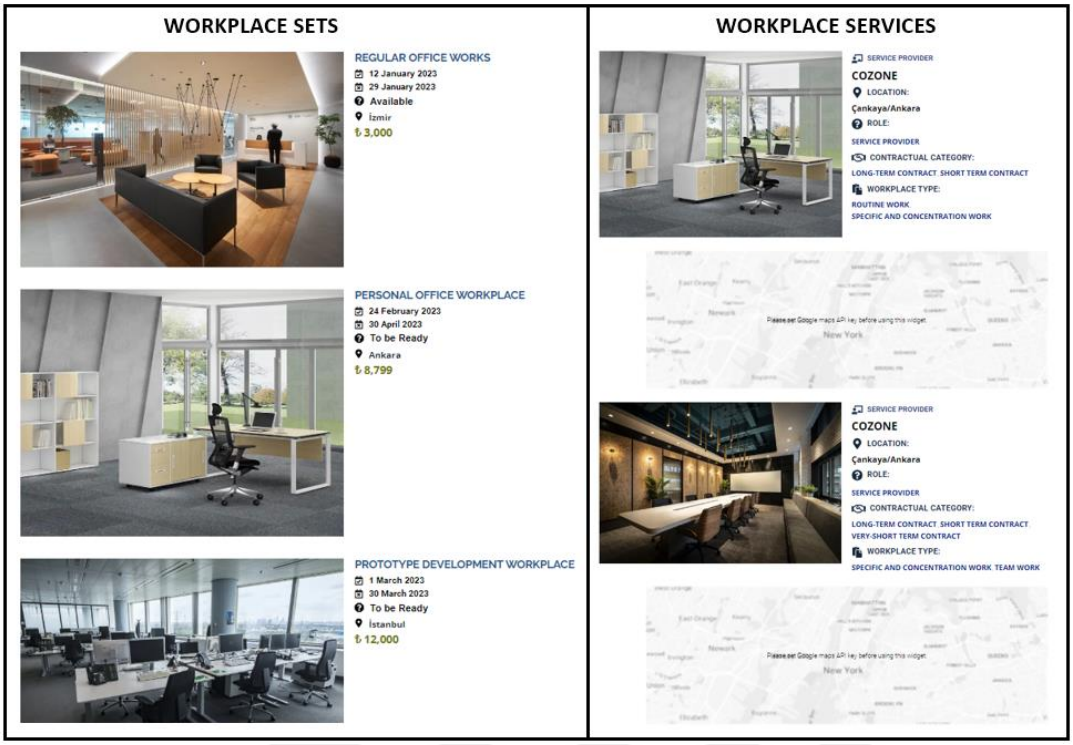

Figure 4-35. List the workplace sets and the workplace services published on the web page.

Figure 4-36. Single workplace sets and service posts are published on the web page.

SERVICE PROVIDER
COZONE

WORKPLACE TYPE:
Routine Work

CONTRACTUAL CATEGORY:
Long-Term Contract / Short Term Contract

LOCATION:
Ankara

LIGHTING COMFORT SETTINGS SERVICE RANGE

B101. Illuminance Level Minimum Service Range	750 lux
B101. Illuminance Level Maximum Service Range	5,000 lux
B102. Circadian Lighting Design Minimum Service Range	750 lux
B102. Circadian Lighting Design Maximum Service Range	360 lux
B103. Uniformity of Illuminance Minimum Service Range	10 lux
B103. Uniformity of Illuminance Maximum Service Range	10 lux
B104. Illuminance of the Immediate Surrounding Areas Maximum Service Range	45 lux
B104. Illuminance of the Immediate Surrounding Areas Minimum Service Range	10 lux
B105. Percentage of the Task Area Meeting the Required Illuminance Maximum Service Range	4,564
B105. Percentage of the Task Area Meeting the Required Illuminance Minimum Service Range	4,564

ACOUSTICAL COMFORT SETTINGS SERVICE RANGE

B201. Noice Criteria Minimum Service Range	750 db
B201. Noice Criteria Maximum Service Range	5,000 db
B202. Reverberation Time Minimum Service Range	750 sn
B202. Reverberation Time Maximum Service Range	360 sn
B203. Speech Transmission Index Minimum Service Range	10
B203. Speech Transmission Index Maximum Service Range	10

THERMAL COMFORT SETTINGS SERVICE RANGE

B301. Air Temperature Minimum Service Range	25 °C
B301. Air Temperature Maximum Service Range	30 °C
B302. Vertical Air Temperature Difference Minimum Service Range	456 °C
B302. Vertical Air Temperature Difference Maximum Service Range	85 °C
B303. Operative Temperature Minimum Service Range	10 °C
B303. Operative Temperature Maximum Service Range	30 °C
B304. Radiant Temperature Asymmetry Minimum Service Range	856
B304. Radiant Temperature Asymmetry Maximum Service Range	10
B305. Floor Surface Temperature Minimum Service Range	856 °C
B305. Floor Surface Temperature Maximum Service Range	856 °C
B306. Air Speed Minimum Service Range	565
B306. Air Speed Maximum Service Range	865

INDOOR AIR QUALITY SETTINGS SERVICE RANGE

B401. Carbon Dioxide Level Minimum Service Range	60
B401. Carbon Dioxide Level Maximum Service Range	550
B402. PM 2.5 Level Minimum Service Range	24
B402. PM 2.5 Level Maximum Service Range	250
B403. PM 10 Level Minimum Service Range	250
B403. PM 10 Level Maximum Service Range	250
B404. Carbon Monoxide Leve Minimum Service Range	20
B404. Carbon Monoxide Level Maximum Service Range	20
B405. Total Volatile Organic Compounds Level Minimum Service Range	15
B405. Total Volatile Organic Compounds Level Maximum Service Range	5
B406. Formaldehyde Level Minimum Service Range	10
B406. Formaldehyde Level Maximum Service Range	1
B407. Sulphur Dioxide Level Minimum Service Range	1
B407. Sulphur Dioxide Level Maximum Service Range	1
B408. Ozone Level Minimum Service Range	0
B408. Ozone Level Maximum Service Range	0
B409. Total Microbial Count Level Minimum Service Range	500
B409. Total Microbial Count Level Maximum Service Range	500

OFFICE LAYOUT SETTINGS SERVICE RANGE

C101. Size of the Area Minimum Service Range	7
C101. Size of the Area Maximum Service Range	250
C102. Height of the Space Minimum Service Range	3
C102. Height of the Space Maximum Service Range	5
C103. Location of Workplace Components Options	User Decides with Full Flexibility
C104. Required Equipment, Furniture and Devices Options	User Decides with Full Flexibility
C105. Color, Texture, Material and Quality of Floor Finishing Options	User Selects among Service Provider Library
C106. Color, Texture, Material and Quality of Wall Finishing Options	User Decides with Available Options
C107. Color, Texture, Material and Quality of Ceiling Finishing Options	None

WINDOW SETTINGS SERVICE RANGE

C301. Window-to-Wall Ratio Options	User Selects among Service Provider's Library, Service Provider Decides
C302. Size of the Window Options	User Selects among Service Provider's Library, Service Provider Decides
C303. Operability of Window Options	User Selects among Service Provider's Library, Service Provider Decides
C304. Position of Window Options	User Selects among Service Provider's Library, Service Provider Decides
C305. Location of Window Options	User Decides with Full Flexibility, User Decides with Available Options, User Selects among Service Provider's Library, Service Provider Decides
C306. Proximity of Workstation to Window Options	User Decides with Full Flexibility, User Decides with Available Options, User Selects among Service Provider's Library, Service Provider Decides

BUILDING PROPERTY SETTINGS SERVICE RANGE

D101. Transportation Options to Facility Service Range	Private Car, Public Services, Bicycle, Electric Vehicles, Take me from my Position
D102. Compliance to Universal Design Principles Service Range	High Level Compliance, Normal Level Compliance
D201. Vibration at Vertical Circulation Service Range	Low Level Vibration
D202. Noise at Vertical Circulation Service Range	High Level Noise, Normal Level Noise
D203. Acceleration/Deceleration Impact at Vertical Circulation Service Range	Soft, Normal
D204. Comfort at Vertical Circulation Service Range	Low, Medium
D301. Exterior Material and Finishing of Building	Glass Curtain Wall
D302. Building Type	Residential

WORKSTATION SETTINGS SERVICE RANGE

C201. Size of the Workspace Options	User Selects among Service Provider's Library
C202. Color, Texture and Quality of Material at Workspace Options	User Decides with Full Flexibility, User Decides with Available Options, User Selects among Service Provider's Library
C203. Orientation of Workspace Options	User Selects among Service Provider's Library, Service Provider Decides
C204. Location of Workspace Options	User Selects among Service Provider's Library, Service Provider Decides

FACILITIES SERVICES SETTINGS SERVICE RANGE

E101. Resting Need and Capacity Service Range	Single Bed, Double Bed
E102. Shower Need and Capacity Service Range	Shower, Bathtube
E103. WC Need and Capacity Service Range	Single, Double
E104. Kitchen Need and Capacity Service Range	Basic, Advanced
E105. Canteen Need and Capacity Service Range	Basic, Advanced
E106. Meeting Room Need and Capacity Service Range	Personal - Single, Group - 5 People, Group - 9 People, Group - 15 People, Group - 21 People, More
E107. Dining Area Need and Capacity Service Range	Personal - Single, Group - 3 People, Group - 7 People, Group - 11 People, Group - 15 People, More
E108. Pantry Options	Yes
E109. Parking Space Need and Capacity Service Range	Bicycle, Car - Single, Car - Multiple
E110. Smoking Area Need and Capacity Service Range	Single, Multiple
E111. Cleaning Options	Standard, Upper- Standard
E112. Safety & Security Options	Basic, Intermediary, Advanced
E113. Maintenance Options	Basic, Intermediary, Advanced
E114. Communication with Facility Manager Options	Face-to-Face, Telecommuting, Virtual Meeting
E115. Network Type and Capacity Service Range	Wireless - High Speed, Wireless - Ultra High Speed, Wired - High Speed, Wired - Ultra High Speed
E116. Audio Visual Systems Needs and Capacity Service Range	User Decides with Full Flexibility, User Selects among Available Options, Service Provider Decides
E117. Modern Technologies Service Range	VR Head Set, Motion Sensors

Figure 4-37. Single workplace service post listing the available service ranges.

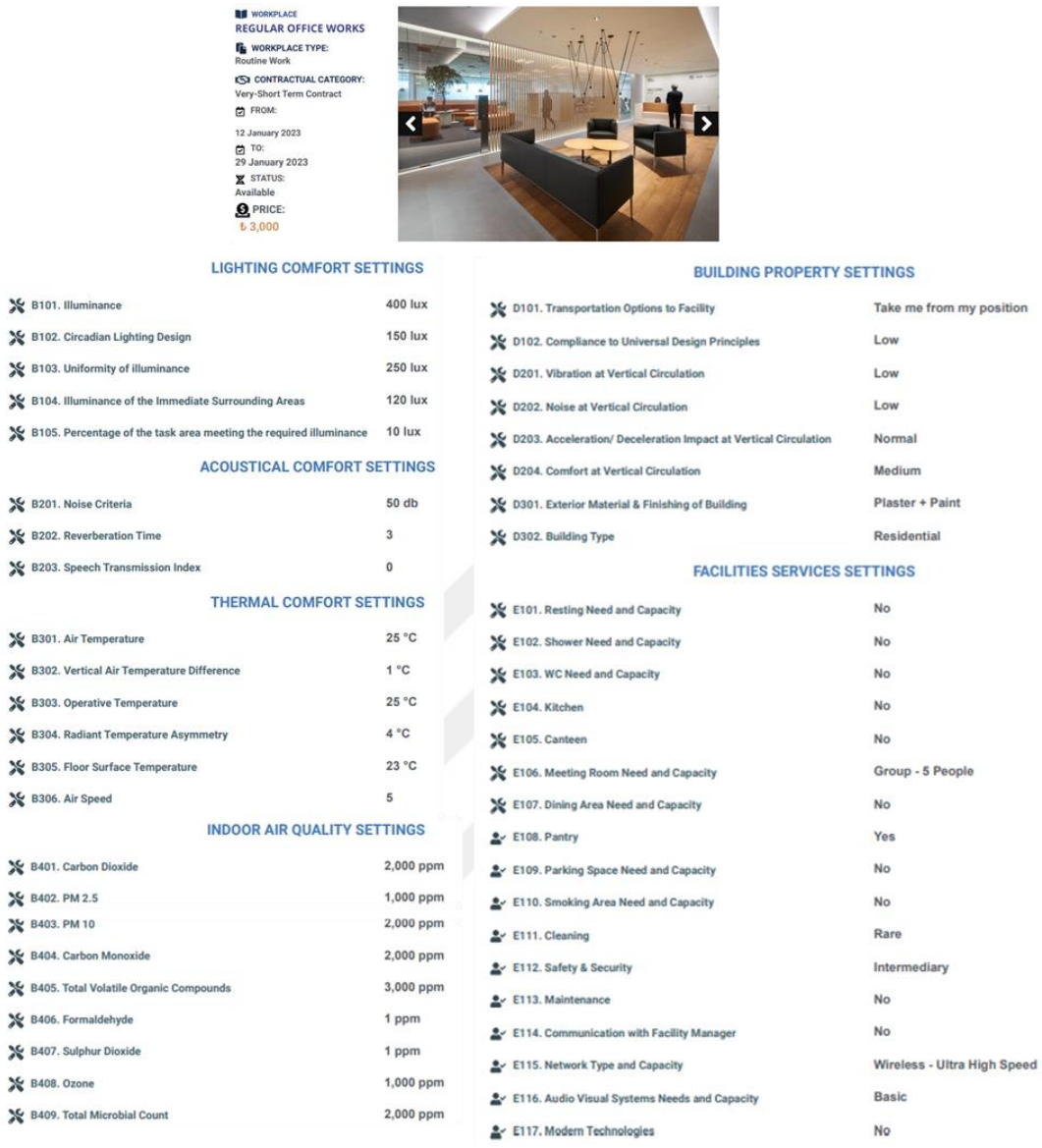

Figure 4-38. Single workplace set post listing the requested service by the knowledge worker.

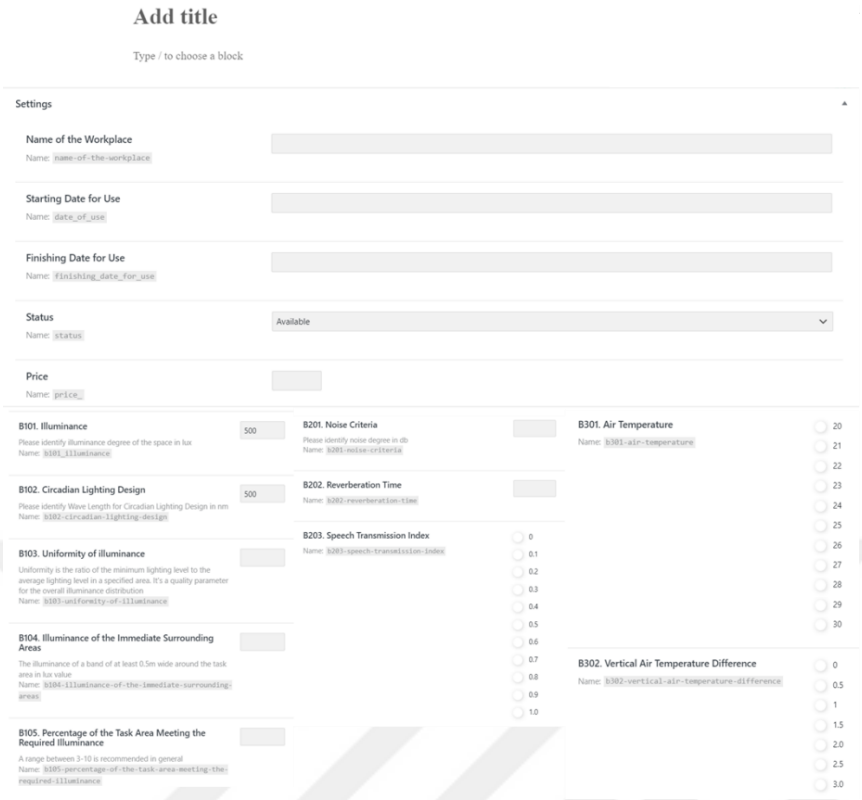

Figure 4-39. Post-creation page for a workplace setting.

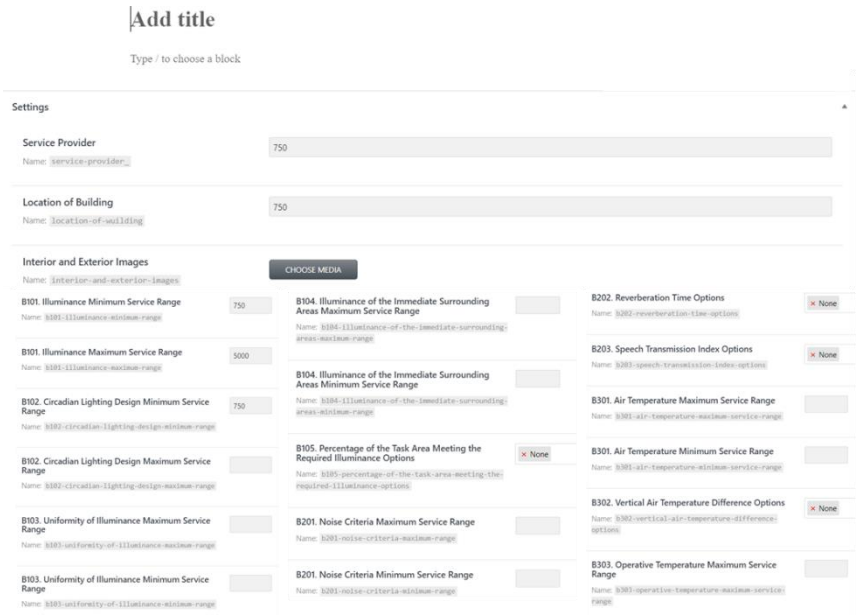

Figure 4-40. Post creation page for workplace services.

4.9 Facilities Management in the New Model

The new workplace service provision model comprehensively analyzes and evaluates the new situations from the employee perspective; however, service provider perspectives must be examined and elaborated. This section explains the changing roles and responsibilities of the office workplace stakeholders.

4.9.1 Office Workplace Stakeholder's Conditions in the New Model

Figure 4-41 compares the traditional office building facility management approach and the new workplace service provision model. As Figure 4-42 explains, the new proposal eliminates the direct connection between landlord and tenant. Instead, the tenant/knowledge worker hires both physical office area and facility management services from the facility manager/service provider upon smart contract. The smart contract establishes transparent, self-executable, and trusted relations between stakeholders. Furthermore, instead of organization, the knowledge worker is the tenant. This approach enables the lease of a knowledge worker-specific workplace where the knowledge worker delivers customization and personalization requirements. On the other hand, in the traditional approach, the organization is the tenant and has limited opportunity for presenting personalization and customization to the knowledge worker.

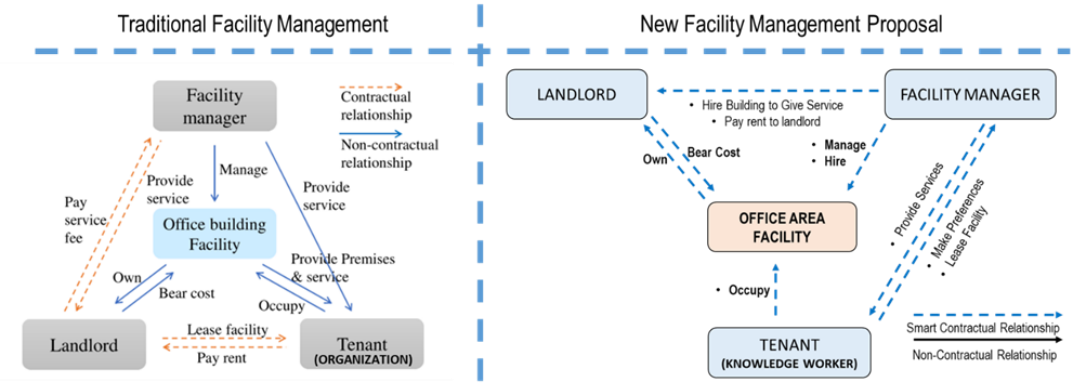

Figure 4-41. Comparison of stakeholder relations at traditional and new facility management model. Adopted from: (Shin et al., 2018)

TRADITIONAL APPROACH

Stakeholders	Roles	Responsibilities
Landlord	• Owner of facility • Lessor by lease agreement • Client by FM service agreement	• To own facility • To lease • To order service and pay service fee
Tenant (organization)	• Occupation of facility • Lessee by lease agreement • No contractual relationship with FM	• To occupy facility • To pay rent
Facility Manager	• Contractor by FM service agreement • No contractual relationship with tenant	• To provide FM service and get service fee

NEW PROPOSAL

Stakeholders	Roles	Responsibilities
Landlord	• Owner of facility • Lessor by lease agreement • Client by FM service agreement	• To own facility • To lease • To order service and pay service fee
Tenant **(Knowledge Worker)**	• Occupation of facility • **Direct contractual relationship for hire the physical space ar smart contract** • **Direct contractual relationship with FM for giving services at smart contract**	• To occupy facility • To pay rent to FM • To pay for FM services to FM
Facility Manager **(Service Provider)**	• Contractor by FM service agreement • **Direct contractual relationship with tenant (knowledge worker) for giving services** • **FM gives much more user specific services to knowledge worker**	• To provide FM service and get service fee

Figure 4-42. Comparison of traditional office building facility management approach and new proposal regarding the roles and responsibilities. Adopted from: (Shin et al., 2018)

4.9.2 Changing Roles and Responsibilities

The comparison study presented in Table 4-4 demonstrated that although the proposed workplace model shares common characteristics in certain parameters, its diversity has impacted all outcomes since it focuses on individual customization and personalization of the workplace by the knowledge worker rather than an organization-based perspective. Almost all workplace settings change the worker's role to the focus and priority of FM services. Furthermore, all workplace settings are presented at smart contract codes, enabling more consistent and formal relations

between service providers and knowledge workers. Moreover, the model has supported in-service and after-service evaluation approaches. Service evaluation represents instant feedback of services to service providers where, rather than post-occupancy, certain services can be changed to meet the occupant's changing needs.

Table 4-4. Comparison of centralized office, co-working, and new model regarding facility management perspectives adopted from (TWINFM, 2021).

	OFFICES AT CBD ZONE	**HOT-DESKING**	**NEW PROPOSAL**
OPERATING ARRAYS	Capacity-Based	Capacity-Based	Capacity-Based
MAINTENANCE APPROACH	Preventative maintenance based on the organization's changing needs and site capacity	Preventative maintenance based on the organization's changing needs and site capacity	Preventative maintenance based on the employee's changing needs and site capacity
COMMON AREA	Ongoing maintenance of common areas such as kitchens, restrooms, and meeting rooms at a high frequency	Changing timelines for common area maintenance	Changing timelines for common area maintenance based on updates in local sanitation guidelines and identification of reoccurring issues
DESKING POLICY	Hot-desk policy	Hot-desk policy	Regarding the employee needs, hot-desking or designated desk
OPERATING FOCUS AND PRIORITY	On-the-go planning and adapting to changing needs:	On-the-go planning and adapting to changing needs:	Since there is a smart contract between parties regarding the daily use of the floor, FM will focus on both individual needs and public requirements
EATING PLACE AND APPROACH	Ordering meals through the app and eating in a predesignated area	Ordering meals through the app and eating in a predesignated area	Since there is a smart contract between parties, meals and eating places can be predesignated.
PARKING SPACE	Smart management of parking space per usage and capacity	Smart management of parking space per usage and capacity	Since there is a smart contract between the employee and FM daily, usage and capacity of parking types and space can be smartly managed.
TRANSPORTATION SCHEDULE	Transportation schedules depending on demand	Transportation schedules depending on demand	Since there is a smart contract between the employee and FM daily, transportation type and demand can be predesignated and smartly managed.
MAINTENANCE PLANNING	Transition to smart maintenance planning considering capacity and team output	Transition to smart maintenance planning considering capacity and team output	Since ambient intelligence will be used, smart maintenance planning will be applied.
SERVICE EVALUATION APPROACH	Data analytics of service requests to understand updated employee needs, such as ergonomic home-office equipment (quality)	Data analytics of service requests to understand updated employee needs, such as ergonomic home-office equipment (quality)	Data analytics collected from ambient intelligence specific for each employee present customized and personalized services. In-service evaluation enables instant evaluation of services within the action.
RESOURCE MANAGEMENT	Traditional resource management	Resource management using data analytics and site capacity	Resource management using data analytics collected from ambient intelligence
BUDGET PLANNING	Allocating budgets per the changing needs of the organization	Allocating budgets per the changing needs of the organization	Allocating budgets per the changing needs of the employee
AGREEMENT PARTIES	Organization / Firm	Organization/Firm	Employee
FM GIVING SERVICES TO	Organization / Firm	Organization/Firm/Employee	Employee

Table 4-4 *continued*

PREPARATION OF WORKSPACE	Done by Organization	Done by Facility Manager	Done by Facility Manager
WORKPLACE CUSTOMIZATION BASED ON	Organization needs	Employee needs	Employee needs
CUSTOMIZABLE OPTIONS	Limited to the organization's opportunity	FM has certain opportunities where employees can make selections among them.	FM has the full opportunity for the customization and personalization needs of employees.

4.9.3 The Workplace Management by the Service Provider

The proposed workplace service provision model requires dynamic and smart workplace management by the service providers. Once the workplace is set and agreement is done in the smart contract, the service provider must respond to the demands of the knowledge worker as soon as possible. Installment of new equipment, change in volume, and material and finishing construction materials are time-consuming. Time for workplace preparation may be a handicap for maintaining the proposed model. Thus, an office workplace area management study is also described and presented for the service providers.

A sample office workplace is prepared, as illustrated in Figure 4-43. The workplace design reflects a typical co-working principle where specialized zones allow variety in workable areas such as private desks, private rooms, meeting rooms, seating, and group work desks. The sample office workplace could be divided into three categories in terms of usability, as demonstrated in Figure 4-44. These are in-use, ready-for-use, and installation areas. In-use area depicts currently occupied or reserved workplaces, while ready-for-use denotes reserved or usable areas for future potential workers. Making small changes and contributions, "ready for use" areas could be easily modified and prepared for the knowledge worker's settings. The installation area, on the other hand, is awaiting and reserved for workplace settings requiring major changes and contributions.

This office workplace management proposal is introductory. During the practice, regarding the incoming workplace settings from the knowledge workers, affordances

of service providers, and opportunities in the office workplace, more effective or specialized management practices could be developed and utilized.

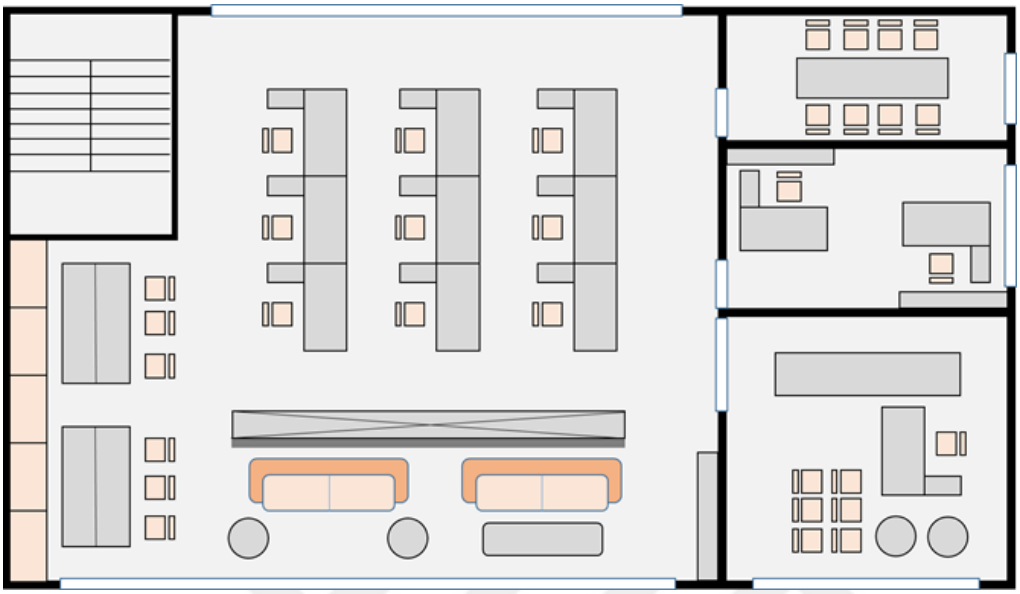

Figure 4-43. A sample office workplace

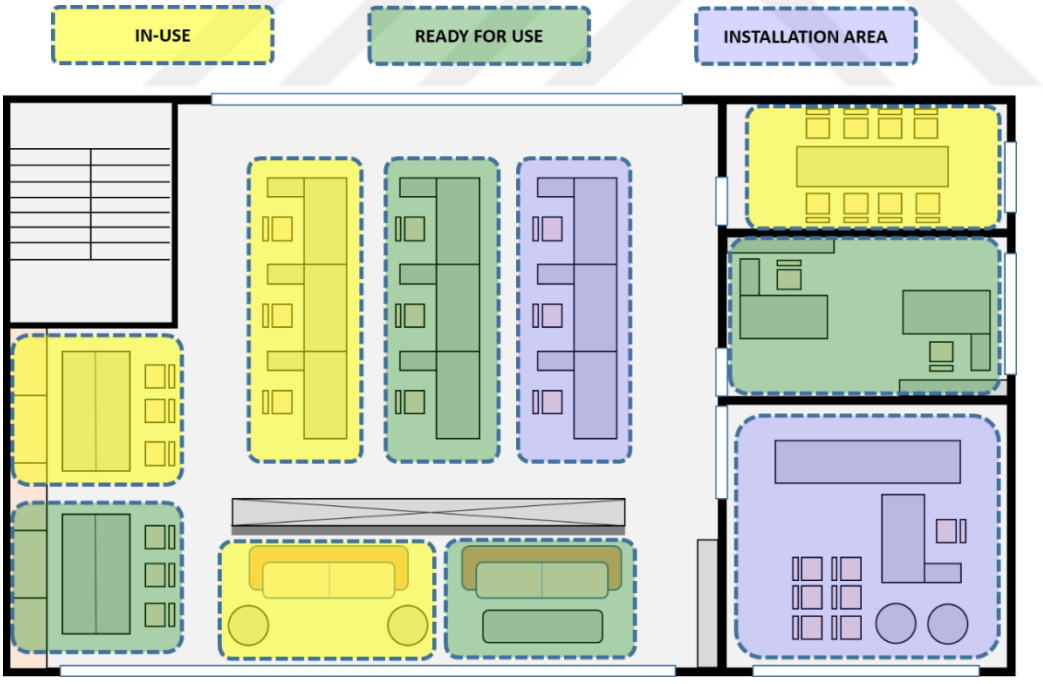

Figure 4-44. Possible division of office workplace for management by service provider

4.9.4 Facilities Management by Service Provider

The facility manager role is transformed into a service provider, and the new model has structured a one-to-one relationship with the knowledge worker. However, preparing the built environment and services needed to be described. This is achieved by describing the preparation of each workplace's comfort and wellbeing services in the physical workplace, as stated in Table 4-5.

IEQ settings require the use of AmI technologies, including sensors and actuators. Since the knowledge worker will designate the required level of comfort for IEQ parameters, AmI will measure both the knowledge worker and workplace using sensors and will respond to the changing status of both knowledge worker and workplace using actuators. Since these devices, equipment, and components now use a wireless network connection, it will be easy for service providers to adopt AmI technologies for knowledge worker changing requirements in the physical workplace. For example, a knowledge worker may require a workplace with particular dimensions. AmI sensors and actuators can be easily installed in the proper workplace location. The service provider can utilize a construction team to design the interior and exterior environment. Current construction technologies enable fast and de-constructible options for creating required space considering wall, floor, and ceiling components and finishing.

Facility management (FM) services in the proposed model may necessitate presenting various available parameters. A team for organizing and setting up these FM services may be utilized to achieve such purposes. Furthermore, service providers may add extra parameters or remove some parameters regarding the demands of the knowledge workers since the nature of the comfort model tries to present customized and personalized settings at the maximum level as much as possible for the workplace and workplace-related comfort parameters.

Table 4-5. Evaluation of workplace parameters regarding the facility management perspective. Abbreviations: KW: Knowledge Worker, SP: Service Provider, AmI: Ambient Intelligence, SC: Smart Contract.

WORKPLACE PARAMETER	WORKING PROCESS	PREPARATION
A101. Duration of Booking	Setting is done at SC by KW. Data is transferred to AmI; the decision-making system informs SP about the booking duration.	AmI and smart contracts must be established.
B101. Illuminance	Setting is done at SC by KW. Data is transferred to AmI and set at the workspace using a sensor and actuator to hold the asset.	SC, AmI, sensors, and actuators must be established and prepared.
B102. Circadian Lighting Design	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold asset.	SC, AmI, sensors, and actuators must be established and prepared.
B103. Uniformity of illuminance	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold asset.	SC, AmI, sensors, and actuators must be established and prepared.
B104. Illuminance of the immediate surrounding areas	Setting is done at SC by KW. Data is transferred to AmI and by use of a sensor and actuator, setting at workspace hold as set	SC, AmI, sensors, and actuators must be established and prepared.
B105. Percentage of the task area meeting the required illuminance	Setting is done at SC by KW. Data is transferred to AmI and by use of a sensor and actuator, setting at workspace hold as set	SC, AmI, sensors, and actuators must be established and prepared.
B201. Noise Criteria	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold asset.	SC, AmI, sensors, and actuators must be established and prepared.
B202. Reverberation Time	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B203. Speech Transmission Index	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B301. Air temperature	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B302. Vertical air temperature difference	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B303. Operative temperature	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B304. Radiant temperature asymmetry	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B305. Floor surface temperature	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B306. Airspeed	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B401. Carbon dioxide	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B402. PM 2.5	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B403. PM 10	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B404. Carbon Monoxide	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B405. Total Volatile Organic Compounds	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.

Table 4-5 *continued*

B406. Formaldehyde	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B407. Sulfur dioxide	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B408. Ozone	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
B409. Total microbial count	Setting is done at SC by KW. Data is transferred to AmI using a sensor and actuator, setting at workspace hold as set.	SC, AmI, sensors, and actuators must be established and prepared.
C101. Size of the Area	The requirement is set at SC by KW. The team of SP constructs the required set of space.	SC, Construction team, and construction materials are required.
C102. Height of the space	The requirement is set at SC by KW. The Team of SP constructs the required set of space.	SC, Construction team, and construction materials are required.
C103. Location of workplace components	The requirement is set at SC by KW. The Team of SP locates the required components.	SC, Construction team, and workplace components are required.
C104. Required equipment, furniture, and devices	The requirement is set at SC by KW. The team of SP provides the required components.	SC, Construction team, and workplace components are required.
C105. Color, texture, material, and quality of floor finishing	The requirement is set at SC by KW. The team of SP constructs the required set of finishing materials	SC, Construction team, and finishing materials are required
C106. Color, texture, material, and quality of wall finishing	The requirement is set at SC by KW. The team of SP constructs the required set of finishing materials	SC, Construction team, and finishing materials are required
C107. Color, texture, material, and quality of ceiling finishing	The requirement is set at SC by KW. The team of SP constructs required set of finishing materials	SC, Construction team, and finishing materials are required
C201. Size of the workspace	The requirement is set at SC by KW. The team of SP provides the required set of workspaces.	SC, Construction team, and workspace components are required.
C202. Color, texture, and quality of material in the workspace	The requirement is set at SC by KW. The team of SP constructs required set of finishing materials	SC, Construction team, and finishing materials are required
C203. Orientation of Workspace	The requirement is set at SC by KW. The team of SP locates the workspace regarding the set of KW.	SC, Construction team
C204. Location of Workspace	The requirement is set at SC by KW. The team of SP locates the workspace regarding the set of KW.	SC, Construction team
C301. Window-to-Wall ratio	The requirement is set at SC by KW. The team of SP presents the required window-to-wall ratio for KW.	SC, Construction team, and construction materials and components for transparency and opacity
C302. Size of the window	The requirement is set at SC by KW, and the Team of SP presents the required size of the window for KW.	SC, Construction team, and window materials for providing variety in window size
C303. Operability of window	The requirement is set at SC by KW, and the Team of SP presents the required operability window option for KW.	SC, Construction team, and window components for providing variety in window operability
C304. Position of window	The requirement is set at SC by KW, and the Team of SP presents the required position of the window for KW.	SC, Construction team, and window components and materials for providing variety in window position
C305. Location of window	The requirement is set at SC by KW, and the Team of SP presents the required window location for KW.	SC, Construction team, and window components and materials for providing variety at the window location
C306. Proximity of workstation	The requirement is set at SC by KW; the Team of SP presents the required position of the workstation to window for KW.	SC, Construction team, workstation
D101. Transportation options to the facility	The requirement is set at SC by KW; the Team of SP presents required transportation options to the facility.	SC, Officer of SP, variety of transportation options such as car, bike, etc.
D102. Compliance with universal design principles	The requirement is set at SC by KW; SP presents either an available set or a set of principles as required by KW.	SC, the Construction team, required systems, technologies, and materials for presenting the required principles.
D201. Vibration at Vertical Circulation	The requirement is set at SC by KW; SP presents either the available set or the vertical circulation as required by KW.	SC, Construction team, required systems, and technologies for presenting required vibration.

Table 4-5 *continued*

D202. Noise at Vertical Circulation	The requirement is set at SC by KW; SP presents either the available set or the vertical circulation as required by KW.	SC, Construction team, required systems, and technologies for presenting required vibration.
D203. Acceleration/ Deceleration Impact at Vertical Circulation	The requirement is set at SC by KW; SP presents either an available set of impact or sets the impact as required by KW.	SC, the Construction team, required systems and technologies for presenting the required impact.
D204. Comfort at Vertical Circulation	The requirement is set at SC by KW; SP presents either an available set of impact or sets the impact as required by KW.	SC, the Construction team, required systems and technologies for presenting the required impact.
D301. Exterior Material & Finishing of Building	The requirement is set at SC by KW; SP presents available material and finishing at building or construction as required by KW.	SC, Construction team, required materials, and finishing for construction
D302. Building Type	The requirement is set at SC by KW; SP presents available building types to the KW.	SC, variety of building type
E101. Resting Need and Capacity	The requirement is set at SC by KW; SP presents the required resting need and capacity to KW.	SC presents a variety and range of resting.
E102. Shower Need and Capacity	The requirement set at SC by KW, SP presents the required shower need and capacity to KW.	SC presents a variety and range of showers.
E103. WC Need and Capacity	The requirement set at SC by KW, SP presents the required WC need and capacity to KW.	SC presents a variety and range of WCs.
E104. Kitchen	The requirement set at SC by KW, SP presents the required kitchen opportunity to KW.	SC presents a variety and range of kitchens.
E105. Canteen	The requirement set at SC by KW, SP presents the required canteen opportunity to KW.	SC presents a variety and range of canteen.
E106. Meeting Room Need and Capacity	The requirement is set at SC by KW; SP presents required meeting room needs and capacity to KW.	SC, presenting a variety and range of meeting room opportunities, a construction team may be required.
E107. Dining Area Need and Capacity	The requirement is set at SC by KW; SP presents the required dining area needs and capacity to KW.	SC, presenting a variety and range of dining area opportunities, a construction team may be required.
E108. Pantry	The requirement is set at SC by KW; SP presents the required pantry need and capacity to KW.	SC, presenting a variety and range of pantry opportunities, a construction team may be required.
E109. Parking Space Need and Capacity	The requirement is set at SC by KW; SP presents required parking space needs and capacity to KW.	SC, presenting a variety and range of parking opportunities, a team may be required to organize
E110. Smoking Area Need and Capacity	The requirement is set at SC by KW; SP presents the required smoking area need and capacity to KW.	SC, presenting a variety and range of smoking area opportunities, a team may be required to organize
E111. Cleaning	The requirement is set at SC by KW; SP presents the required cleaning opportunity to KW.	SC, a cleaning team
E112. Safety & Security	The requirement is set at SC by KW; SP presents required safety and security opportunities to KW.	SC, a safety and security team, system and technology
E113. Maintenance	The requirement is set at SC by KW; SP presents the required maintenance opportunity to KW.	SC, a maintenance team, system, and technologies for organizing maintenance period and cycle
E114. Communication with the Facility Manager	The requirement is set at SC by KW; SP presents the required communication opportunity to KW.	SC, communication platform and opportunity, a PR team may be used for this purpose
E115. Network Type and Capacity	The requirement is set at SC by KW; SP presents the required network type and capacity to KW.	SC, network infrastructure, and an IT expert may be used.
E116. Audio Visual Systems Needs and Capacity	The requirement is set at SC by KW; SP presents the required needs and capacity to KW.	An IT expert may be used for organizing SC, a variety and range of audio-visual systems and components.
E117. Modern Technologies	The requirement is set at SC by KW; SP presents the required needs and capacity for modern technologies to KW.	SC, a variety and range of modern technologies, and an IT expert may be used for organizing such systems.

CHAPTER 5

EVALUATION AND FINDINGS

After the expression of the development of the web ontology model in the initial chapter, this chapter is devoted to the evaluation of the proposed model in various aspects and layers. The chapter is structured as follows. The web ontology model is verified regarding the available methods and validated regarding the method presented in Chapter 3. The validation of the proposed study is followed by a finding and discussion section. Limitations and future implementations are addressed regarding the outcomes of the overall study.

5.1 Verification of the Web Ontology Model

The reasoning task performed in Protégé using HermiT represented no inconsistency regarding evaluating class hierarchy, object property hierarchy, data property hierarchy, class assertions, object property assertions, and individuals, as illustrated in Figure 5-1. The debugging task was executed, and regarding the total 2216 created axioms in the ontology, no inconsistency and incoherency were inspected, as the result was illustrated in Figure 5-2.

```
Pre-computing inferences:
    - class hierarchy
    - object property hierarchy
    - data property hierarchy
    - class assertions
    - object property assertions
    - same individuals
Ontologies processed in 12047 ms by HermiT
```

Figure 5-1. The HermiT reasoning result.

Figure 5-2. The OntoDebug debugging result.

5.2 Validation of the Web Ontology Model

5.2.1 Test Cases

Tiwari & Abraham (2020) proposed using test cases, including six test criteria, to check the validity of the ontologies. Figure 5-3 illustrates the existence of individuals as T1, the class hierarchy as T2, the property as T3, multiple inheritance as T4, equivalence as T5, and disjointness as T6. The test criteria were elaborated with test explanation syntax, test explanation in ontology, and test case with requirements. Test results presented in Table 5-1 assure the validity of the test cases for the proposed ontology.

Test Criteria	Test Exp. Syntax	Test Expression in Ontology	Test Case with Requirement
T1 for Individual in Ontology	X Type Y	John type Knowledge_Worker	T1.1 John_as_Knowledge_Worker is a Knowledge Worker
		Mark type Service_Provider	T1.2 Mark_as_Service_Provider is a Service Provider
		Jena type Data_Collector	T1.3 Jena_as_Data_Collector is a Data Collector
		Physical_Workplace of Meeting_Place type Physical_Workplace	T1.4 Physical Workplace of Meeting_Place is a Physical_Workplace
		Regular_Office type Routine Work	T1.5 Regular_Office is a Routine Work
		Acceleration_Sensor instanceOf Acceleration	T1.6 Acceleration_Sensor instanceOf Acceleration
		Booked Concentration Place instanceOf Booked_Workplace	T1.7 Booked Concentration Place instanceOf Booked_Workplace
		Concentration_Place_Set instanceOf WORKPLACE SET	T1.8 Concentration_Place_Set instanceOf WORKPLACE SET
		John's_Body instanceOf Knowledge_Worker_Body	T1.9 John's_Body instanceOf Knowledge_Worker_Body
		www.findaworkplace.com instanceOf WEB_SITE	T1.10 www.findaworkplace.com instanceOf WEB_SITE
T2 for SubClass	X SubClassOf Y	Sensors SubClassOf AMBIENT INTELLIGENCE CONCEPT	T2.1 Sensors is subclass of Ambient Intelligence Concept
		Refriger SubClassOf Actuators	T2.2 Refriger is an Actuator
		Acceleration SubClassOf Sensor	T2.3 Acceleration is a Sensor
		Test_Room SubClassOf DATA_COLLECTION_METHODS	T2.4 Test_Room is a DATA_COLLECTION_METHOD
		Workplace SubClassOf PHYSICAL WORKPLACE CONCEPT	T2.5 Workplace is a PHYSICAL WORKPLACE CONCEPT
		Provisions SubClassOf SMART CONTRACT CONCEPT	T2.6 Provisions are subset of SMART_CONTRACT_CONCEPT
		Workplace_Service_Archive SubClassOf STORAGE	T2.7 Workplace Service Archive is a STORAGE
		Marketplace SubClassOf WEB APPLICATIONS	T2.8 Marketplace is a WEB APPLICATIONS
		Routine Work SubClassOf BUSINESS_OPERATIONAL	T2.9 Routine Work is a BUSINESS_OPERATIONAL
		Short-Term_Use SubClassOf CONTRACTUAL	T2.10 Short-Term_Use is a CONTRACTUAL
		WORKPLACE SET SubClassOf WORKPLACE CREATION CONCEPT	T2.11 WORKPLACE_SET is subset of WORKPLACE_CREATION_CONCEPT
T3 for Property between Two Classes	X SubClassOf P some Y	Knowledge_Worker SubClassOf WORKPLACE CREATION CONCEPT can_access AMBIENT INTELLIGENCE SET	T3.1 Knowledge Worker can_access AMBIENT INTELLIGENCE SET
		Service_Provider SubClassOf PHYSICAL WORKPLACE CONCEPT can_manipulate AMBIENT INTELLIGENCE SET	T3.2 Service Provider can_manipulate AMBIENT INTELLIGENCE SET
		Knowledge_Worker SubClassOf WORKPLACE CREATION CONCEPT chooses CONTRACTUAL	T3.3 Knowledge Worker chooses CONTRACTUAL
		Immersive Virtual Environment SubClassOf Data Collection Method detects B101-Uniformity_of_Illuminance_Set	T3.4 Immersive Virtual Environment detects B101-Uniformity_of_Illuminance_Set
		Workplace Type directs & guides Data Collector	T3.5 Workplace_Type directs & guides Jena as Data_Collector
		Service_Provider and Knowledge_Worker finds Data_Collector	T3.6 Service_Provider and Knowledge_Worker finds Data_Collector
		Data_Collector inspects WORKPLACE SERVICE RANGE	T3.7 Jena_as_Data_Collector inspects WORKPLACE SERVICE RANGE
		Installation_Crew installs Installation_Area	T3.8 Mark's_Installation_Team installs Installation Area
		AMBIENT INTELLIGENCE SET is_installed_at Booked_Workplace	T3.9 Meeting_Place_Aml_Set is_installed_at Booked Meeting Place
		Knowledge Worker occupies Booked_Workplace	T3.10 John_as_Knowledge_Worker occupies Booked_Concentration_Place
		Service Provider approves Provisions	T3.11 Mark_as_Service_Provider approves Provisions
		Knowledge Worker initiates Smart_Contract	T3.12 John_as_Knowledge_Worker initiates Smart_Contract
		Booked Workplace is appointed for Knowledge Worker	T3.13 Booked Concentration_Place is_appointed_for John_as_Knowledge_Worker
		WORKPLACE SET is transformed to Provisions	T3.14 Regular_Office_Set is_transformed_to Regular Office Service Provisions
		Knowledge Worker creates an account at WEB SITE	T3.15 John_as_Knowledge_Worker creates an account at Web Site
		WORKPLACE SET is compared with WORKPLACE SERVICE RANGE	T3.16 Concentration_Place_Set is compared with Concentration Place Service Range
		WORKPLACE SET and WORKPLACE SERVICE RANGE is uploaded to Marketplace	T3.17 Meeting_Place_Set and Meeting_Place_Service_Range is uploaded to www.findaworkplace.com
T4 Multiple Inheritance	X SubCLassOf Y and Z	Knowledge Worker subClassOf WORKPLACE CREATION CONCEPT and User	T4.1 John_as_Knowledge_Worker can be Knowledge Worker and User
T5 Equivalence	X EquivalentTo Y	Service Cost equivalentTo Deposit Amount	T5.1 Service Cost and Deposit Amount are equivalent entities
		WORKPLACE SET equivalentTo Provisions	T5.2 Meeting Place Set is equivalent to Meeting Place Service Provisions
		A101-Duration of Booking Service Range equivalentTo A101-Duration of Booking Aml Service Range	T5.3 A101-Duration of Booking Service Range is equivalent to A101-Duration of Booking Aml Service Range
		B301-Air Temperature Set equivalentTo B301-Air Temperature Aml Set	T5.4 B301-Air Temperature Set is equivalent to B301-Air Temperature Aml Set
T6 Disjointness	X disjoint with Y	ACTUATORS disjoint with SENSORS	T6.1 ACTUATORS and SENSORS are disjoint entities
		Data_Collector disjoint with Knowledge_Worker	T6.2 Jena_as_Data_Collector disjoint with John_as_Knowledge_Worker
		Service_Provider disjoint with Knowledge_Worker	T6.3 Mark_as_Service_Provider disjoint with John_as_Knowledge_Worker
		Data_Collector disjoint with Service_Provider	T6.4 Jena_as_Data_Collector disjoint with Mark_as_Service_Provider
		Knowledge Worker Personal Account disjoint with Service Provider Personal Account	T6.5 John's_Address disjoint with Mark's_Address

Figure 5-3. Test case study for Protégé. Adopted from: (Tiwari & Abraham, 2020)

Table 5-1. Test case results in Protégé. The right column illustrates the screenshots.

Test Case with Requirement	Test Results in Protege
T1.1 John is a Knowledge Worker	John_as_Knowledge_Worker Type Knowledge_Worker
T1.2 Mark is a Service Provider	Mark_as_Service_Provider Type Service_Provider
T1.3 Jena is a Data Collector	Jena_as_Data_Collector Type Data_Collector
T1.4 Physical Workplace of Meeting_Place is a Workplace	Physical_Workplace_of_Meeting_Place Type Workplace
T1.5 Regular_Office is a Routine Work	Regular_Office Type Routine_Work
T1.6 Acceleration_Sensor instanceOf Acceleration	Acceleration_Sensor Type Acceleration
T1.7 Booked Concentration Place instanceOf Booked_Workplace	Booked_Concentration_Place Type Booked_Workplace
T1.8 Concentration_Place_Set instanceOf WORKPLACE SET	Concentration_Place_Set Type WORKPLACE_SET
T1.9 John's_Body instanceOf Knowledge_Worker_Body	John's_Body Type Knowledge_Worker_Body
T1.10 www.findaworkplace.com instanceOf WEB_SITE	www.findaworkplace.com Type WEB_SITE
T2.1 Sensors is a subclass of the Ambient Intelligence Concept	SENSORS SubClassOf AMBIENT_INTELLIGENCE_CONCEPT
T2.2 Refriger is an Actuator	Refriger SubClassOf ACTUATORS
T2.3 Acceleration is a Sensor	Acceleration SubClassOf SENSORS
T2.4 Test_Room is a DATA_COLLECTION_METHOD	Test_Room SubClassOf DATA_COLLECTION_METHODS
T2.5 Workplace is a PHYSICAL WORKPLACE CONCEPT	Workplace SubClassOf PHYSICAL_WORKPLACE_CONCEPT
T2.6 Provisions are a subset of SMART_CONTRACT_CONCEPT	Provisions SubClassOf Smart_Contract
T2.7 Workplace Service Archive is a STORAGE	Workplace_Service_Archive SubClassOf STORAGE
T2.8 Marketplace is a WEB APPLICATIONS	Marketplace SubClassOf WEB_APPLICATIONS
T2.9 Routine Work is a BUSINESS_OPERATIONAL	Routine_Work SubClassOf BUSINESS_OPERATIONAL
T2.10 Short-Term_Use is a CONTRACTUAL	Short-Term_Use SubClassOf CONTRACTUAL
T2.11 WORKPLACE_SET is a subset of WORKPLACE_CREATION_CONCEPT	WORKPLACE_SET SubClassOf WORKPLACE_CREATION_CONCEPT
T3.1 John_as_Knowledge Worker can_access Concentration_Place_Aml_Set	John_as_Knowledge_Worker can_access Concentration_Place_Aml_Set
T3.2 Mark_as_Service Provider can_manipulate Concentration_Place_Aml_Service_Range	Mark_as_Service_Provider can_manipulate Concentration_Place_Aml_Service_Range
T3.3 John_as_Knowledge Worker chooses 3_Months	John_as_Knowledge_Worker chooses 3_Months
T3.4 Immersive Virtual Environment detects B101-Uniformity_of_Illuminance_Set	Immersive_Virtual_Environment detects B101_Illuminance_Set

Table 5-1 *continued*

T3.5 Workplace_Type directs & guides Data_Collector	Workplace_Type directs_&_guides **Jena_as_Data_Collector**
T3.6 Service_Provider and Knowledge_Worker finds Data_Collector	**John_as_Knowledge_Worker** finds Jena_as_Data_Collector **Mark_as_Service_Provider** finds Jena_as_Data_Collector
T3.7 Jena_as_Data_Collector inspects WORKPLACE SERVICE RANGE	**Jena_as_Data_Collector** inspects Concentration_Place_Service_Range
T3.8 Mark's_Installation_Team installs Workplace_Set	**Mark's_Installation_Team** installs Concentration_Place_Set
T3.9 Meeting_Place_Aml_Set is_installed_at Booked Meeting Place	**Meeting_Place_Aml_Set** is_installed_at Booked_Meeting_Place
T3.10 John_as_Knowledge_Worker occupies Booked_Concentration_Place	**John_as_Knowledge_Worker** occupies Booked_Concentration_Place
T3.11 Mark_as_Service_Provider approves Provisions	**Mark_as_Service_Provider** approves Concentration_Place_Service_Provisions
T3.12 John_as_Knowledge_Worker initiates Smart_Contract	**John_as_Knowledge_Worker** initiates Smart_Contract_for_Regular_Office
T3.13 Booked Concentration_Place is_appointed_for John_as_Knowledge_Worker	**Booked_Concentration_Place** is_appointed_for John_as_Knowledge_Worker
T3.14 Regular_Office_Set is_transformed_to Regular Office Service Provisions	**Regular_Office_Set** is_transformed_to Regular_Office_Service_Provisions
T3.15 John_as_Knowledge_Worker creates an account at Web_Site	**John_as_Knowledge_Worker** creates_an_account_at www.findaworkplace.com
T3.16 Concentration_Place_Set is compared with Concentration Place Service Range	**Concentration_Place_Set** is_compared_with Concentration_Place_Service_Range
T3.17 Meeting_Place_Set and Meeting_Place_Service_Range is uploaded to www.findaworkplace.com	**Meeting_Place_Set** is_uploaded_to www.findaworkplace.com **Meeting_Place_Service_Range** is_uploaded_to www.findaworkplace.com
T4.1 Knowledge Worker and Service Provider can be User	Knowledge_Worker_Personal_Account **EquivalentTo** Users Service_Provider_Personal_Account **EquivalentTo** Users
T5.1 Service Cost and Deposit Amount are equivalent entities	Deposit_Amount **EquivalentTo** Service_Cost
T5.2 A101-Duration of Booking Aml Service Range is equivalent to A101-Duration of Booking Service Range	A101_Duration_of_Booking_Aml_Service_Range **EquivalentTo** A101_Duration_of_Booking_Service_Range
T5.3 B301-Air Temperature Set is equivalent to B301-Air Temperature Aml Set	B301_Air_Temperature_Aml_Set **EquivalentTo** B301_Air_Temperature_Set
T5.4 Provisions are equivalent to Workplace Set	**Provisions** EquivalentTo WORKPLACE_SET
T6.1 ACTUATORS and SENSORS are disjoint entities	**ACTUATORS** DisjointWith SENSORS
T6.2 Jena_as_Data_Collector disjoint with John_as_Knowledge_Worker	John's_Address DifferentAs **Mark's_Address**
T6.3 Jena_as_Data_Collector disjoint with Mark_as_Service_Provider	**Jena_as_Data_Collector** DifferentAs Mark_as_Service_Provider
T6.4 John's_Address disjoint with Mark's_Address	**John's_Address** DifferentAs Mark's_Address

5.2.2 Survey Study

A pairwise comparison study was prepared and directed to the knowledge workers in a co-working company in Ankara. The study was conducted in October 2023, and seventeen volunteers participated. The nine questions referencing the emerging demands of the knowledge worker were formalized as a selection of the best choice among the double comparisons. The questions and their total points regarding the survey participants' preferences are illustrated in Figure 5-4.

The survey result represented that the most important parameters were (Q9) having the ability to decide the location and position of the workplace within the office building, (Q8) the use of new technologies and methods for hiring and using the workplace, (Q6) making personalization in the workplace and (Q3 & Q7) selecting service content and hiring duration. Therefore, pairwise comparison study results comply with the emerging demands of the knowledge workers presented in the literature.

EVALUATION PARAMETERS		SCORE
Q1	Having Ability to Select the Location of Office Building	43
Q2	Having Ability to Select the Transportation Options to Office Building	52
Q3	Having Ability to Select the Service Content	74
Q4	Having Ability to Select the Service Provider	24
Q5	Having Ability to Select the Options at Office Interior Design	47
Q6	Having Ability to Make Personalization at Workplace	86
Q7	Having Ability to Decide Hiring Duration	74
Q8	Use of New Technologies and Methods for both Hiring and Use of Workplace	101
Q9	Having Ability to Decide the Location and Position of Workplace within Office Building	104

Figure 5-4. The questions used in and results of the pairwise comparison study.

5.2.3 User Interface Demo

A user interface was prepared in the Microsoft PowerPoint application as a small demonstration of the workplace creation concept. Six parameters were presented with selectable options, as illustrated in Figure 5-5. The test group was the same people who participated in the pairwise comparison study and were asked to choose one option for each parameter. Each selection of the participants directs them to the next parameter. Each selectable item was supported with a proper image to increase the participant's perception of the options, as depicted in Figure 5-6. At the end of selecting the six parameters, the participants were directed to a 3-Dimensional virtual environment reflecting their selections, as depicted in Figure 5-7. The participants had navigation opportunities inside the virtual scene; thus, all of the participants had the opportunity to examine the virtual environment carefully.

Following the user interface demo test, the opinions of the participants were asked regarding the following aspects:

- Is the 3-D virtual environment reflecting the user selections?
- Could such a user interface be useful for creating or designing a personalized workplace?
- Does using such a user interface impact the perception of the workplace design parameters?

All of the participants in the test group agreed that the selectable options presented in the interface and resulting virtual environment were compliant with each other and correctly reflected the participants' desires. Furthermore, all participants were satisfied with the ability to see and navigate inside the virtual environment created due to their selections. Moreover, the user interface was useful for creating a personalized workplace since they can decide on the components.

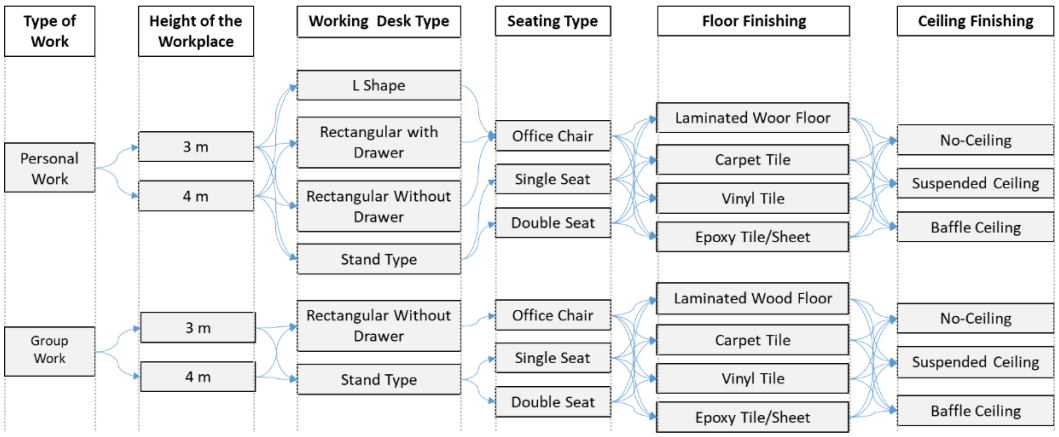

Figure 5-5. Selectable parameters in user interface demo.

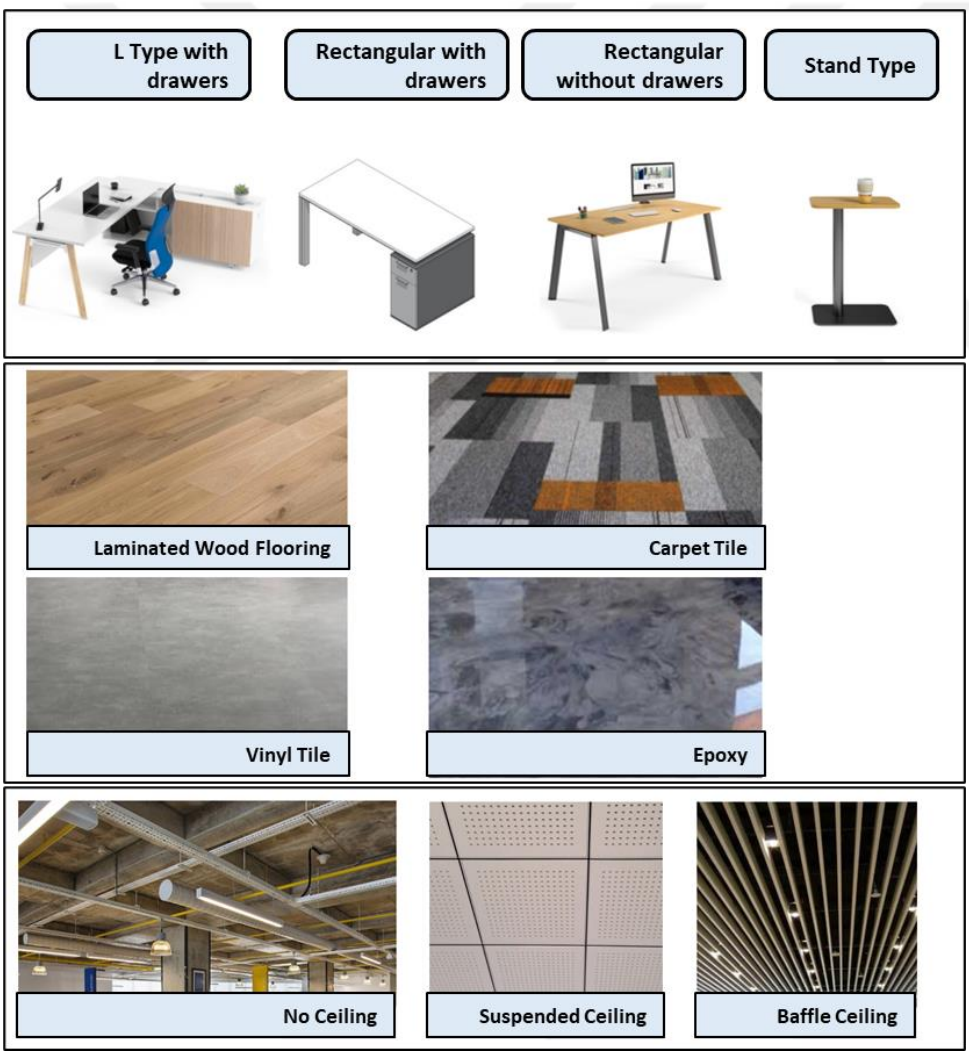

Figure 5-6. Each selectable item was supported with sample images.

Figure 5-7. 3-Dimensional virtual scenes that user can navigate inside and see their selections.

5.2.4 Interview Study

Although the new workplace service provision model was established and represented as a web ontology model, the applicability, potential, and handicaps of the new model needed to be clarified by facility managers. An interview study was prepared and conducted with seven facility managers. The information and

characteristics of the facility managers and the questions directed to them were presented in Table 5-2 and Table 5-3.

Table 5-2. The information of the facility managers participated in the interview.

Facility Manager (FM)	Location	Area of Expertise
FM #1	Istanbul	Office Buildings, Centralized Services
FM #2	Ankara	Office Buildings, Co-Working Services
FM #3	Istanbul	Office Buildings, Centralized and Co-Working Services
FM #4	İstanbul	Office Buildings, Centralized and Co-Working Services
FM #5	Antalya	Office Buildings, Co-Working Services
FM #6	Antalya	Office Buildings, Co-Working Services
FM #7	Antalya	Office Buildings, Co-Working Services

Table 5-3. The conditions, assumptions, and questions were directed to the facility managers in the interview.

Current Condition:
• The office workplace design and comfort decisions are given by either the tenant company in the centralized office concept or the office workplace service provider in the co-working concept. • Thus, personalization and customization opportunities for employees in office workplaces are limited.
Assume that in an Office Workplace:
• The employee can personalize and customize certain comfort parameters. • The office workplace is prepared for the employee's desire regarding his/her work duration. • After the occupation, the workplace could be reset for the desire of another employee.
Questions:
Q1. What kind of comfort parameters could be personalized and customized? Q2. What kind of challenges could be raised to achieve these targets? Q3. What are the advantages and disadvantages of the new model? Q4. What could be the primary costs of the new model? Q5. What is the ideal contract duration for such a working method? Q6. What kind of opportunities could be provided for the stakeholders? Q7. Which industries are proper, and which are not to apply such a new model? Q8. Other comments and concerns.

The comments of the facility managers were illustrated separately in Tables 5-4, 5-5, 5-6, 5-7, 5-8, 5-9 and 5-10. The approaches of the FM were varied to the questions; however, all participants shared that the proposed model could be implemented in the current market.

Table 5-4. The comments of FM #1 in the interview study

To	Explanations
Q1	The employees could make personalization and customization opportunities in limited options such as interior decoration, hardware, equipment, smart monitoring, and easily applicable settings.
Q2	This model could be applied when the employee number is low. Otherwise, dealing with the desires of a high number of employees may cause chaotic conditions. Furthermore, knowing the party that will compensate for the expenditures is important. The employer may seek cost efficiency while the employee may seek his/her maximized comfort when the cost is not a concern.
Q3	An effort to maximize the employee's comfort would be returned as work productivity and a sense of belonging to the organization. If the costs are affordable and could be compensated by the gained productivity, the employer will also be satisfied with the results.
Q4	Priorities are important. Considering the priorities, one can prefer investing in staff, equipment, interior decoration, adapting to the changing business life, and having happy employees. It is a matter of priorities for the organization.
Q5	Since the technology and practices are so fast and continuously changing, the minimum duration for this kind of model should not be less than two years.
Q6	Giving such personalization opportunities would increase the trust between employees and employers. If the employer would compensate the cost of these preferences and even a limited budget is presented, the employee may feel and think about working with the company for the long term. When such a trust environment has already been established between employer and employee, the employer will allow personalization opportunities.
Q7	Creative industries, corporate companies, and firms with horizontal hierarchies could be proper, while traditional companies with vertical hierarchies are not proper since they generally reject the chances.
Q8	The personalization and customization opportunities may cause dissatisfaction among employees. They may start to compare their preferences and the employer's support. Besides these preferences, the social and communal necessities of the employee must be satisfied.

FM#1 was concerned that the customizable parameters must be limited and implemented in micro-sized companies. The high number of employees and preferences may cause chaotic operational conditions. Allowing workplace configuration in certain opportunities would increase the trust between employees and employers. However, the cost of the customization and the party that will pay for the customization are the important challenges for implementing the proposed model effectively. Regarding competitiveness and ambition in the business industry,

the employee may start to compare their colleagues' preferences, which may result in dissatisfaction.

Table 5-5. The comments of FM #2 in the interview study

To	Explanations
Q1	The employees could make personalization and customization opportunities in limited options such as interior decoration, hardware, equipment, smart monitoring, and easily applicable settings.
Q2	When such personalization and customization opportunities are provided, these selectable items' delivery, store, or asset management could be problematic. For example, what can we do after using these items in a workplace set? If the selectable items will be hired from the suppliers, what will be the cost of hiring? If the service provider owns the selectable items, then there is a need to store a wide collection of them, and there will be a limited option since it is hard to manage the idea of owning the selectable items. Furthermore, the logistics of exchanges of these selectable items are another challenge when the selectable materials are hired from the suppliers.
Q3	Personalization and customization of a workplace are subjective topics. Although, at first glance, presenting certain personalization in the workplace environment may increase workplace satisfaction, managing and controlling many individual workplaces in an office workplace would be hard, even impossible, regarding facility management and operation of the workplace environment.
Q4	The primary costs would be the material, equipment, devices, and furnishings used according to the users' preferences.
Q5	In a co-working environment, there are three, six, and one-year contract durations. In the post-pandemic era, the demand for co-working offices has been significantly increased. Thus, the subscribers have asked to make a contract for two years. The ideal contract duration may be changed depending on the market's demand.
Q6	Since personalization and customization opportunities are subjective topics regarding my co-working management experiences, I am not sharing any optimistic opportunities for the stakeholders in the long term. On the other hand, since the cost of operations has increased and profit has decreased in the post-pandemic era, centralized offices have started to decrease their occupation in headquarters by either finding smart allocation of shared desk concepts or finding alternative working methods such as remote and distributed working practices. The proposed model could be an alternative for the office workplaces in the centralized office concept; however, the model's applicability strictly depends on discovering the optimum level of personalization and customization of the workplace.
Q7	The sectors highly using co-working services could use the new model.
Q8	The applicability and implementation of high-level personalization and customization of workplace parameters are challenging issues. Rather than providing a space for a specific individual, presenting many spaces fit for many space requirements would be logical preferences for effective office management as we try to do in co-working offices.

Table 5-6. The comments of FM #3 in the interview study

To	Explanations
Q1	The employees could make personalization and customization opportunities in limited options such as interior decoration, hardware, equipment, smart monitoring, and easily applicable settings.
Q2	If these workplace desires are sold, the operation scenario is also changed. However, rather than selling, the leasing option presents fewer handicaps for implementing the new model. The roles and responsibilities of the administration, management, operation, technical, and leasing teams must be re-designed since the new model proposes unique challenges in all these management fields. On the other hand, having individual configurations in a building does not reflect any outstanding challenges because, in the centralized office concept, the office areas are leased to the tenant in raw condition. The tenant studies interior design and submits the plans to the facility manager. The facility manager checks the plan from administrative, managerial, operability, and technical perspectives. Incompliant design components are requested to be revised, and after confirmation by the facility manager, the tenant's interior design could be constructed, and the tenant could start to occupy the workplace. Similar procedures or approaches could be adapted to the proposed model.
Q3	Maximized flexibility, personalization, customization in the workplace, and high-level use of digitalization and technology would be the advantages of the proposed model. Furthermore, owning office devices and equipment that would be used rarely are certain cost items of the organization. Owning them is a cost, while not owning them is a handicap for productivity. Using the new model may decrease operation costs for the employer while creating a productive working pattern since there is an opportunity to hire these rarely-required devices and equipment from the service provider.
Q4	Regarding the target users (tenants), the priorities could be changed. These priorities may be digital equipment for social media experts and office devices for a regular white-collar worker.
Q5	Ideal duration could be defined and described by the tenant's necessities.
Q6	The workers would have his/her configured workplace. Independent from the office headquarters, the workers may have a high level of flexibility to be connected to the work anywhere and anytime. The service provider could gain maximized efficiency of workplace occupation and profit. The employer may eliminate the high-level operation and real estate cost of having an office headquarters while increasing business efficiency and productivity.
Q7	Social media experts, influencers, and creative industry workers.
Q8	The proposed model is the realities of the current industry. Since the work pattern, type, and workers change, the space to do such activities must be changed. Applying the new model requires a well-regulated operation plan, smart allocation of the individual workplace sets in the workplace area, adopting the new model to the social and cultural priorities, and making good advertisements. In a shopping mall, a single tenant could use an individual property, or if the property is divided into ten individual units, ten tenants could use the same area. This is a matter of demand in the market, social and cultural necessities, and society's adoption of the new proposed models and systems. Thus, many individual configurations of workplaces in a huge area would not be an extraordinary facility management practice for the facility managers.

Table 5-7. The comments of FM#4 in the interview study

To	Explanations
Q1	The parameters could be defined and described by the occupant's needs. However, the service provider's capability and the cost of the services are the major decision-makers on this issue. It is not logical to present the same or equal parameters to everyone. For example, Although the physical characteristics vary, tall or small workers are forced to use the same furniture or furniture with limited or no customization for its comfort.
Q2	Many of the co-working service providers have limited capital opportunities. In some cases, the co-working area design and construction were completed and owned by the landlord rather than the service provider. Due to the limited operation budget, the service provider would avoid owning many customizable items. Instead of presenting temporary configurations, permanent configurations would be advantageous and affordable for the service provider. On the other hand, when the knowledge worker owns the configuration where the service provider will prepare the workplace regarding the knowledge worker's configuration and the entire construction of the configuration cost would be provided by the knowledge worker, the service provider would accept because such options have already been presented in current practice.
Q3	Personalization and customization may be beneficial and productive for the knowledge worker. Presenting a workplace that would be established wherever and whenever the user requires would be the preference of many knowledge workers. However, presenting such services requires particular facility management approaches. A proper workplace management system, a workplace configurator, an installment team, and new roles and responsibilities may be aroused. Since these roles and responsibilities are new and there would be limited know-how information, it is likely to meet with unpredicted operation problems, which are great risks for all stakeholders. Furthermore, co-working spaces are preferable for many organizations and employees for their communal and social opportunities. For example, many companies lease private offices in co-working areas to be inside the business environment and synergies the co-working area presents. These opportunities must also be maintained in the new model.
Q4	The configuration parameters and items would be the primary costs.
Q5	Return of Investment (ROI) is important, and a detailed ROI must be done for each configuration, whether the configuration is profitable or not for the knowledge worker, employer, and service provider. A minimum six-month contract duration may be useful but not profitable for a simple workplace configuration. On the other hand, if the contract does not allow free cancellation of any parties, then the new model may not be performed as expected.
Q6	The new model presents a new marketing opportunity for the service provider. Personalization and customization attract not only the knowledge workers but also the employers. This is because the operation costs of the companies have rigorously increased, and micro and small companies have started to prefer co-working areas. The new model may initially attract these companies requiring high-level privacy, personalization, or particular configuration while having limited operation budgets.
Q7	The industries looking for high-level workplace configurations are proper, while other industries sharing the same workplace understandings may not be proper due to cost, capability, and management of operation of the workplace area.
Q8	When the configuration level and depth are high, there would likely be complex operation conflicts and problems for service providers. On the other hand, in current business practices, it has been recognized and widely accepted that in many organizations, there is no need to exist in the headquarters offices physically. The administrative units having regular office work must stay in the office. The majority of the remaining staff in an office can work anywhere and anytime. The new model may present an alternative workplace supporting and promoting the mobility of the knowledge workers in this sector.

Table 5-8. The comments of FM#5 in the interview study

To	Explanations
Q1	The parameters could be defined and described by the occupant's needs.
Q2	The personalization or customization opportunities must be limited. Otherwise, high-level and complex facility management and operation capabilities are required. Furthermore, certain customization opportunities could not be public. For example, a smell requested by an occupant may distort or disturb another occupant. Rather than one-to-one personalization, particular services should be provided regarding the emerging needs of the user and a particular level of customization opportunities may be presented so that another user can occupy the area without making major changes.
Q3	Personalization and customization increase the self-satisfaction of the user. However, when the workplace operation is focused on self-satisfaction, the cost of the services becomes high. Thus, the service cost would be a disadvantage for this model.
Q4	Configurable parameters would be the primary cost.
Q5	If the occupant owns the configurable parameters, then contract duration could be defined by the knowledge worker. If the service provider owns the configurable parameters, then the contract duration must be longer than regarding the services' return on investment (ROI) period.
Q6	The new model may change the workplace environment and industry. The new roles and responsibilities may open new working and expertise fields.
Q7	Every knowledge worker may desire a particular level of customization and personalization. The demand in the market is important at this point. For example, the new model may not be implemented, or the demand may be low in cities such as Antalya while the cities İstanbul, Ankara, or İzmir having high-level economic capacity are proper to implement.
Q8	The marketing, expansion, and acceptance of the new idea are crucial for implementing the new model. Otherwise, the new model could be implemented in zones with high-level financial incomes and not applied in other zones of the cities and countries.

FM#2, regarding his co-working experiences, was sharing more concerns about implementing the proposed model than others. The key topics shared by FM#2 were asset ownership and management in the workplace, the subjectiveness of the preferences may cause chaotic operations in the workplace, and the FM practices should not rely on subjective aspects of the workers. Thus, rather than configuring a particular workplace for a knowledge worker, similar to the co-working concept, various workplaces could be prepared and presented to meet the diverse subjective needs and requirements of the knowledge workers.

FM#3 shared the most optimistic comments on implementing the proposed model. Together with sharing almost the same arguments with this dissertation study, FM#3 stated that the proposed model was more compliant to be used by social media experts, influencers, and creative industry workers since they require temporary spaces.

Table 5-9. The comments of FM#6 in the interview study

To	Explanations
Q1	The parameters could be defined and described by the occupant's needs.
Q2	The new model is out of the shared workplace concept. Since a particular and customized workplace environment is presented to a specific person for a particular period, this workplace could only be reserved for this person. The occupant would use the office equipment within the configured area; however, using the same area by another person at another time may create security and privacy problems. Although some particular rooms, such as meeting areas, could be used in this concept, the meeting area is not continuously or regularly occupied by the same person. Thus, no personalization or limited customization is required. However, the new model presents a particular level of configuration where the configured area must be reserved for the occupant without sharing with other users, increasing the service cost. This situation preserves in-use-related handicaps and conflicts, especially among the occupants using the same area at different times. Many co-working areas are used by individual entrepreneurs where these initiatives are required to express a physical address for their business activities officially. Formal and official procedures are also considered when the entrepreneurs use the new model. For example, co-working companies suffer from foreclosure cases because the entrepreneurs officially state the company's address for their physical existence, and all official documents, statements, and executives are directed to the company. These are the handicaps that exist in current practice, and the new model must be considered. Furthermore, the new model's applicability requires a particular level of business culture in the applied cities or regions. For example, İstanbul, İzmir, and Ankara would be proper, while Antalya and other cities do not apply properly due to their economic activities and inherent business culture.
Q3	Especially the new generations request customization and personalization. Their workplace satisfaction may increase, but the new model must be elaborated to overcome the application-based problems.
Q4	The configuration parameters would be the primary cost items.
Q5	The contract duration regarding the return on investment (ROI) will be described.
Q6	The new model may change the workplace environment and industry. The new roles and responsibilities may open new working and expertise fields.
Q7	The new model is very proper for Gen-Z since they desire high privacy and personalized workplace areas.
Q8	The co-working spaces present numerous activities to increase the network capabilities of the occupant. The same opportunities must be presented in the new model; otherwise, the new model may fail in long-term practices.

Table 5-10. The comments of FM#7 in the interview study

To	Explanations
Q1	Presenting personalization and customization opportunities at the individual level are likely to cause complex facility management and operation situations. Rather than individual level, group level or persona level configuration may be provided in a permanent area, and these ready areas could be presented as a reference to the knowledge workers. Furthermore, allowing preferences for a parameter requires a pool of preferences. Owning, managing, and allocating these preferences in a physical workplace cause another challenge while increasing the cost of the services. Moreover, when the occupant owns the configuration cost, a particular configuration level is presented to the occupant in current practice. However, it is not preferable for the service provider since the individual configuration is out of the standard services of the service provider.
Q2	The cost of the configuration will be a problem. It requires a high level of capital to operate the physical workplace for the service provider, besides allocating some workplaces to store the configuration components. The client looks for low service cost and high comfort and quality. If the cost of the services is acceptable, then the employer may compensate the service cost. The official regulations for business activities require a constant address for entrepreneurship. When the service provider accepts the official responsibilities when a tenant hires and configures a workplace, then formal conditions in case of any claims and responsibilities aroused for the tenant's business activities must be identified and clarified among the service provider and the knowledge worker.
Q3	The applicability of the new model is weak in cities such as Antalya, while it could be implemented in big cities such as İstanbul and Ankara. Considering the number of clients, it is hard to manage and operate the individual-level requests of the clients regarding facility management practices. New roles and responsibilities must be established, including extra service costs.
Q4	The configuration components would be the primary costs.
Q5	The model could be applied when the occupant compensates for the configuration cost. In this case, the occupant decides the contract duration. However, rather than a short-term period, long-term contracts are applicable. The short-term contracts may cause disruptive movements such as the movement of the equipment, installment, and construction, causing noise, dust, dirt, and so on in the offices. It is hard to maintain the comfort of the existing clients in the workplace when these acts happen in short intervals.
Q6	The knowledge worker would be more satisfied. The employer may get rid of dealing with the comfort of the employee. The employer may look for only the performance, which decreases the responsibility of the management of the office staff.
Q7	It could be identified by return on investments (ROI). If the new model is acceptable and affordable to the employer, every industry could use it.
Q8	Business practices are continuously fluctuating. This situation makes it necessary to keep the companies' operation costs low. The co-working concepts are often cheaper options than other alternatives for small and micro-sized companies. The wide acceptance of the new model strictly depends on keeping the operation cost of the services at a low level.

FM #4, #5, #6, and #7 addressed that many co-working workplaces were managed with a limited operation budget in the current market. On the other hand, customization and personalization opportunities require high capital to manage and operate the workplace environment. Owning the configuration cost by the knowledge worker or employer may be a solution; however, such conditions may not fit with the objectives of the proposed model.

The facility managers' comments in this section illustrate practice-based handicaps of the proposed ontology. The facility managers' shared concerns must be overcome during the implementation in the real world. These concerns and handicaps are addressed in the following section by referencing the root factors.

5.3 Findings and Discussions

In workplace services, workplace customization and personalization decisions are made by organizations in the centralized office concept and service providers in the shared desk concept. The literature findings stated that existing practices cannot present a sustainable option to increase the occupancy comfort and wellbeing while decreasing the operation cost of the facility's services using greener technologies. The new workplace service provision model presents a knowledge base to allow knowledge worker-centric workplace services.

This is achieved by uniquely adopting semantic web services where the workplace service stakeholders are brought together, humans and systems collaborate, and the knowledge worker defines and selects workplace comfort and wellbeing parameters. The model allows the flow and transfer of customized and personalized workplace service data through the semantic web interface among systems in the physical workplace, knowledge workers, and service providers.

The findings of the research against the research questions and objectives were presented as follows:

- ***Finding the customizable and personalized workplace services:***

The new workplace service provision model requires personalization and customization of workplaces by knowledge workers. No model or method allows required personalization and customization in literature and practice. Thus, a data collection concept was proposed in the model. The data collector has a new role to collect personalized comfort and wellbeing parameters from the knowledge worker and inspect the physical workplace to identify the workplace service range.

- ***Matching the user persona and workplace services with the most suitable preferences:***

Available user persona and workplace service matching opportunities provide users with a shared level of specification by adopting the idea that “one size for some people.” On the other hand, the research study aimed to find the best matches of workplace and user requirements. Rather than describing workplace opportunities by third parties in current practices, the employee was assigned the role and responsibility of making decisions on workplace comfort desires. Therefore, the motto “one size for a single person” was tried to be achieved.

- ***The new roles and responsibilities of workplace services stakeholders:***

The service provider contracts with the knowledge worker since the knowledge worker would describe the workplace comfort and wellbeing parameters. The new model would be facilitated on the semantic web interface. This may allow participation and integration of all spaces and environments, having the ability to give workplace service into the new model. Rather than focusing on the commercial and financial districts of the cities, a city-wide distribution of workplaces could be achieved.

- ***Finding a method and technique to formalize and represent the proposed model:***

Web ontology models allow formalized representations of the proposed model by establishing class hierarchies, defining object and data properties, and incorporating instances and individuals with object and data properties. Thus, the conceptual model could be formally represented before implementing the real-world model. Furthermore, various verification and validation studies could be accomplished.

The survey study on the knowledge workers validated the needs and requirements of the proposed model in a real-world office workplace environment. The survey results

addressed that the knowledge workers in the market would demand much personalization and customization in the workplace through new technologies.

The knowledge workers particularly liked and desired the user interface demo study. Since certain workplace parameters could be selected and their selections would be viewed and immersed virtually, the understanding and perception of the parameters were outstanding. The participants were very satisfied with the limited number and ratio of preferences in the workplace environment. The study shows that when the selection opportunity could be provided in a semantic web interface, user experience and workplace service satisfaction could be maximized.

Although the proposed workplace service provision model was attractive and desirable by the knowledge worker, facility management practices preserve several challenges. The findings of the interview study as illustrated in Figure 5-8 could be itemized as (i) applicability, (ii) handicaps and problems, (iii) advantages and opportunities, (iv) ideal contract duration, and (v) risks of the new model.

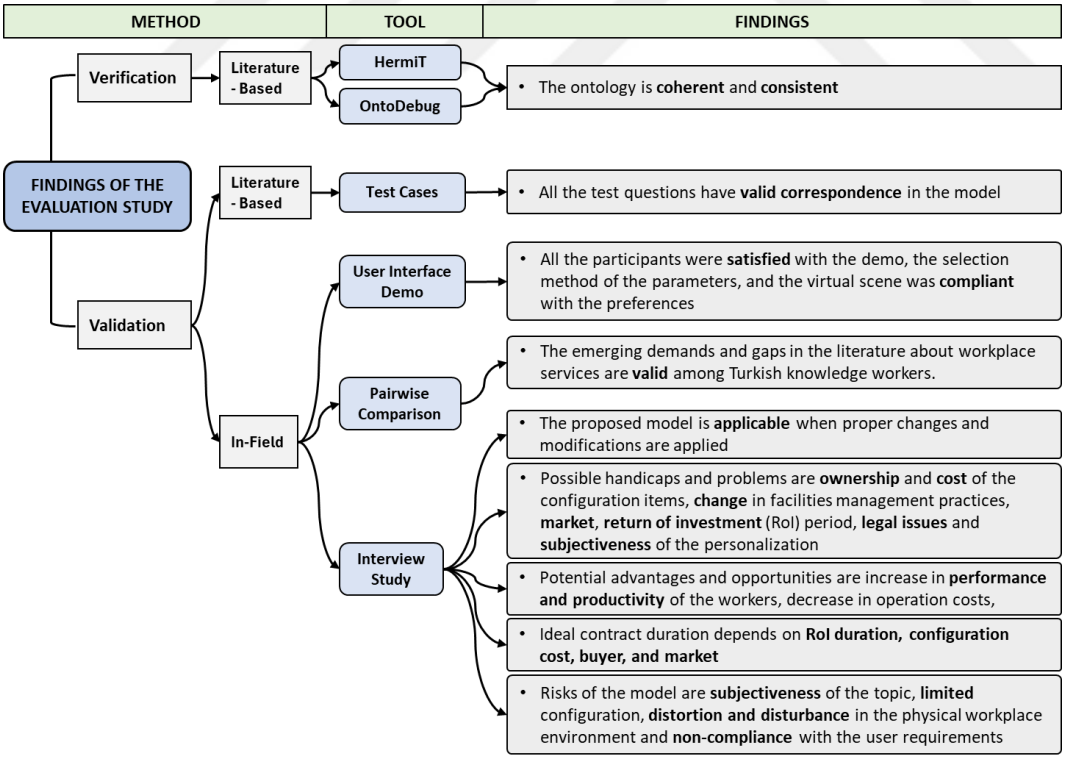

Figure 5-8. Findings of the evaluation study

5.3.1 Applicability of the Proposed Model

Although there are a few differences, all the FMs shared that the proposed model could be applied to workplace service industries by making proper improvement strategies to overcome its deficits. Furthermore, FM #3, #4, #5, and #6 stated that personalization and customization opportunities to the occupants are provided to a particular level where the clients completely decide the configuration in current practice. On the other hand, the configuration cost is completely owned by the client. The FM owns the configuration cost when the return on investment (ROI) period is acceptable.

Similarly, all FMs agree that personalization and customization opportunities must be limited. It is unlikely to manage and operate the physical workplace area of the proposed model with existing facilities management strategies. FM #3 and #4 advise adopting smart management systems and technologies to apply high customization opportunities, while FM #2 and FM #7 consider high customization unnecessary and unrealistic.

Different than others, FM#6 stated that the configured area by the occupant could only be used by the occupant. The shared desk concept could not be worked in this situation. Otherwise, a particular level of security and privacy problems could be aroused among the users of the same configuration in different time intervals. The resulting condition increases the service cost of the personalization and customization opportunities.

5.3.2 Shortages and Problems of the New Model

The handicaps and problems of the new model could be categorized as (i) configuration items and workplace service cost, (ii) change in the facilities management practices, (iii) market, (iv) ROI, (v) legal issues and (vi) subjectiveness of the personalization and customization. Each of these handicaps and problems were discussed as follows:

- **Configuration items and workplace service cost:**

Ownership of the configuration items requires a high level of capital, a specific area to store them, and management of these items regarding the daily customization and personalization practices. FM #4 stated that the physical workplace area could be divided into three to achieve these targets: ready-for-use, configured areas used by the occupants, and reserved areas waiting for configurations. When the service provider owns the configuration item, the service cost would still be affordable compared to existing workplace services.

The second option may be to lease these configuration items from manufacturers, as FM#2 mentioned. In this case, the service provider eliminates ownership costs, increasing the initial investment cost of the physical workplace area and allocating a specific area to store these items. On the other hand, a proper logistic system must be established to browse these items in the required time to the required place. In this case, the service cost would be increased due to increased service parameters.

The third option is owning the configuration cost by the occupant / the knowledge worker. Then, the workplace service cost for the service provider remains low while the initial investment cost of the workplace area is high for the knowledge worker. This option requires the allocation of the configured area by only the configurator occupant, as FM#4, #5, and #6 have mentioned. Otherwise, specific in-use-related problems and handicaps may occur regarding security and privacy. This situation does not allow a shared workplace concept, increasing the operation cost of the physical workplace area for the service provider.

FM #1 depicted that the buyer of the services is another important topic. When the employer provides the cost of the services, the knowledge worker may look for his/her satisfaction and comfort. This situation may lead to excessive operation costs. In the reverse case, the knowledge worker may have a limited budget where the available configuration opportunities may not be satisfactory for the knowledge worker.

- **Change in the facilities management practices:**

The change at the scale of the facilities management practices occurs in two phases. Firstly, existing facilities management practices are used to give standard services with standard equipment and devices to all clients in the physical workplace area. New configurations mean new facilities management practices requiring individualized services rather than standard services. Secondly, existing facilities management practices consider the entire physical workplace area to give standard services. On the other hand, the new model requires zone-based approaches where there will be many different sizes and scaled zones within the same physical workplace area to be considered.

The changes at the scale of the facilities management practices bring extra roles and responsibilities. As stated by FM#4, a construction or installation team must prepare the workplace configurations. A similar concept is applied in the centralized office concept, as mentioned by FM#3, where the tenant hires a raw area and makes an initial design and construction study to prepare the workplace area. On the other hand, the tenant executes these configuration studies for longer contract durations, such as a year or years, in wide workplace areas, while the new model promotes short-term occupation in the workplace configurations. The short duration of the configuration means construction and installment works, noise, dust, and dirty activities in the physical workplace area can disturb the other occupants and complicate the management of the overall progress, as FM #7 has mentioned.

- **Market:**

All FMs agree that the new model could not be implemented in every business market. The market must have a particular level of economic and business activities, including high creative works and value-added activities. For example, FM #5, #6, and #7 expressed that, in Turkey-specific conditions, the new model could be applied in big cities such as İstanbul, Ankara, and İzmir but could not be implemented in Antalya and other cities.

Not all industries are proper for applying such a new model. Knowledge workers in creative industries, social media experts, influencers (social media advertisement), architecture, engineering, finance, and similar white-collar sectors are proper, while civil service workers are not.

The FM #3 argued that marketing and advertisement of the model are important to be widely accepted in the business world. The need for the model, expectations, and contributions of the model must be introduced.

Social and cultural aspects of the business society are crucial to defining and describing the workplace comfort and wellbeing parameters. Since the understanding, perception, needs, requirements, and priorities are changing from country to country, local factors must be clarified. It is not likely to describe comfort and wellbeing parameters compliant with all countries.

- **Return of Investment (ROI):**

The business industry looks to gain profit from their daily practices. The business industry considers the ROI period to invest in a particular field. The ROI period must be low to accept that an investment is tradable. The companies invest in their staff's physical workplace environment because the ROI period is acceptable for the company. FM #4, #6, and #7 stated that the business industry would likely look at the new model from the ROI perspective. The cost and benefits of the workplace configuration must be tradable by keeping the ROI period in an acceptable time. The ROI period may change regarding the business sector. Therefore, before implementing the new model, a comprehensive ROI study must be done for each sector to state that the new model is tradable compared to the organizations' existing workplace services.

- **Legal issues:**

FM #6 and #7 mentioned that co-working companies take their tenants' legal responsibilities, which means that all official documents, statements, and executives directed to the entrepreneurs are monitored and received by the co-working

companies. Sometimes, a foreclosure may be executed in the co-working companies, causing legal issues. It is a time-consuming activity for the co-working companies to prove that although the co-working company receives the official documents, the assets of the co-working company in the physical address do not belong to the tenant. The new model must consider such legal issues to not fail in practice and not cause any disputes and claims.

- **Subjectiveness of the personalization and customization:**

FM #2 and FM #7 strongly stated that personalization and customization are subjective matters on which the facilities management practices should not rely. There may be cases in which the knowledge worker makes a configuration, and soon after, he/she may get annoyed and ask to change the configuration. When these changing durations become short, or allowing deep-level personalization may cause chaotic circumstances for the knowledge worker and service provider. The results may be dissatisfaction of the stakeholders.

Therefore, rather than presenting individual-level personalization, FM #2 and #7 insist on preparing diverse workplaces fitting the certain needs of the individuals and giving standard services. Another concern of these FMs is that giving personalized services may distort the standard of the services, and this case may cause potential claims and disputes between the service provider and occupant to deal with giving and taking satisfactory services. Since the services are personalized, the occupant may claim taking unsatisfactory services while the service provider claims vice-versa.

Considering the competitive characteristics of the business world, FM #1 indicated that the knowledge workers may start to compare the configurations of their colleagues. This sense of jealousy may cause dissatisfaction among employees and distort the logic and targets of giving personalization and customization opportunities to the employees.

5.3.3 Advantages and Opportunities of the New Model

All of the FMs share the idea that the new model has particular advantages to the knowledge worker and employer in terms of productivity and performance of the employee when customization and personalization opportunities are provided to the workers. When it properly works, the new model decreases the employer's operational cost, similar to the co-working services.

Providing certain workplace preferences and configuration opportunities would increase productivity, organizational commitment, and trust between employer and employee. On the other hand, the social and communal background of the new model must be established and support the new model. Another concern at this point is that people may start to compare each other’s opportunities since the business world is dominated by ambition and competition.

FM#6 stated that the proposed model is very much appropriate to the characteristics of Gen-Z. Gen-Z looks for in-person relationships, prioritizes privacy, and has a specific workplace area.

FM #3 expressed that small and micro enterprises suffer from initial investment costs required to operate the companies. Owning expensive but rarely used office devices and equipment presents a particular level of cost concerns for enterprises. Because owning these assets is expensive, while not owning them presents handicaps for productivity within the company. Similar to the co-working concept, the proposed model may decrease these operation cost concerns of small and micro enterprises by allowing leasing opportunities.

FM #3, #4, #5, and #7 mentioned that a particular level of workplace configuration has already been presented in the current practices. However, the configuration opportunities were provided when the user owned the ownership of the expenditures. Moreover, the existing practice has not had deeper flexibility when compared to the proposed model. On the other hand, the available practices demonstrated an even limited demand for personalization, and a certain level of practice has already been

applied in the market. This may decrease the proposed model's adoption time among the service providers.

5.3.4 Ideal Contract Duration for the New Model

All of the FMs agreed that some factors affect the ideal contract duration. These are (i) the ROI duration, configuration cost, buyer, and market. FM #4, #5, #6, and #7 stated that the ROI duration is the key factor in determining the ideal contract duration. On the other hand, FM #3, #5, and #7 share the same opinion that the cost of the configuration describes the ideal contract duration. FM #1 and #5 argued that the buyer of the services is the key factor in describing the contract duration. Due to the conflict of interests, the employer may seek cost efficiency while the employee may desire his/her maximized comfort. FM#1, #2, #3, and #4 provided a minimum contract duration of 6 months, one year and two years. Furthermore, FM #2, #3, and #6 consider the market conditions in describing the ideal contract durations. When the demand is high, the tenants may desire to make long-term service contracts, while in reverse cases, the tenants may deal with very short-term contracts.

5.3.5 Risks of the New Model

The new model consists of many risks at various implementation levels. The personalization and customization idea may fail if these opportunities are not properly presented among the employees. It is unclear to state the optimum duration for allowing change of the workplace configuration as FM #2 and #7 addressed. When social and communal opportunities are not provided, or the knowledge worker cannot benefit from these services, the model may cause isolation of the users, and thus, the model may fail, similar to telecommuting practices.

Personalization and customization require an asset pool that the knowledge worker can select. The personalization and customization levels need to be identified. Other users may not welcome individual-level configurated elements. In this case, as

mentioned by FM #2, what will be the aftermath of these elements after being used by an occupant and not preferred by another occupant for a long period? Besides asset management problems, there may be an unnecessary waste of the configuration assets.

The new model may present limited configuration opportunities to the knowledge worker due to the service costs. In this case, the new model may not be unique compared to the co-working practices. Another risk in this case would be that personalization and customization opportunities may remain within a specific industry and may not have further expansion and wider acceptance among business industries. This situation prevents the practices from reaching the targets of the proposed model.

The configurations requiring construction and installment activities may cause distortion and disturbance within the physical workplace environment. Managing these activities while maintaining the comfort and wellbeing of the existing occupants in the same place may be unrealistic, as FM #2 and #7 have mentioned. In this case, the proposed model could not be performed in shared workplaces. Instead, the service provider prepares a limited number of workplace configurations and gives services only for those areas outside the scope of the objectives of the proposed model.

FM#3 expressed that the local conditions, business culture, and social priorities must be considered in determining the configuration parameters. Otherwise, the model will likely fail or perform poorly due to non-compliance with the user requirements.

The challenges mentioned above were collected from facility managers in the interview study. Their concerns and suggestions address the implementation steps of the proposed model in the real world. This means that, although the proposed model was semantically established, verified, and validated, implementation in the real world requires extra effort to adapt the model to local factors. During the implementation, the feedback that would be collected from the industry stakeholders are the key critics to consummate the study.

5.4 Limitations and Future Implementations

The full implementation of the proposed model could not be achieved during the research phase. On the other hand, the following items are anticipated as the limitations and handicaps for future implementation of the proposed model:

- The data collection lab is unique, although the data collection methods are available technics in literature and practice. Integrating the data collection methods in the data collection lab may present real-world application-related challenges.
- The investment cost for building a data collection lab would be expensive due to the required devices, equipment, and expert personnel.
- A data collector is required to facilitate the data collection lab. The required skills and expertise may be changed considering the data collection methods.
- The web ontology models could be easily adopted and used in semantic web applications. Although the main ontology was established, the verification and validation were achieved, and further developments and additions may occur during the realization stages.
- The semantic web interface proposed in the model incorporates many concepts and thus facilitates diverse systems, technologies, devices, and people. Therefore, realizing the semantic web interface may require high-level web programming and software engineering skills and expertise.
- The realization of the proposed model may bring challenging roles and tasks in the physical workplace environment as the facility managers were addressed and referenced.
- Adopting the proposed model in a physical workplace environment requires implementing many systems and technologies such as AmI, semantic web, and smart contract.
- The handicaps and problems referenced by the facility managers are managing the configurable assets, service cost, legal issues, subjectiveness of the personalization and customization, market conditions, and return on

investment (ROI) period. These statements are also accepted and considered as limitations.

CHAPTER 6

CONCLUSION

This research has focused on conceptualizing and formally describing a new workplace service provision model. A working scenario was established, and the entities required for the model were clarified. Rather than permanent workplaces where the workplace configuration was done by third parties, temporary workplaces where the knowledge worker did the configuration of the workplace environment were described. Potential and usable workplace comfort and wellbeing parameters were collected from the literature. Occupant data collection methods were identified and assigned for each comfort and wellbeing parameter. A data collector and service provider role were proposed. The data collector acquires workplace comfort and wellbeing parameter data from the knowledge worker and the physical workplace. Both parties could manipulate the collected data to create workplace configurations to take and give workplace services. Each configuration could be marketed in semantic web applications.

The knowledge worker and service provider deals could be done using smart contracts. A special purchasing process was created and coded for the smart contract. The workplace service configuration sets were transformed into workplace service provision in smart contracts. When both parties confirmed the services, the workplace configuration was booked for the knowledge worker in the physical workplace regarding the appointed time interval. The service provider prepares the workplace for the occupation of the knowledge worker. The workplace configurations of the knowledge worker were continuously tracked and monitored using AmI technologies. A special algorithm was prepared for the operation of the AmI during the in-use of the workplace by the knowledge worker.

After the verification and validation of the web ontology model in the ontology editor, real-world validation studies were accomplished. The arguments and requirements of the proposed model were directed at the knowledge workers in a co-working office workplace. Their answers and preferences in the survey study have paralleled the emerging needs and demands of the knowledge workers in the literature. A user interface demo was prepared and tested with the same knowledge workers. The participants could select a couple of workplace preferences, and at the end, their preferences were reflected through a virtual scene where the user could be immersed. Then, the reflectance level and the perception of the configured preferences were asked. All of the participants were satisfied with the test.

In the last step of the real-world validation, the logic of the proposed model was expressed to the facility managers. The facility manager's comments addressed many application-based challenges and referenced how to implement the model in the real world. The facility managers shared that the proposed model could be implemented in the real world when these application-based deficits and local adaptations of the model could be overcome. Furthermore, some of the implementation-based problems were also identified.

The management of the configuration items, workplace service cost, change in the facilities management practices, market conditions, return of investment (ROI) period, legal issues, and subjectiveness of the configuration concept are the key handicaps stated and mentioned by the facility managers.

The increase in productivity, commitment of the knowledge worker to job and employer, increase in the trust between employer and employee, decrease in the initial investment cost of the entrepreneurs, and compliance to the characteristics of Gen-Z are the key advantages referred by the facility managers.

On the other hand, the proposed model consists of many risks in diverse implementation levels. The risks stated by the facility managers are:

- The configuration frequency must be low, and the configuration duration must be long.
- The determination of the way to manage the required asset for the configuration opportunity.
- Resulting in high service cost
- Management of the configuration within the workplace environment without disturbing the existing users.
- Compliance of configuration parameters to local conditions, business culture, and social priorities.

6.1 Contributions of the Study

The unique and value-added contribution of the proposed workplace service provision model regarding the evaluation study were listed as follows:

- A workplace setting is a unique and comprehensive data set specific and personalized for a knowledge worker depicting the business operation and contractual duration.
- The workplace service range is a unique and comprehensive data set specific and personalized for service providers representing the operational capacity of the workplace environment for the potential knowledge workers.
- Current marketplace websites are based on single ad archiving where a party posts an ad, and another party buys the ad. It is possible to browse specific ads regarding the properties and attributes of the item or product in the ad. On the other hand, the system is established upon single ad archiving where the buyer ad is not matched with the seller ad. Instead, the proposed ontology presents two separate post-archiving as workplace sets and services. Matching a specific workplace set with services or vice versa is possible.
- It is another unique opportunity for the workplace dataset to be transferred from the website to the service provider's AmI system so that the knowledge

worker can be continuously monitored, and his/her comfort can be maximized.

- Existing offices providing workplace services are static design, with limited alteration opportunities outside IEQ parameters. This is because the entire workplace is designed and ready for use. The proposed ontology offers "statuses" for operating and managing the physical workplace where the statuses are in use, ready for use, and to be ready. To-be-ready status is devoted to the installation area where workplace sets outside the available service limits could be installed at this reserved area.
- The proposed ontology allows the use of smart contracts for purchasing and agreement. Therefore, the workplace setting is transformed into provisions of the ontology; each smart contract will be different. Rather than using standard service contracts at existing use, each workplace will have a specific smart contract between the knowledge worker and service provider.
- Maximizing personalization and customization can increase employee comfort and productivity.
- The proposed model allows storing personal workplace settings in the semantic web environment. This means the knowledge worker can ask for a personalized workplace wherever and whenever required.

6.1.1 Contribution to Workplace Stakeholders, Cities and Sustainability

The proposed model eliminates the need for home and central offices to perform the job. Instead, the knowledge worker can select any workable places as alternatives available in the neighborhood. Like teleworking and working from home (WFH), this opportunity will likely eliminate the required communal and non-communal trip for the knowledge workers within the city, thus likely decreasing the transportation time and cost to access the office workplace. The time and cost spent on transportation could be directed to the personal expenditures of the knowledge worker.

Since the knowledge worker in the proposed model could decide the workplace location, the knowledge worker can select the transportation type, such as biking, walking, and so on, offering a greener and more sustainable lifestyle. This will eliminate the traffic scrawl, CO2 emissions, and noise in the cities and is likely to change the regular flow of the city's traffic in the morning and evening.

In the current metropolitan cities, the business zones of the knowledge workers are located in specialized areas. The COVID-19 pandemic has shown that current infrastructure in dwelling zones can perform certain job tasks and education. Although there were negative outcomes due to strict regulations and enforcement, the pandemic has proved that certain tasks could be executed in digital and virtual platforms due to the digitalization of the world for a couple of decades.

When the proposed model is widely implemented, the entire city could be a workable environment. The social, cultural, and communal infrastructure in the city's primary commercial and business zones may be required to be dispersed within the city and city skirts. The new model can change the city context by changing the central business and commercial district concept to decentralized business and commercial zones, presenting more equality, accessibility, and diversion with greener approaches.

The centralized office concept in the current practices occupies 70% of the workable area, and the remaining ratio is preserved for deviations of the staff (Hirst, 2011; Kleeman, 1992). This means that 30% of the workable area is not used. Regarding real estate and operation costs in the centralized office concept are particularly high, the proposed model has a chance to eliminate the unoccupied workable area. Instead, the employees will occupy the required workplace area, and the employer may pay for only the occupied area's real estate and operation costs. Other knowledge workers employed by other initiatives may hire the unoccupied areas of the organization. This situation presents more

efficient use of the resources during business operations, thus contributing to greener business operations.

Since the social, cultural, and communal opportunities of the central business areas are limited in and not spread to other zones of the city, the proposed model includes the architectural aspects and characteristics of a workplace. When the new model is widely implemented, the workplace comfort and wellbeing parameters may change to working environment parameters by including social, cultural, and technical characteristics. In other words, the proposed model can evolve the creation, designation, and configuration of personalized and customized working environments by the knowledge workers.

6.2 Future Remarks

The proposed workplace service provision model was developed, and a formal model description was represented. A couple of verification and validation studies were accomplished. The study allows the knowledge worker to configure his/her workplace by giving particular flexibility to the time and place to work. Since the alternative workplace options were increased in the post-pandemic era, this study established a model ready for implementation. The workplace comfort and wellbeing parameters could be changed and adapted to local factors.

It is anticipated and referenced by the facility manager that, during the real-world implementation, the established model could be revisited by minor changes. Occupant data collection roles and responsibilities must be elaborated to be particular and descriptive. Although it was not addressed in the interview study, occupant data collection opportunities would be a limitation in identifying the workplace comfort and wellbeing parameters. Thus, further research is required to clarify occupant data collection for this study.

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Zhu, Y., Saeidi, S., Rizzuto, T., Roetzel, A., & Kooima, R. (2018). Potential and challenges of immersive virtual environments for occupant energy behavior modeling and validation: A literature review. *Journal of Building Engineering*, *19*(January), 302–319. https://doi.org/10.1016/j.jobe.2018.05.017

Zouaq, A., & Nkambou, R. (2009). Evaluating the generation of domain ontologies in the knowledge puzzle project. *IEEE Transactions on Knowledge and Data Engineering*, *21*(11), 1559–1572. https://doi.org/10.1109/TKDE.2009.25

CURRICULUM VITAE

Surname, Name: Sarı, Ramazan

EDUCATION

Degree	Institution	Year of Graduation
MS	METU Building Science	2017
BS	METU Department of Architecture	2012
High School	Atatürk High School, Antalya	2006

RESEARCH INTERESTS

Energy Efficiency, Building Information Modeling (BIM), Construction Systems and Technologies, 3-D Printing in Construction, Web Ontology Models, Workplace Services, Service Provisions, Smart Contracts

PUBLICATIONS

Journal Articles

1. **Sari, R.**, Çalişkan, E., B., (2022). 3-Boyutlu İnşaat Yazımı ile Hızlı ve Güvenilir Barınma Çözümleri. Digital International Journal of Architecture, Arts & Heritage, 1(1), 88-112
2. **Sari, R.**, Pekeriçli, M., K., (2020). An investigation of comparison and evaluation of official BIM documents released in the USA, UK, and Turkey. Journal of Construction Engineering, Management Innovation, 3(1), 67-84., Doi: https://doi.org/10.31462/jcemi.2020.01067084

Conference Papers

1. **Sari, R.,** Pekeriçli, M., K., (2022). A New Approach for Workspace Service Provision. Nextbuilt: Challenges for the Next Generation Built Environment.
2. **Sari, R.,** Caliskan, E., B., (2021). Impact of Remote Working upon User's Wellbeing. 4th International Symposium on Art and Design Education: Art and Design during and after the Covid-19 Period, 488-496.

3. **Sari, R.,** Pekeriçli, M., K., (2020). An Investigation on Benefit-Cost Analysis of Greenhouse Structures in Antalya. 6. International Project and Construction Management Conference (IPCMC)
4. **Sari, R.,** Pekeriçli, M., K., Tanyer, A., M., (2018). Compliance of Standard Forms of Construction Contracts and Protocols with BIM-Adopted Construction Sector in the USA and UK. 5. International Project and Construction Management Conference (IPCMC), 620-628.
5. **Sari Ramazan**, Aybek, H., (2018). An Investigation on Digital Wind Tunnel Simulation Study on Urban Scale and Urban Transformation. International Symposium on Problems of Urbanization and Environment: Change/Transformation/Originality, Eskişehir / Turkey
6. Aybek, H., **Sari, R.,** (2017). Evaluate and Measure Performance of the Building Design to Reduce Energy Consumption. Recent Advances in Energy Conservation Techniques for Buildings Workshop: From Micro Scale to Urban Level.
7. **Sari, R.,**,Pekeriçli, M., K.,Tanyer, A., M., (2017). Türkiye'deki Mimarlık ve Mühendislik Firmalarında Yapı Bilgi Modellemesi OlgunluğuÜzerine Bir Araştırma. XI. Mimarlıkta Sayısal Tasarım Ulusal Sempozyumu - MSTAS 2017, 214-227.

Technical Skills

BIM Tools: Autodesk Revit (Architecture-Structure-MEP), Autodesk Navisworks Manage, Tekla Structures,

Simulation & Analysis: Autodesk Green Building Studio, Autodesk Insight, Autodesk Flow, Autodesk Robot Structural Analysis, Autodesk

Vector Drawing & Visualization: Autodesk AutoCAD, SketchUp, Adobe Photoshop

Web Programming Languages and Editors: Solidity – Remix IDE, HTML & CSS – Visual Studio Code.