Dissertation

学 位 論 文

Visualization System of Energy-saving for Smartification in Urban and building planning

都市・建築計画におけるスマート化を目指した省エネルギー効果の可視化

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ABSTRACT

The purpose of this Ph.D. research is in order to clarify how to realize energy saving visualization in architectural space and urban space, establish visualization system of energy-saving for smartification in urban and building planning.

Since the industrial revolution in the 18th century, economic and social development has been accompanied by the problem of "energy consumption". As the main energy-consuming industries, cities and buildings have attracted much attention. Whether it is from the perspective of planning full-cycle management or from different urban space dimensions, there are clear requirements for energy saving. As mentioned in the previous table, the main energy consumption is reflected in industry, household, business, transportation, etc. This research will discuss how to reduce energy consumption through visualization from these aspects. For example, from the perspective of different spatial scales, there are requirements for energy saving in urban space, underground space in the city, and architectural space. Such as urban space， underground space, architectural space, including sound, light, heat and other architectural five senses, as well as the use of various smart devices, and the use of plot energy such as solar energy have been researched in the past. As in homes and offices, many energy devices are in operation in order to live and work comfortably and efficiently, which is a major source of CO_2 emissions. In order to significantly reduce the energy load, it is important to design the building so that the cold and warm air inside the building does not escape and solar energy and natural wind are taken into the building. In order to popularize such buildings, it is effective to implement measures to reduce the economic burden on those who introduce them, and to introduce environmental performance evaluation systems and labeling systems for buildings. High thermal insulation of buildings reduces temperature differences in rooms and makes it possible to supply high-quality heating using radiant heat, etc.。

However, for how to carry out energy-saving design of smart urban space and urban space and how to figure out the construction of building space， and how to apply smart technology in urban space when planning compilation before planning implementation， how to make the Energy Consumption Simulation and Design Phase Evaluation on Air-Conditioning System of The Intelligent and Healthy Building and how to apply the

task and ambient air condition for building environment before planning implementation are not mentioned in the previous studies.

From the perspective of planning and design full-cycle management, planning and design full-cycle management includes five stages: status analysis, planning goal setting, planning preparation, planning implementation, and planning evaluation. The analysis of the status quo includes analyzing the basic situation and existing problems of the city and buildings. Secondly, through the establishment of the indicator system and the extraction of indicators, the planning goals are set. Thirdly, through planning compilation, it is determined how to implement the planning and design. Finally, the planning is evaluated.

However, the aforementioned studies did not focus on how to carry out energy-saving planning in each stage of the planning and design full-cycle management, and how to use visualization in different spatial sizes to conduct energy-saving simulations before planning implementation.

Therefore, this research is dedicated to the design of zero-energy smart city space and the establishment of intelligent perception design standard for active and passive design methods in buildings and urban spaces in different urban space scales based on the planning and design

full-cycle management. standard. In order to ensure low energy consumption requirements in the stages of design planning, construction implementation and maintenance, build a building environment visualization system, simulate and analyze the building environment, implement management of the city and building space, and finally control the low-carbon energy saving of buildings and urban components Efficiency is evaluated.

Based on the full-cycle management of planning and design, through the visualization simulation of urban space and building space intelligent energy saving, in order to achieve different spatial scales, how to reduce energy consumption through visualization in each stage of planning and design , there are the following methods.

First, set planning objects and goals, and establish an energy-saving index system

Besides, Clear planning and design guidelines are the basis for planning compilation and planning implementation.

Furthermore, Visual simulation of the energy system consumption of the overall building space can reduce energy consumption in the planning, implementation and management stages.

Finally, Energy visualization simulation of air conditioning consumption in a built environment. Serve as the basis for the last step in the planning lifecycle management (planning evaluation). Planning evaluation is not only the management of the smooth implementation of planning and design, but also an important method and means for predicting and early warning of urban and architectural space utilization.

Through this research， clarify the requirements for energy-saving visualization at each stage of planning, sort out energy-saving related indicators, establish an evaluation index system for urban and architectural space implementation, and finally evaluate the implementation effect of planning in architectural space, and achieve energy-saving effects through visualization

Keywords. Full cycle management of planning and design , Building Energy Efficiency ,Energy Saving Visualization, urban space, architectural space, spatial scale

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Chapter 1 Introduction

1.1 Research background

As human activity expands in recent years, large amounts of greenhouse gases such as carbon dioxide and methane are artificially emitted into the atmosphere, threatening to cause excessive global warming. In particular, a huge amount of carbon dioxide is anthropogenically emitted by burning fossil fuels.

Japan's total greenhouse gas emissions in fiscal 2010 were approximately 1,258 million tons. This is 0.3% lower than the total emissions in the base year specified in the Kyoto Protocol. It also increased by 4.2% compared to the previous year.

Looking at each greenhouse gas, carbon dioxide emissions in fiscal 2010 were 1,192 million tons (up 4.2% from the base year). Looking at the breakdown by sector, emissions from the industrial sector were 422 million tons (down 12.5% year on year). In addition, emissions from the transportation sector were 232 million tons (up 6.7% year on year). Emissions from business and other sectors amounted to 217 million tons (an increase of 31.9% year on year). Emissions from the household sector amounted to 172 million tons (up 34.8% year on year).[1]

Table 1-1 Based on the whole cycle of planning, the spatial scale change of the research target and the change of the field of low-carbon society

Full-cycle management system	**chapters**	**Spatial scale**	**In the field of low-carbon society (reduction amount based on CO_2).**
Planning objective and planning compilation	Chapter 2	Urban space	Industry ,business and others , transportation， household
1：Explore the energy-saving policy as planning objectives	Chapter 3	Urban space	Industry
2 : Before planning implementation	Chapter 4	Underground space in the urban space	Industry
	Chapter 5	Architectural space in urban/underground space	Industry， household

[1] According to the <Ministry of the Environment's Establishment of a Low-Carbon Society>, Ministry of the Environment

	Chapter 6	The building environment in the building space	Industry, household Business and others

Since the industrial revolution in the 18th century, economic and social development has been accompanied by the problem of "energy consumption". As the main energy-consuming industries, cities and buildings have attracted much attention. Whether it is from the perspective of planning full-cycle management or from different urban space dimensions, there are clear requirements for energy saving. As mentioned in the previous table, the main energy consumption is reflected in industry, household, business, transportation, etc. This research will discuss how to reduce energy consumption through visualization from these aspects. For example, from the perspective of different spatial scales, there are requirements for energy saving in urban space, underground space in the city, and architectural space. Such as urban space , Zhang, Y. et al. developed a land-use planning support system based on three types of indicators: the population recovery, the degree of land-use mix, and the degree of land-use specialization at the urban scale [1]; Teng, X. et al. proposed an intelligent access service management system for personal information collection based on isolated island [2]; underground space, Shen, Z. et al. compiled guidelines for sensor installation in underground spaces based on the characteristics of different types of underground spaces [3];underground space , Shen, Z. et al. compiled guidelines for sensor installation in underground spaces based on the characteristics of different types of underground spaces [3]; architectural space, including sound, light, heat and other architectural five senses, as well as the use of various smart devices, and the use of plot energy such as solar energy have been researched in the past . Fitriaty, P. et al. presented a 3D daylight color rendering using BIM Revit solar analysis tool to analyze the potential for PV installation on residential building envelopes in equatorial regions [4] while proposing that the optimal location for installing PV panels was on the roof of a building where incident solar radiation levels are high and uniform throughout the year [5].As,in homes and offices, many energy devices are in operation in order to live and work comfortably and efficiently, which is a major source of CO_2 emissions. In order to significantly reduce the energy load, it is important to design the building so that the cold and warm air inside the building does not escape and solar energy and natural wind are taken into the building.Shen, Z. et al. proposed a framework for a house solar energy management system through environmental and behavioral analysis [6]; Tutuko, P. et al. used the house as a base unit aiming to eventually achieve a sustainable urban form [7]. In order to popularize such buildings, it is effective to implement measures to reduce the economic burden on those who introduce them, and to introduce environmental performance evaluation systems and labeling systems for buildings. Zhang, Y. et al. proposed a computational model aimed at forming an energy efficiency evaluation system by using principal component analysis (PCA) [8]; Zhao, L. et al. also determined the relationship between the building or built environment and physical activity by specifying variables such as the time of moderate to vigorous physical activity (MVPA) and the correlation between activity [9]. High thermal insulation of buildings reduces temperature differences in rooms and makes it possible to supply high-quality heating using radiant heat, etc.。

However, for how to carry out energy-saving design of smart urban space and urban space and how to figure out the construction of building space， and how to apply smart technology in urban space when planning compilation before planning implementation， how to make the Energy Consumption Simulation and Design Phase Evaluation on Air-Conditioning System of The Intelligent and Healthy Building and how to apply the task and ambient air condition for building environment before planning implementation are not mentioned in the previous studies.

From the perspective of planning and design full-cycle management, planning and design full-cycle management includes five stages: status analysis, planning goal setting, planning preparation, planning implementation, and planning evaluation. Yamato, Y. et al. also confirmed the priority level of facilities (required activity spaces) for planning evacuation spaces and educational spaces from the process of current status analysis, goal setting, planning preparation, planning implementation, and planning evaluation [10]. The analysis of the status quo includes analyzing the basic situation and existing problems of the city and buildings. Zeng, F. et al. from the perspective of the analysis of the current state of the built environment, identified the content of changes in the walkability of the built environment and changes in the walking behavior of the inhabitants through a longitudinal and quasi-longitudinal approach [11]; Aini, N. et al. start from the analysis of the status quo tree planting locations in the built environment and clarify the relationship between the design of tree planting locations and the reduction of CO2 diffusion [12]; Dan, Y. et al. also from the perspective of the current environment, analyzed the possibility of using mixed reality

(MR) technology to improve the designer's live design experience in order to enable design in the existing environment [13]. Secondly, through the establishment of the indicator system and the extraction of indicators, in order to set the planning goals ,Guo, X. et al. by sorting out the requirements for the layout of the indicator and room of artificial intelligence (AI) products, clarified the objectives of the layout of intelligent products, and proposed the layout of intelligent products [14]; Sugihara, K. et al. obtains the final conclusion by sorting out the environment-related indicators of solar photovoltaic power generation, acquiring the indicator data and analyzing them through an integrated system of geographic information system (GIS) and CG [15].Thirdly, through planning compilation, it is determined how to implement the planning and design. Shen, Z. et al. presented the difficulties of implementing planning design through planning preparation from the analysis of challenges and opportunities facing port development [16]. Finally, the planning is evaluated. Aini, N. et al. proposed the design of tree planting pattern through a previous study of tree planting locations [17]; Dan, Y. et al. implemented a live design of a community park using mixed reality (MR) tools [18]. Finally, the planning is evaluated.Aini, N. et al. proposed the design of tree planting pattern through a previous study of tree planting locations [17]; Dan, Y. et al. implemented a live design of a community park using mixed reality (MR) tools [18]

However, the aforementioned studies did not focus on how to carry out energy-saving planning in each stage of the planning and design full-cycle management, and how to use visualization in different spatial sizes to conduct energy-saving simulations before planning implementation.

Therefore, this research is dedicated to the design of zero-energy smart city space and the establishment of intelligent perception design standard for active and passive design methods in buildings and urban spaces in different urban space scales based on the planning and design

full-cycle management. standard. In order to ensure low energy consumption requirements in the stages of design planning, construction implementation and maintenance, build a building environment visualization system, simulate and analyze the building environment, implement management of the city and building space, and finally control the low-carbon energy saving of buildings and urban components Efficiency is evaluated.

1.2 Research purpose.

In order to achieve intelligence, for urban space and architectural space, the full-cycle management of planning and design is used as the carrier to carry out visualization research on energy saving effects.

1.3 Research method

This study is based on the full-cycle management of planning and design, through the visualization simulation of urban space and building space intelligent energy saving, in order to achieve different spatial scales, how to reduce energy consumption through visualization in each stage of planning and design , there are the following methods.

Step 1: Set planning objects and goals, and establish an energy-saving index system

Step 2: Clear planning and design guidelines are the basis for planning compilation and planning implementation.

Step 3: Visual simulation of the energy system consumption of the overall building space can reduce energy consumption in the planning, implementation and management stages.

Step 4：Energy visualization simulation of air conditioning consumption in a built environment. Serve as the basis for the last step in the planning lifecycle management (planning evaluation). Planning evaluation is not only the management of the smooth implementation of planning and design, but also an important method and means for predicting and early warning of urban and architectural space utilization.

Clarify the requirements for energy-saving visualization at each stage of planning, sort out energy-saving related indicators, establish an evaluation index system for urban and architectural space implementation, and finally evaluate the implementation effect of planning in architectural space, and achieve energy-saving effects through visualization

1.4 Dissertation organization

First of all, through the Design of a Smart Visiting Service Management System in an Isolated Island, this research is committed to clarifying in the overall urban dimension, through the planning of the urban smart service system and smart infrastructure system, urban space design, in the industry, commerce, transportation, and households, which mainly generate carbon dioxide, conduct visualization research in the design stage of energy-saving effects.

1.4.1 . *Design of a Smart Visiting Service Management System in an Isolated Island*

Presently, smart city constructions have been implemented in many cities around the world as pilot urban development, however, the issue of cyber security and privacy of big data in cyber-physical-social systems is rising too [19]. Big data is the sensor-based product of Information Communication Technology (ICT) [20] collected from all smart devices and Internet of Things (IoT) in urban and building spaces, that has the ability to change the lifestyle of a human, and also cause a significant effect on the usage of urban and building spaces [21]. Thus, big data and its smart services will create a new trend of designing smart buildings in the near future, due to the providing of the new smart services in daily life to people based on their personal information [22]. In this paper, we consider the smart city project on Huangguan Island as the case study for analyzing the kinds of personal information used, and how the relatively big data standing for individual activities can be synergized in the system design of smart visiting service management systems.

Li et al. [23] determined the definition of smart tourism as an individual tourist support system within the context of information services and an all-encompassing technology. In this case study, the current approach to the development of the smart visiting service management system (SVSMS) is discussed to identify the principles of personal information collection, and if it is possible to synergize

the personal data in an integrated database system, where personalized smart services can specify the personal information between each other on the isolated island.

From a viewpoint of big data usage in smart management services, personal information collected by many smart devices and IoT sensors in urban spaces is very helpful for the urban management [24]. Big data analytics have been widely implemented in marketing and business innovation processes, which also create business value at a larger scale [25]. Urban planning and design will be changed greatly by the application of big data, as a result of the urban management services' ability to be improved in many aspects by using that data [26]. Andreani et al. [27] offers an alternative perspective to a design-driven and human-centered smart city approach. Therefore, even though ICT has provided new data sources for the urban management, integrating these new data sources for providing smart services to planning and designing with collected personal information still remains a challenge. Thus, we attempt to find how the currently collected personal information in the case study project can improve or limit the capacity of the smart visiting service management system (SVSMS).

From a viewpoint of personal information protection, smart tourism includes privacy and data protection; its challenges have been reviewed in some research reports [28]. Kontogianni and Alepis [28] introduce the concept of smart tourism system, and reach to a conclusion that all the technologies, such as the augmented reality, social media, image recognition, wearables of all kinds, smart vehicles, sensors, etc., are still constantly evolving, so the smart tourism sector still has a long way to go. Researchers attempt to take advantage of the constantly emerging technologies with the purpose of establishing the foundations of the smart tourism sector. In regard to the innovative ideas in our work, we propose a smart visiting service management system using virtual reality that integrates all kinds of smart devices and provides diversified data sources for tourism management.

Lin et al. [29] investigated the law system for protecting the usage of personal information, due to the big data collected from mobile devices and sensors in different countries, which are very valuable for business activities in urban spaces. As for the education, Teng et al. [30] concluded that student information is necessary for management of all education activities, and if all students' activities and their information can be stored in a cloud system, the convenience of education management will be significantly improved. From the view of personal information usage disputed in Teng et al. [29,30], if an interaction between different smart service systems can be done in an integrated cloud database of SVSM, real-time feedback to staff and users in our case study island will greatly improve smart visiting services.

In the present study, the data, big data in particular, collected from urban spaces, is the personal data of human activities and monitoring data of smart infrastructure. There are two types of big data; one type is monitored from infrastructure and its devices, and another type is personal information collected from smart devices observing human activities. Even though it is only possible to provide smart services based on the functions of smart infrastructure and its devices, smart infrastructure cannot produce personal information. Considering the smart city management for personalized smart services as the goal, a smart city management system can be divided as an infrastructure monitoring system and a smart service system.

The concept of smart cities has been evolving for more than 20 years [31]. The Internet of Things (IoT) is the network of devices monitoring the connected infrastructure and communicating with each other without requiring human-to-human or human-to-computer interaction. In order to provide smart services to the smart city management system, Brdys [32] introduces a critical infrastructure system as an infrastructure monitoring tool; the smart devices using ICT are indispensable equipment for monitoring. Monitoring the situation of smart infrastructure is a vital aspect of smart city management [33], which is essential before starting to provide smart services to the users. Moreover, different scales of urban spaces will have diverse systems of architecture in scale. For example, due to the size of collected data, the data center [35] will be different. In this paper, the system framework of SVSMS is discussed in order to fully use big data in the urban study of Huangguan Island, and the system design is divided into infrastructure monitoring system and smart service system. Therefore, a comprehensive review on personal information for smart visiting services is conducted, and the differences between non-public personal information, public personal information, and their usages are clarified, according to the personalized smart visiting services in the case study of the SVSMS of Huangguan Island.

The above is the first step in the pre-assessment before the design stage through the visualization research on the energy saving effect of the urban smart service system and smart infrastructure system in the overall urban spatial scale.

1.4.2 *Energy-saving evaluation index system for the development of low-carbon industrial*

Secondly, through the analysis of various industrial indicators in the planning documents, the energy-saving indicator system in the smart city is formed, and the first stage in the whole cycle of planning and design is carried out: the setting of planning goals. Planning goal setting is the first step in the whole planning cycle, while the formation of the indicator system is the basis for all subsequent energy-saving visualization research. We use Pingtan Island as a case study

To promote the development of low-carbon industries of Pingtan, it is necessary to establish a scientific, comprehensive and reasonable index system to evaluate the energy-saving of low-carbon industrial development. This paper firstly introduced the development background of Pingtan. By analyzing the domestic and foreign industrial low carbon development evaluation theory, the energy-saving evaluation system of Pingtan industrial low carbon development is constructed by selecting three subsystems of energy consumption index, emission reduction index and technical index, including 12 specific indexes. Finally, the paper proposed a calculation model using Principal Component Analysis (PCA). The evaluation system has a crucial practical significance to optimize the industrial structure layout of Pingtan, promote the transformation and upgrading of traditional industries, accelerate the pace of low-carbon industries development, and improve resource utilization efficiency.

Pingtan Island located in the eastern part of Fujian Province in China. It is the largest island in Fujian Province, and ‘Chinesefifth-largest island, with a land area of 392.92 km^2. Pingtan is the nearest place from Taiwan, only 68 miles from the Hsinchu port of Taiwan.

In May 2009, the State Council of China issued the “Opinions on Supporting Fujian Province to speed up construction of the West Coast Economic Zone”, and proposed “to further explore conditional islands in coastal Fujian to establish cross-strait cooperation customs special supervision and implement more preferential policies” [36]. In July 2009, Fujian Province’s government decided to establish Pingtan Comprehensive Experimental Zone, which opened the prelude to opening up and development of Pingtan [37]. In November 2011, “The overall development plan of Pingtan Comprehensive Experimental Zone” was formally approved by the State Council of China, marking the development of Pingtan as a national strategy [38].

The construction of Pingtan Comprehensive Experimental Zone will focus on low carbon technology innovation and the research and development of low carbon technology, popularize green low carbon energy-saving technology, develop knowledge economy with “intelligent” residence and energy-saving tourism to build low carbon and intelligent science and technology demonstration area [39].

To explore the development model of green economy, circular economy and low-carbon industries actively, highlighting the characteristics of the island’s low-carbon industries, and promote economic and social coordinated development with resources and environment. It is of great practical significance to construct an energy-saving evaluation system for low-carbon industry to improve resource utilization efficiency and realize low-carbon development goal following the actual situation in Pingtan.

In recent years, global warming has caused common concerns around the world. Under this background, in 2003 the British Government published the "Energy White Paper" entitled "Our Future Energy: Creating a Low- Carbon Economy" [40]. For the first time "Low-Carbon Economy" was proposed. Then, Johnston explored the technological feasibility of achieving CO2 emission reductions above 60% within the UK housing stock by the middle of this century. The research results show that if the existing technology is used, it is easy to reduce carbon dioxide emissions by more than 80% in the UK housing stock by the middle of this century [41]. Hereafter, many scholars in the world focus their research on low-carbon economy, low-carbon industries, low-carbon community, and low-carbon city and so on [42–44] and [45].

"Low-carbon industry" is an industry which is based on low energy consumption and low pollution. The content covers building, electricity, manufacturing, tourism and so on. How to accurately evaluate the development of the low-carbon industry has become a research focus worldwide. Lintunen analyzed the economic impacts of the low- carbon roadmap made for the Finnish forest industries and assessed the value-added and employment effects to the Finnish economy [46]. Hayashi studied the influence of the degree of knowledge flow in low-carbon technology by its organizational mechanism, which took India's wind power industry as a case study [47].

As there is not a criteria with clearly definite, or uniform standards, for evaluate the development of low- carbon industries currently, and the "energy-saving" as an important content of low-carbon industrial development. Therefore, the authors believe that it is very import to improve resource efficiency and achieve low-carbon development goals by constructing an energy-saving evaluation system for low-carbon industrial development.

1.4.3 *Guidelines for Installation of Sensors in Smart Sensing Platforms in Underground Spaces*

Third, after establishing the planning objectives, it enters the preparation stage of specific planning and implementation.

Therefore, at this stage of this study, the spatial scale of the research object is further reduced, and we enter the underground space in the urban space. In a low-carbon society, most of the underground space belongs to the public business field. The same thing as urban space is that it belongs to urban space and also includes smart service system and smart infrastructure system. At this stage, we have carried out specific planning and design for the intelligentization of underground space in urban space. At present, although there are certain laws and regulations on underground space and construction-related laws and regulations in various countries in the world, there is a lack of relevant legal basis and design guidelines for the growing intelligent underground space construction. Laws and regulations are the cornerstone of system construction. The whole cycle of planning and design must be based on policies, regulations, and planning, so that there is evidence to follow. Therefore, this study further clarifies the intelligent design guidelines including the underground space, including the type of equipment, installation location, specific installation method, maintenance management after installation, and planning and design of the intelligent perception system. In the planning and design stage, accurate simulation control is carried out for the building materials, equipment usage, location, and installation stage to be used in the later specific construction stage, so as to achieve zero waste as much as possible, so as to achieve the goal of energy saving and visualization in the design and planning stage.

This chapter clarifies the sensor types and corresponding parameters for smart sensing scenes by analyzing the needs of different types of underground space scenes. Based on the sensor parameters and acquired data required by the underground space smart sensing platform system, the sensor installation guidelines are formed accordingly.

This chapter needs to clarify types of underground spaces, and we can refer to the laws and regulations of underground spaces in each country. Japan has a perfect legal and management mechanism for underground spaces [48–51], such as the "Act on Special Measures concerning Public Use of Deep Underground", which clarifies the specific problems and technical measures for underground space utilization. Meanwhile, for different types of underground spaces, there are different technical standards and construction regulations [52], such as "Standard Specification for Tunneling" and so on. The "State Lands Act" and "Land Acquisition Act" clarify the classification ba-sis and ownership of underground spaces, and the "Common Services Tunnels Act" and others have introduced new technical requirements for different underground spaces. There are also different technical standards and construction procedures in different underground space classifications such as "Railway applications Fixed in-stallations Electric traction overhead contact lines". In the United States, there is al-so a relatively complete legal and management mechanism for underground space [53], and state laws such as "Laws of Minnesota for 1985 Mined Underground Space" and "Oklahoma Statutes Property" have clarified the technical measures in the development and use of underground space according to the characteristics of each state. There are also different technical standards and construction procedures in different underground space types, such as "Underground Electric Distribution Standards Manual" and "Underground Construction (Tunneling)". Similar to the United States, the United Kingdom also has a comprehensive legal and regulatory mechanism [54], such as the "London Underground Act 1992", which proposes measures to deal with various problems in different areas of London's underground space. The United Kingdom also has different technical standards and construction regulations in different underground space types, such as "The Road Tunnel Safety (Amendment) Regulations". Through these laws and regulations, the classification of underground space can be clarified [8,13].

From the location of the underground space, it requires arterial energy from facilities such as water, electricity, transportation and data flow [2, 54–57], and waste water and waste disposal through veins [57–61], while the underground space contains the infrastructure that ensures the function and operation of urban infrastructure and is the "lifeline" that combines the arteries and veins of the city [14,60–66] in addition to the services and facilities that bring benefits and taxes from commercial operations and provide commercial value to the city [67,68]. Therefore, the planning of under-ground spaces also emphasizes the actual equipment [69], and smart sensing of un-derground spaces can improve the responsiveness of equipment and thus the effi-ciency of the city's arteries and veins [70,71]. As a basic component of smart con-struction, the installation of sensors (including model selection, location selection, combination mode, etc.) is an important part of smart work [1, 72–75].

Based on the existing design guidelines in Japan, such as "Facility Construction Safety Construction Technical Guidelines" and "Civil Engineering Work Safety Construction Technical Guidelines", The requirements for equipment in underground spaces in the traditional Japanese design guidelines are mainly reflected in the types of equipment, the general location of equipment and the occasions of use of equipment. The existing regulations and guidelines basically do not involve smart devices, sensors and other new equipment content. This prob-lem is common in the design guidelines for underground spaces in all countries. From the devices used in the current underground space in Japan, also these devices consume more energy and have a lower degree of smart-ness, and most of them are universal and do not select devices for the characteristics of different types of underground spaces.

1.4.4 *Energy Consumption Simulation and Design Phase Evaluation on Air-Conditioning System of The Intelligent and Healthy Building*

Fourth, as the basis for planning implementation and management, this chapter further narrows down the spatial scale of the study and enters into the interior of specific buildings in urban space and underground space. By studying Energy Consumption Simulation and Design Phase Evaluation on Air-Conditioning System of The Intelligent and Healthy Building to clarify how to apply the HAVC technology before planning implementation. Realize how to simulate and verify the energy saving effect through visualization during the implementation and maintenance management phase.

With the continuous growth of energy consumption in the world, energy shortage has become a major issue in the current economic and social development. It has become an urgent task for human beings to continuously reduce the consumption of non-renewable energy, improve the utilization rate of primary energy, and vigorously develop new energy sources. The continuous progress of the Internet, artificial intelligence, big data and other technologies has a profound impact on the development of the construction industry. As a basic carrier of human activities, the concepts of intelligent building, green building and healthy building have emerged continuously.

With the continuous development of society and economy, the building area increases year by year, and the proportion of building energy consumption in the total energy consumption of society also continues to rise. Among the building energy consumption, the energy consumption of public buildings accounts for a relatively large proportion, and the energy consumption of office buildings, which are an important part of public buildings, accounts for about 20% of the energy consumption ratio of public buildings.

Office buildings have been the major contributors to building energy consumption due to their large load and relative concentration of air conditioning systems, and air conditioning energy consumption accounts for most of the office building energy consumption, which has great potential for energy saving. by conducting an energy audit of a typical office building, Bagci and Bariset et al.found that energy consumption was mainly concentrated in air conditioning systems and lighting systems. kajsa et al.studied the factors affecting energy consumption in office buildings, and the results showed that the most important thing for energy saving is to control the amount of fresh air and the area of glass windows, on the other hand it is also important to reduce the energy consumption of lighting and office equipment. Therefore, it is necessary to simulate and analyze the air conditioning energy consumption of office buildings. Energy-consuming building simulation is one of the important tools for green building design and energy-saving renovation of existing buildings .

In this study, we used Sketchup plugin in Openstudio to build an energy consumption model, followed by Openstudio to simulate and analyze the air conditioning energy consumption of an office building in an area of Sapporo, Japan. By changing the parameters in the building, the energy consumed in the office building and the influencing factors are analyzed. The evaluation of the total energy consumption of the intelligent and healthy building was carried out in the design phase.

The purpose of this paper is to explore the main influencing factors of air conditioning energy consumption in office buildings and their energy saving methods, to provide a theoretical basis for energy consumption prediction in intelligent and healthy buildings.

1.4.5 *Application of virtual reality to visualize the design guidelines for intelligent control of temperature and heat environments and energy consumption in office environments*

Finally, in the planning and design stage, prepare for the planning and design evaluation, and simulate the energy saving effect of the building environment through virtual visualization. Through the design of Application of virtual reality to visualize the design guidelines for intelligent control of temperature and heat environments and energy consumption in office environments, the purpose is to clarify how to apply the task and ambient air condition for building environment before planning implementation.

In recent years, environmental problems caused by urbanization, such as global warming and the heat island phenomenon, have been highlighted as issues that need to be addressed internationally. In Japan, these problems are caused by anthropogenic heat emissions from buildings and vehicles in cities and carbon dioxide emissions from primary energy consumption in urban activities. The item that accounts for the largest share of primary energy consumption in Japan is electricity generation through burning fossil fuels, and Japan's per capita CO_2 emissions are second only to those of the United States, South Korea, and Russia among major countries.

In the field of architectural design, recent technological advances have enabled the visualization of the architectural design process in a virtual space and the simulation of the analysis and optimization of construction to improve efficiency. The example of actual architectural design using virtual space presented in Unity Technology’s "Unity Japan Office Project" implements the design solutions to simulation and other sample problems needed. In addition, when applied to VR and AR, design intent can be communicated not only to the designer, but also to all parties involved in the building project. Although BIM data and component data can be visualized in this way, there are few examples of visualizing interior environments and their digital information, and their visualization methods have not yet been established.

The energy efficiency of Task and Ambience air conditioners can be determined through energy consumption calculation simulations and operational data analysis. However, it is impossible to know the energy savings in the design phase because there is no method to visualize the heat load of such air conditioning equipment again, and there are no guidelines for assuming up-to-date air conditioning in conventional simulation software in the design phase. Therefore, it is necessary to develop design guidelines to account for the energy consumption of energy-efficient air conditioners. This study focuses on the Task-Ambience area and aims to estimate the thermal load by comparing various temperature and humidity patterns with conventional temperature and humidity settings to create a design guide to give guidance to the design phase of office air conditioning installations.

Database that can be organized in one integrated database in this system; it is also easy to integrate the database of smart services as one visiting management system for cooperation between the service providers. Personal information collected in the island space is complicated, due to different service providers collecting different personal data for various business purposes. Personal information is collected by the sensors not only in personal mobile devices, but also in smart LoT facilities deployed in the buildings of the urban space. Thus, the smart visiting service management system is able to share the personal information for integration of all separated smart visiting services.

Finally, we discuss the principles of personal information collection. The personal information is supplied by different providers, which usually makes it impossible to share this information between them, thus, it is unreasonable to identify an individual person for protection of non-public personal information, if there is no integrated database. Besides the non-public personal information, public personal information can be shared between smart service systems, and there is also a kind of smart device that will not collect personal information. As a result, we can divide personal information into three types: public, non-public personal information, and non-personal information.

Different smart services require different types of personal information, so it is important to organize smart devices in building spaces. In further research, we investigate what kind of personal information is necessary for different types of smart services, and then we can further discuss the standards of planning and design for smart devices in the smart city constructions.

1.5 Future work

The future work is to compare and analyze the evaluation results with the planning objectives, further measure the indicators of the planning objects, and evaluate the realization of energy indicator

Chapter 2 Smart City Project Planning and Design Involving Smart Management System Platform for Visiting Service

This chapter will through the design of a smart visiting service management system in an isolated island to clarifying in the overall urban dimension, through the planning of the urban smart service system and smart infrastructure system, urban space design, in the industry, commerce, transportation, and households, which mainly generate carbon dioxide, conduct visualization research in the design stage of energy-saving effects.

2.1 Introduction

Presently, smart city constructions have been implemented in many cities around the world as pilot urban development, however, the issue of cyber security and privacy of big data in cyber-physical-social systems is rising too]. Big data is the sensor-based product of Information Communication Technology (ICT) collected from all smart devices and Internet of Things (IoT) in urban and building spaces, that has the ability to change the lifestyle of a human, and also cause a significant effect on the usage of urban and building spaces . Thus, big data and its smart services will create a new trend of designing smart buildings in the near future, due to the providing of the new smart services in daily life to people based on their personal information . In this paper, we consider the smart city project on Huangguan Island as the case study for analyzing the kinds of personal information used, and how the relatively big data standing for individual activities can be synergized in the system design of smart visiting service management systems.

Li et al. determined the definition of smart tourism as an individual tourist support system within the context of information services and an all-encompassing technology. In this case study, the current approach to the development of the smart visiting service management system (SVSMS) is discussed to identify the principles of personal information collection, and if it is possible to synergize

The personal data in an integrated database system, where personalized smart services can specify the personal information between each other on the isolated island.

From a viewpoint of big data usage in smart management services, personal information collected by many smart devices and IoT sensors in urban spaces is very helpful for the urban management . Big data analytics have been widely implemented in marketing and business innovation processes, which also create business value at a larger scale . Urban planning and design will be changed greatly by the application of big data, as a result of the urban management services' ability to be improved in many aspects by using that data . Andreani et al. offers an alternative perspective to a design-driven and human-centered smart city approach. Therefore, even though ICT has provided new data sources for the urban management, integrating these new data sources for providing smart services to planning and designing with collected personal information still remains a challenge. Thus, we attempt to find how the currently collected personal information in the case study project can improve or limit the capacity of the smart visiting service management system (SVSMS).

From a viewpoint of personal information protection, smart tourism includes privacy and data protection; its challenges have been reviewed in some research reports . Kontogianni and Alepis introduce the concept of smart tourism system, and reach to a conclusion that all the technologies, such as the augmented reality, social media, image recognition, wearables of all kinds, smart vehicles, sensors, etc., are still constantly evolving, so the smart tourism sector still has a long way to go. Researchers attempt to take advantage of the constantly emerging technologies with the purpose of establishing the foundations of the smart tourism sector. In regard to the innovative ideas in our work, we propose a smart visiting service management system using virtual reality that integrates all kinds of smart devices and provides diversified data sources for tourism management.

Lin et al. investigated the law system for protecting the usage of personal information, due to the big data collected from mobile devices and sensors in different countries, which are very valuable for business activities in urban spaces. As for the education, Teng et al. concluded that student information is necessary for management of all education activities, and if all students' activities and their information can be stored in a cloud system, the convenience of education management will be significantly improved. From the view of personal information usage disputed in Teng et al. ， if an interaction between different smart service systems can be done in an integrated cloud database of SVSM, real-time feedback to staff and users in our case study island will greatly improve smart visiting services.

2.1.1 *Smart City Management and Personal Information*

With the informatization and the development of globalization in the recent years, local government also aims for higher efficient urban management and ICT equipment is applied during the process of urbanization。 The flexible application of smart city management services using ICT will become the strategic development goal worldwide. Thus, higher quality of urban management is a result of the application of the advantages of ICT. On the other hand, smart services provided for users are based on personal information collected by smart infrastructure under management of different personalized smart service providers.

There are also some reports related to cultural and political tradition to personal information in the literature. Das argued that the smart city management ways will be different based on various urban governance systems, infrastructure monitoring, and smart services. Wang et al. investigated the issue of consumer intentions to disclose personal information via mobile applications.

As mentioned above, it is important to review the efficient usage of the personal information, while protecting personal information, for running a smart city management system. From our perspective, the new form of city management using ICT is composed of all kinds of systems related to smart infrastructure and its devices based on the smart city construction. Personalized smart services can only be provided by connecting personal information to the smart devices.

2.1.2 *Big Data by Infrastructure Monitoring System*

In the present study, the data, big data in particular, collected from urban spaces, is the personal data of human activities and monitoring data of smart infrastructure. There are two types of big data; one type is monitored from infrastructure and its devices, and another type is personal information collected from smart devices observing human activities. Even though it is only possible to provide smart services based on the functions of smart infrastructure and its devices, smart infrastructure cannot produce personal information. Considering the smart city management for personalized smart services as the goal, a smart city management system can be divided as an infrastructure monitoring system and a smart service system.

The concept of smart cities has been evolving for more than 20 years . The Internet of Things (IoT) is the network of devices monitoring the connected infrastructure and communicating with each other without requiring human-to-human or human-to-computer interaction. In order to provide smart services to the smart city management system, Brdys introduces a critical infrastructure system as an infrastructure monitoring tool; the smart devices using ICT are indispensable equipment for monitoring. Monitoring the situation of smart infrastructure is a vital aspect of smart city management , which is essential before starting to provide smart services to the users. Moreover, different scales of urban spaces will have diverse systems of architecture in scale. For example, due to the size of collected data, the data center will be different.

Personal Information of a Smart Service System

The information included in an ID number does not only include merely personal information, but also specific personal information that can be defined as non-public information and is not allowed to be opened. Therefore, the users who have provided their ID information have higher risks of being disclosed, so, management should follow strict protection regulations towards their personal information. If there are limitations for providing specific personal information by law, even though the person himself or herself agrees, the information still cannot be transferred, exceeding the application scope. Accordingly, the information must be applied cautiously, if personal information is involved in the smart service procedures in the case study on the island.

As reported by Kim et al. , there is a lot of personal information in a city, such as the following lists: visitor list, staff lists, locations of the visiting places, and related documents, such as health status, telephone numbers, and so on. The personal data is collected from the people who are willing to put their personal information on personal cloud-based storage applications in order to use relative services . The direct effects on perceived benefits and risks induce the ultimate intention to disclose personal information, due to the convenience of using mobile apps . From the view of personal information protection, the consent of a person and the limitations of providing personal information concerning a specific person are the critical conditions for smart services, if the personal information can be provided to the third party that is managing a respectively smart service system .

In this paper, the system framework of SVSMS is discussed in order to fully use big data in the urban study of Huangguan Island, and the system design is divided into infrastructure monitoring system and smart service system. Therefore, a comprehensive review on personal information for smart visiting services is conducted, and the differences between non-public personal information, public personal information, and their usages are clarified, according to the personalized smart visiting services in the case study of the SVSMS of Huangguan Island.

2.2 Theoretical Concept and Methodology

Generally speaking, the application of big data is changing human lifestyle and city management worldwide, and, reversely, physical urban and building environments will be necessarily changed to match the style of smart life and business spaces using ICT. As mentioned above, in the field of urban planning and design, urban management is more and more dependent on smart city management system. The big data of human activities stored from ICT, and plenty of personal information, is useful in this case. With the purpose of improving the quality of visiting services management in the case study area, the application of personal information is indispensable in the system design, and we are trying to figure out the principle of employment of the personal information in this project.

Firstly, smart visiting service management includes management for physical infrastructure facilities and human activity. Thus, we develop the SVSMS in Huangguan as two systems, namely the smart services system (SSS) and the infrastructure monitoring system (IMS). Accordingly, the infrastructure monitoring system is not the system for handling the personal information database. Considering the personal information collection, we can focus on the smart service system. Based on the personal data, if it is possible to identify an individual person, the information can be divided into non-public personal information and public personal information. Public personal information can be disclosed and shared by different smart service providers.

Secondly, we analyze the personal data that is being collected by the smart services system for managing purposes, as well as the ID as a form of personal information collected from different smart devices, that is linking all databases in different providers. Finally, the principles of personal information collection can be discovered, while protecting non-public personal information by reviewing the application of the SVSMS on Huangguan Island. In this study, we focus on the application of personal information to the system design; hereby, the data collection and analysis are not organized for further discussion in the following sections.

2.3 Case Study on Huangguan Island

Smart city management systems are now popular in the world of managing cities; they can increase the capabilities of local government with the help of ICT. On Huangguan Island, the SVSMS is composed of two databases; one is the physical information database, which includes the environment data and infrastructure data; the other is the human information database, including personal data collected from all smart services, such as mobile devices, transportation cards, personal identification systems, and cameras monitoring human activities on the island.

Huangguan Island is an isolated island in Fujian Province, China. There are no original residents there. The island was developed by the Longshen Group in 2016. The island is located close to Dongbi Island, where it can take people one hour to get to Fuqing City, which belongs to the Fuzhou New District, as demonstrated in Figure 2-1. Huangguan Island is located near the Fuzhou New District, and belongs to the Fuzhou–Putian–Ningde Metropolitan Area. It is based within the 0.5-hour travel circle of Fuqing, and the 1-hour travel circle of Fuzhou. The capacity of visiting services is fifteen log houses for 60 persons or 15 families, and the main hotel for 100 guests. In total, there are 20 staff members for all of the office work on the island. Thus, it is a small database for management.

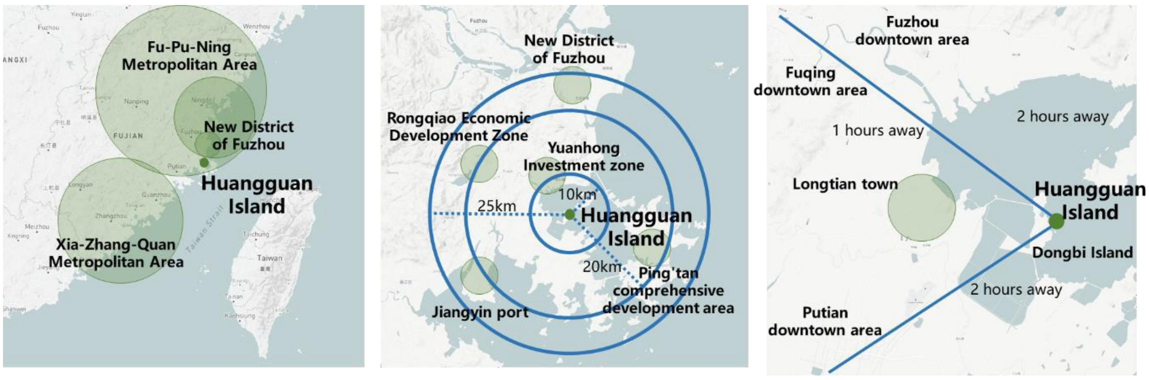


Figure 2-1. Location of Huangguan Island.

There are two systems proposed in the Huangguan SVSMS: the smart services system and the infrastructure monitoring system, as indicated in Figure 2-2. Therefore, the smart service system is used for the human information database containing personal information and data, while the infrastructure monitoring system is used for the physical information database containing the environment data and the infrastructure data. In this research, we focus on the understanding of the ways to deal with personal information collected by the SSS for the improvement of visiting management, which is an integrated system with all of the smart services on Huangguan Island.

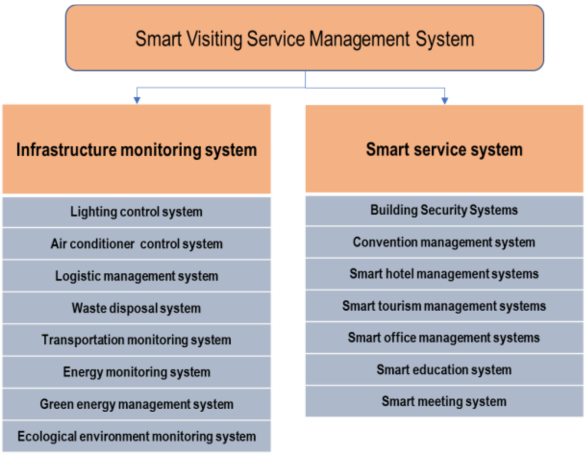


Figure 2-2. Smart visiting service management in Huangguan.

Hereafter, we explain how the SVSMS is composed of different smart services, how the personal information is collected by those systems, and how that data can be provided in order to support the integrated services on the island.

2.3.1 *Infrastructure Monitoring System*

The smart infrastructure and smart services are the two main components of the Huangguan SVSMS. The smart infrastructure is presented in Figure 2-3. The smart data center is designed to employ the unified construction specifications and data exchange standards, with the purpose of ensuring that data resources are properly collected and transmitted. Therefore, the data is smoothly shared between different systems on the island to maintain smart services that are provided by smart infrastructures to visitors, residents, staff, and others on the island.

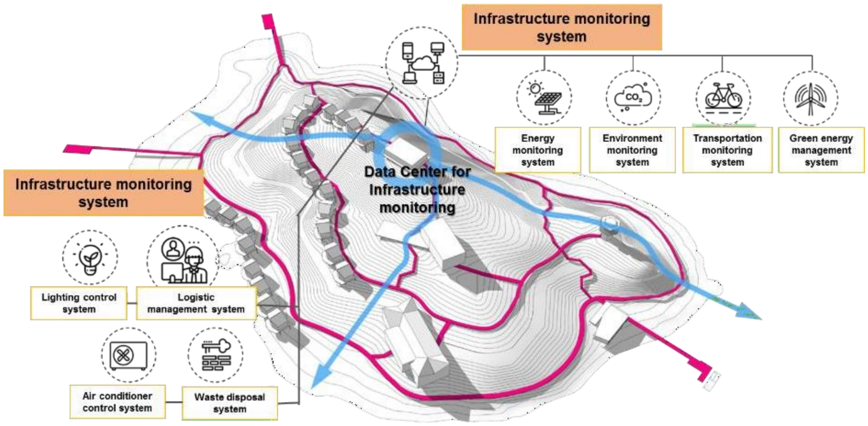


Figure 2-3. Smart infrastructure in Huangguan.

2.3.2 *Personal Information and Smart Service System*

In order to use smart services, the users should be registered in the system. As demonstrated in Table 2-1, there are seven smart services in the SSS, that contain personal information such as facial recognition, ID, system user ID, bank account information, phone number, address, sex, and age. Table 2-2 shows the building spaces where smart services systems are installed. Users, who use smart services on Huangguan Island, open their personal information to smart service systems. The personal information registered in the SSS can be shared by different systems for management purposes.

Table 2-1. Personal information in the smart service system (SSS) proposed on Huangguan Island.

Smart Service System	Personal Information						
	Facial Recognition	User ID	ID	Bank Account Information	Phone Number	Address	Sex and Age
Building security systems	Y	Y					
Convention management system	Y	Y	Y				
Smart hotel management systems	Y		Y	Y	Y		
Smart tourism management systems		Y		Y	Y		
Smart office management systems	Y	Y					
Smart training system		Y					
Smart meeting system		Y			Y		

Table 2-2. Buildings spaces and the SSS.

	Resident Center	Visitor Center	Hotel	Innovation Office	Training Center	Convention Center	Conference Center
Building security systems	Y	Y	Y	Y	Y	Y	Y
Convention management system						Y	Y
Smart hotel management systems			Y				
Smart tourism management systems		Y	Y			Y	Y
Smart office management systems				Y	Y	Y	Y
Smart training system					Y		Y
Smart meeting system		Y	Y	Y	Y	Y	Y

2.4 Smart Management Services and Personal Information in the Huangguan SVSMS

In order to use SVSMS in a suitable way, the collection of personal information and sharing of personal information should provide the diversity of smart services for the visitors of Huangguan Island.

2.4.1 *Building Spaces and Smart Service Systems in the SVSMS*

As indicated in Table 2-2, there are seven types of smart services provided in the island; the buildings of the services are installed in the same table.

2.4.2 *Building Security System and Personal Information*

It is usually necessary to collect personal information for building security management. As demonstrated in Figure 2-4 and Table2-3, we take the building security system as an example for explanation of the relationship between smart services, buildings, and users. Due to the large amount of products used for collecting the personal information, we take wearable hand ring and facial recognition as an example, as indicated in Table2- 3.

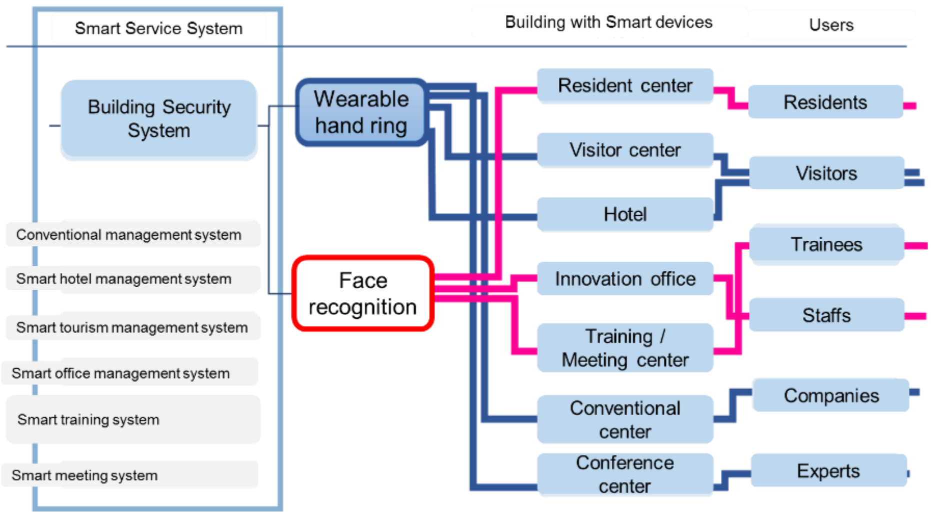


Figure 2-4. The building security system in the smart visiting service management system (SVSMS).

2.4.3 *Smart Service System and Personal Information*

In the present work, local public institutions make the laws and regulations for the protection of personal information, generating rules for the objects of personal information, rules for obtaining the personal information, protection and management rules of personal information, and rules for providing personal information to the third parties.

In this section, we did not classify all of the smart devices for collecting personal information in the other smart service systems. There are a lot of smart devices that can be used to collect personal information, such as the wearable hand ring and facial recognition, with the purpose of building a security system, as demonstrated in Table 2-3.

In Figure2-5 and Table2-3, we determine the kinds of smart service systems needed to collect personal information in different buildings from different users.

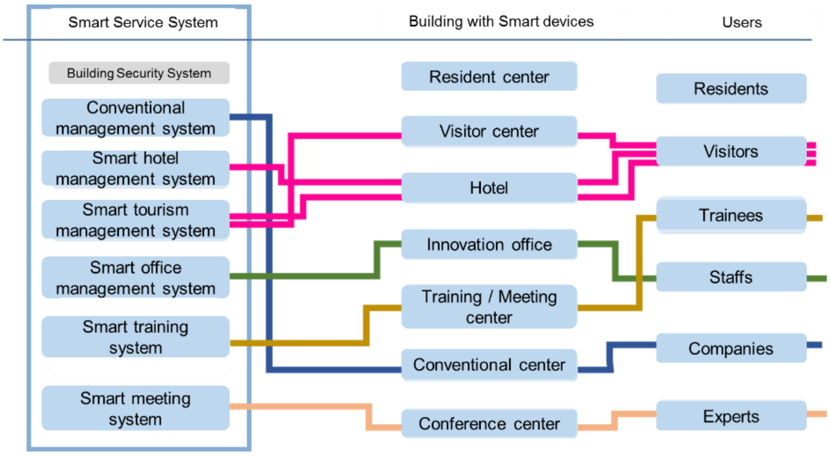


Figure 2-5. The other smart service system in the SVSMS.

Table 2-3. Integrated personal information in building spaces with the SSS.

Smart Service System	Buildings	Smart Service Users				
		Residents	Visitors	Trainees	Staffs	Experts
Conventional management system	Convention center	Y	Y		Y	Y
	Conference center		Y		Y	Y
Smart hotel management system	Visitor center		Y		Y	
	Hotel		Y		Y	
Smart tourism management system	Visitor center		Y		Y	
	Hotel		Y		Y	
	Convention center		Y		Y	
	Conference center		Y		Y	
Smart office management system	Resident center	Y			Y	
	Visitor center		Y		Y	
	Hotel		Y		Y	
	Innovation office			Y	Y	
	Training center			Y	Y	
	Convention center	Y	Y		Y	Y
	Conference center	Y	Y		Y	Y
Smart training management system	Innovation office	Y	Y	Y	Y	Y
	Training center	Y	Y	Y	Y	Y
Smart meeting system	Resident center	Y			Y	
	Visitor center		Y		Y	
	Hotel		Y		Y	
	Innovation office			Y	Y	Y
	Training center			Y	Y	Y
	Convention center			Y	Y	Y
	Conference center			Y	Y	Y

The personal information collected from all smart service systems could be shared with each system for the visiting management. But for protecting personal information, the kinds of personal information necessary for sharing need to be clarified and kept in the integrated database system.

2.5 Integrated Smart Services and Personal Information

Smart services operated by users are provided by different companies which use the selected service information and user information, including the private personal information. In our case study, the necessary purposes for using personal information in the island project are payment, identification, security checking, and so on. In this research, the management system is developed based on the virtual reality (VR) engine, namely Unity3D, in which the entire workflow, from data acquisition to VR visualization, is designed in detail, with particular emphasis given to the 3D modelling. Using this kind of system makes it possible to move through the VR environment for interactive visual navigation while exploring VR-modelled landscapes .

An integrated system for smart services is needed for the visiting management in Huangguan, as shown in Figure 2-6. Since Huangguan is a small island for tourism, the number of visitors is limited, and the developer is the owner of the island, who is also a resident of the island. Thus, it is easy to integrate all smart service systems as smart visiting management systems, with the key ID as a form of personal information is set up in order to connect all databases of smart services.

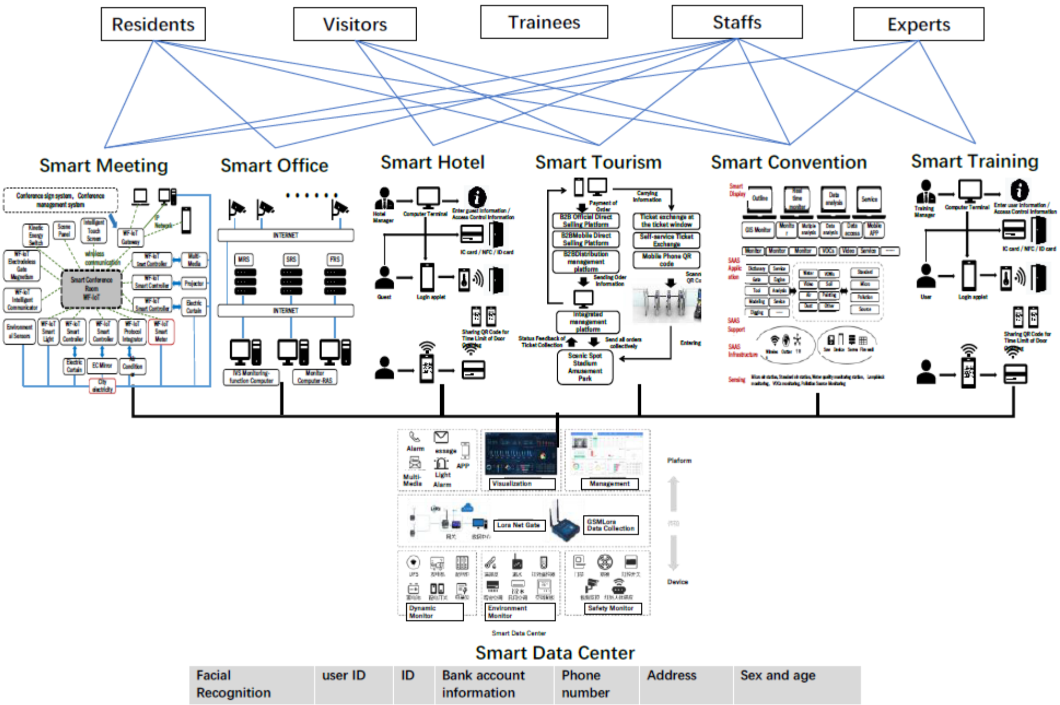


Figure 2-6. Personal information integrated in the SVSMS.

As for the personal information for the integrated visiting smart service management system, there are three types, described in the following sections.

2.5.1 *Public Personal Information*

Visitors or other users have to access smart service systems, thereby it is possible to ask them for cooperation in sharing their data for smart visiting management on the island. One of the possible cooperative tasks is sharing the personal information for security checking, hotel, and conference rooms, setting the time schedule between different smart service systems. In order to identify the correct person who needs the support from another service, it is necessary for the personal information to be shared in the servers of the integrated database. Meanwhile, personal information should be transferred between smart service systems in order to provide the correct relative smart service, due to different services being run by the different providers. Usernames and other necessary information, such as IDs, birthdays, and so on, which can be shared with different smart services systems, can be defined as public personal information. However, the kind of data that can be defined as public personal information depends on the kind of information that is needed between different systems.

2.5.2 *Non-Public Personal Information for Identification*

Services used by the people do not necessary need to be shared with other smart service systems; they can be saved in one smart service system. Moreover, payment information of each system should be recorded in the integrated database, to pay once, for all of the expenses on the island, after visiting. The total amount of payment to one service system can be sent to the integrated database, in order to calculate the total consumption on the island. It is not necessary to share the bank account information with all of the systems, if only one integrated payment system is used for visiting management, thereby, the users do not need to register their bank information in different service systems. In this case, the bank account information that belongs to the non-public personal information is not shared with different smart service systems.

2.5.3 *Non-Personal Information for Smart Services*

There are some products, such as automatic doors, water sensors in toilets, and automatic lighting, that are separated from smart service systems. Even these products are deployed in all building spaces, as indicated in Figure 2-7, and it is necessary to take the status data of these products for maintenance. However, there is no need to save the personal information of users in the integrated database. There are many smart devices that respond to each individual user, but it is not necessary to save their personal information. Furthermore, it is not fundamental to save it in any additional database. This kind of data without the personal information can be kept in the devices only.

(**a**) Data center(**b**) Visitor center (**c**) Convention/conference center

(**d**) Waste disposal center (**e**) Hotel (**f**) Data storage space

Figure2- 7. SVSMS using virtual reality in Huangguan Island:

(**a**) Data center; (**b**) Visitor center;

(**c**) Convention/conference center; (**d**) Waste disposal center; (**e**) Hotel; (**f**) Data storage space.

2.5.4 *Principle of Personal Information Application on Huangguan Island*

Based on the discussion above, the principles of personal information application are demonstrated in Table 2-4. As a result, it is important to divide personal information into three types: non-public personal information, public personal information, and non-personal information. Firstly, let us consider the non-public personal information. Facial photos, IDs, and so on are made by the government, and can be used to identify the personality for security checking. Other private information, such as sex and birthday, address, phone number, bank account, and credit card information, are necessary for the service companies, in order to provide tourism services and collect service fees. All this information is related to the personal private information, thus, it does not need to be shared by the data center in the SVSMS. Secondly, when using the SVSMS, user names, IDs, and the services to which they applied, are important for their payments to smart services, and can be shared in the data center of the SVSMS. Finally, the infrastructure monitoring is not considered as the personal information, even when users use the smart infrastructure.

Table 2-4. Principles of personal information application for the smart visiting service management.

Data Protection	Personal Information	Smart Service System Run by a Service Company	Data Center in SVSMS Run by Government	Application of Personal Information
Non-public personal information	Facial photo	Scanned but not saved	Identified by government database	Security checking
	ID	Scanned but not saved	Identified by government database	Security checking
	Sex and birthday	Saved exclusively	Not shared with data center	Identification of service user
	Phone number	Saved exclusively	Not shared with data center	Identification of service user
	Address	Saved exclusively	Not shared with data center	Identification of service user
	Bank account or credit card information	Scanned but not saved. (Identified by bank or credit card companies)		Payment
Public personal information	Name	Shared	Shared with data center	Identification of service user
	User ID	Shared	Shared with data center	Calculation total amount service fee
	Services used	Shared	Shared with data center	Calculation total amount service fee
Non-personal information		Productions	Data center in SVSMS	
		Light sensor	No recorded data	
		Door sensor	No recorded data	
		Others		

2.6 Conclusions

Previous works are focused on the development of different kinds of tourism information services for tourism organizations, and claim that by using big data analysis and processing means, researchers can improve practices in tourism businesses and serve tourists better. In this paper, we proposed a management system using virtual reality for tourism services, and took the Huangguan smart island project as a case study in order to figure out how to design the visiting service system in the island space, and how to collect personal information for smart visiting service management.

We suggest the infrastructure monitoring system and the smart service system for smart visiting management on the island. Personal information collected in the island space is a relatively small database that can be organized in one integrated database in this system; it is also easy to integrate the database of smart services as one visiting management system for cooperation between the service providers. Personal information collected in the island space is complicated, due to different service providers collecting different personal data for various business purposes. Personal information is collected by the sensors not only in personal mobile devices, but also in smart LoT facilities deployed in the buildings of the urban space. Thus, the smart visiting service management system is able to share the personal information for integration of all separated smart visiting services.

Finally, we discuss the principles of personal information collection. The personal information is supplied by different providers, which usually makes it impossible to share this information between them, thus, it is unreasonable to identify an individual person for protection of non-public personal information, if there is no integrated database. Besides the non-public personal information, public personal information can be shared between smart service systems, and there is also a kind of smart device that will not collect personal information. As a result, we can divide personal information into three types: public, non-public personal information, and non-personal information.

Different smart services require different types of personal information, so it is important to organize smart devices in building spaces. In further research, we investigate what kind of personal information is necessary for different types of smart services, and then we can further discuss the standards of planning and design for smart devices in the smart city constructions.

So far, we have completed the first step of this research, and visualized the design of smart space for the purpose of saving energy from the scale of urban space. In the next step, we will start from the first step of planning and design, planning goal setting, to form an energy-saving index system for urban space and architectural space.

Chapter 3 Achieving Planning Objectives of Energy-saving using Energy Consumption Index for Smart City Project

Secondly, as the first step in planning and design full-cycle management, setting planning objects and goals, this research through the analysis of various industrial indicators in the planning documents, the energy-saving indicator system in the smart city is formed, and the first stage in the whole cycle of planning and design is carried out: the setting of planning goals. Planning goal setting is the first step in the whole planning cycle, while the formation of the indicator system is the basis for all subsequent energy-saving visualization research. We use Pingtan Island as a case study.

To promote the development of low-carbon industries of Pingtan, it is necessary to establish a scientific, comprehensive and reasonable index system to evaluate the energy-saving of low-carbon industrial development. This paper firstly introduced the development background of Pingtan. By analyzing the domestic and foreign industrial low carbon development evaluation theory, the energy-saving evaluation system of Pingtan industrial low carbon development is constructed by selecting three subsystems of energy consumption index, emission reduction index and technical index, including 12 specific indexes. Finally, the paper proposed a calculation model using Principal Component Analysis (PCA). The evaluation system has a crucial practical significance to optimize the industrial structure layout of Pingtan, promote the transformation and upgrading of traditional industries, accelerate the pace of low-carbon industries development, and improve resource utilization efficiency.

3.1 Introduction

Pingtan Island located in the eastern part of Fujian Province in China. It is the largest island in Fujian Province, and ‘Chinesefifth-largest island, with a land area of 392.92 km^2. Pingtan is the nearest place from Taiwan, only 68 miles from the Hsinchu port of Taiwan.

In May 2009, the State Council of China issued the "Opinions on Supporting Fujian Province to speed up construction of the West Coast Economic Zone", and proposed "to further explore conditional islands in coastal Fujian to establish cross-strait cooperation customs special supervision and implement more preferential policies" . In July 2009, Fujian Province's government decided to establish Pingtan Comprehensive Experimental Zone, which opened the prelude to opening up and development of Pingtan . In November 2011, "The overall development plan of Pingtan Comprehensive Experimental Zone" was formally approved by the State Council of China, marking the development of Pingtan as a national strategy .

The construction of Pingtan Comprehensive Experimental Zone will focus on low carbon technology innovation and the research and development of low carbon technology, popularize green low carbon energy-saving technology, develop knowledge economy with "intelligent" residence and energy-saving tourism to build low carbon and intelligent science and technology demonstration area .

To explore the development model of green economy, circular economy and low-carbon industries actively, highlighting the characteristics of the island's low-carbon industries, and promote economic and social coordinated development with resources and environment. It is of great practical significance to construct an energy-saving evaluation system for low-carbon industry to improve resource utilization efficiency and realize low-carbon development goal following the actual situation in Pingtan.

In recent years, global warming has caused common concerns around the world. Under this background, in 2003 the British Government published the "Energy White Paper" entitled "Our Future Energy: Creating a Low- Carbon Economy" . For the first time "Low-Carbon Economy" was proposed. Then, Johnston explored the technological feasibility of achieving CO2 emission reductions above 60% within the UK housing stock by the middle of this century. The research results show that if the existing technology is used, it is easy to reduce carbon dioxide emissions by more than 80% in the UK housing stock by the middle of this century . Hereafter, many scholars in the world focus their research on low-carbon economy, low-carbon industries, low-carbon community, and low-carbon city and so on and .

"Low-carbon industry" is an industry which is based on low energy consumption and low pollution. The content covers building, electricity, manufacturing, tourism and so on. How to accurately evaluate the development of the low-carbon industry has become a research focus worldwide. Lintunen analyzed the economic impacts of the low- carbon roadmap made for the Finnish forest industries and assessed the value-added and employment effects to the Finnish economy . Hayashi studied the influence of the degree of knowledge flow in low-carbon technology by its organizational mechanism, which took India's wind power industry as a case study .

As there is not a criteria with clearly definite, or uniform standards, for evaluate the development of low- carbon industries currently, and the "energy-saving" as an important content of low-carbon industrial development. Therefore, the authors believe that it is very import to improve resource efficiency and achieve low-carbon development goals by constructing an energy-saving evaluation system for low-carbon industrial development.

3.2 Development direction of low-carbon industry in Pingtan

Guided by the requirements of the Overall Development Plan of Pingtan Comprehensive Experimental Zone, Pingtan should firstly widely absorb or learn from foreign advanced experiences and development concepts, apply and promote low-carbon technologies. Secondly, it should give priority to the development of high-tech industry, change the way of economic defense, and find the development mode of low input, low consumption, high output and high efficiency. Therefore, the flowing carbon industry in Pingtan mainly promotes the development of high-tech industry, service industry, marine industry and tourism. Figer.3-1 illustrated the block diagram of low-carbon industrial development in Pingtan.

The high-tech industry can use wind energy in the process of creating and utilizing new energy sources. Pingtan has a large amount of wind resources, with a total area of more than 230 square kilometers that can be used for wind energy. It is among China's top locations for wind energy.

As the geographical and resource advantage is obvious , Pingtan has exclusive preferential policies , a good investment environment ,a wide range of radiation , and abroad market . Therefore, considering the geographical location of Pingtan City, the development of service industry in Pingtan City can not only take advantage of the fast-growing general market, abundant resources and cheap mainland labor. In addition, Pingtan can also make full use of Taiwan's advantages in technology, finance and management to meet the demand of Taiwan market while satisfying the requirement of industrial structure optimization in mainland China.

Marine industry will actively promote precision agriculture, the seafood processing industry, and the marine physical industry through the introduction of cutting-edge technology and concepts from Taiwan, taking advantage of historic industries and resources in Pingtan.

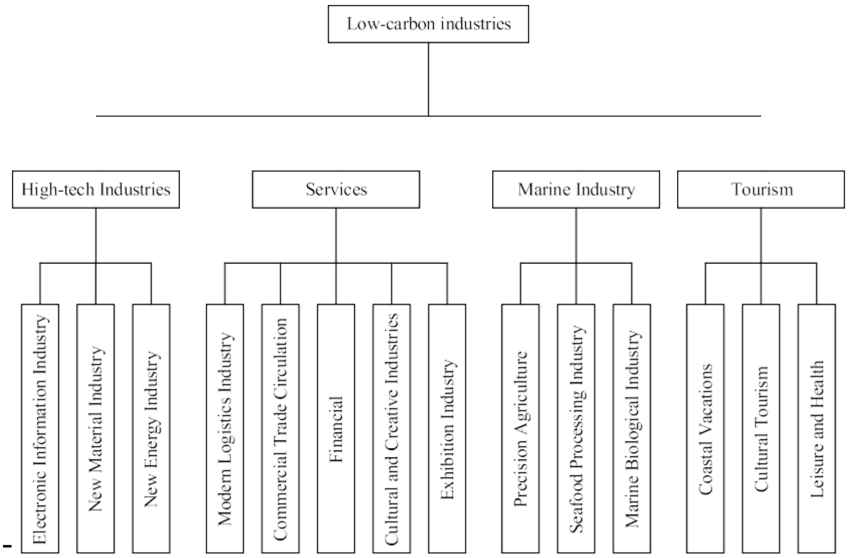


Fig. 3-1. The block diagram of low-carbon industrial development in Pingtan.

Pingtan is rich in tourism resources and diversity. There are 78 types of tourism resources in China, and Pingtan has 36 types [14]. In order to turn Pingtan into a well-known island and tourist and leisure destination, it can make use of the island's tourism resources, improve relations between the mainland and Taiwan, expand tourist routes, and develop a "Channel Travel" brand.

3.3 Construction of energy-saving evaluation system for low-carbon industrial development of Pingtan

3.3.1 *Selecting principle of energy-saving index*

In order to ensure the sustainable development of Pingtan Islan, the construction of energy-saving evaluation system for low-carbon industrial development must be based on actual and scientifc concept of development and correctly handle the relationship between development and protection to build Pingtan as a business travel low-carbon industries Island , ecological leisure is land and liveable city is land. The principles are as follows:

Scientific principle. Pingtan Comprehensive Experimental Zone needs to meet the concept of people-oriented, comprehensive, coordinated and sustainable development to ensure the scientific, harmonious and green development of Pingtan. Therefore, the selection of energy-saving indexes need to understand the system and study on scientifc fully, essentially refect the requirements of the scientifc development , and refect the energy-saving situation of low-carbon industrial development more objective and truly.

Integrated principle. Integrated principle mainly refected in two aspects : (1)Comprehensiveness that the indexes can cover all aspects of energy-saving work for developing low-carbon industries in Pingtan,ensuring that it can be used to evaluate most of the energy saving industries.(2)Systematic, namely the indexes of energy-saving evaluation should apply to all kind of directions of low-carbon industries,to ensure that the index can comprehensively evaluate the status of energy-saving in each direction.

Operational principle. The operational direction includes accessibility and assessment. Therefore, the indexes must easily collect and calculate with a clear concept , clear content to reduce subjective error.Also,it can be created and available through specifc statistical tools to carry out inspections,assessments and comparisons and to ensure such a principle is to simplify the operation process and enhance the practical value of this indicator.

Dynamic principle. In view of the fact that the energy-saving evaluation system will change with the development of the social and economy, the characteristics of dynamic changes should be fully considered when selecting indicators to ensure that the results of the evaluation system can better describe and measure the future trend and improve the accuracy and efficiency of the dissemination of the products,and through this principle, this set of evaluation indicators can respond to changes in the development of the industry and assess the energy efficiency at each stage of development .

Objective principle. In order to build the Pingtan Comprehensive Experimental Zone, it is necessary to innovate in science and technology, expand the building, energy, and transportation sectors, and create low-carbon industrial structures that are low-cost, high-value-added, and environmentally friendly. The selection of evaluation indices should accurately reflect the needs of low-carbon industrial development, promote the rapid growth of clean energy and low-carbon industries, increase the effectiveness of resource use, and realize the development objectives of low-carbon islands.

3.3.2 *Construction of energy-saving evaluation system*

Energy conservation refers to lowering the amount of energy used in a system, process, organization, or society through economy, waste removal, and sensible use. China makes significant strategic decisions about energy-saving that are related to scientific development, harmonious development, and forward-moving development. According to the requirement of "The synthesis work program of energy-saving in the current five-year plan", that was issued by the State Council of China . According to the requirements of the document, each region should establish a green, low-carbon development concept, and promote energy-saving vigorously. Therefore, it is imperative to establish and improve the energy-saving evaluation system for low-carbon industrial development, optimize the industrial structure layout of Pingtan, promote the transformation and upgrading of traditional industries, accelerate low-carbon industries development, and improve resource utilization efficiency,which is also the necessary road for the development of Pingtan City, and the problems of Pingtan's development can be found from the essence and solved in a targeted manner.

The highest comprehensive index of the energy-saving evaluation system of low-carbon industrial development depends on the degree of energy saving of low-carbon industrial development. The evaluation system includes three indices: energy consumption index, emission reduction index and technology index,which are called three subsystems, and each subsystem includes several specific indicators. Table 3-1 showed the energy-saving evaluation system for the low-carbon Industrial development of Pingtan.

Table 3-1. Energy-saving evaluation system for low-carbon industrial development

Objective layer	Criteria layer	Index layer	Mark	Index properties
Energy-saving degree of low-carbon industrial development	Energy consumption index	Power consumption per GDP (kWh/million Yuan)	x_1	Negative
		GDP power consumption decrease rate (%)	x_2	Positive
		Wind power accounted for the proportion of electricity use (%)	x_3	Positive
		Water consumption per unit of industrial added value (m^3/million Yuan)	x_4	Negative
	Emission reduction index	Carbon emission intensity per GDP decreases (%)	x_5	Negative
		Ammonia emissions (tons/year)	x_6	Negative
		Nitrogen oxide emissions (tons/year)	x_7	Negative
		SO2 emissions (tons/year)	x_8	Negative
		COD emissions (tons/year)	x_9	Negative
	Technical index	Garbage treatment rate (%)	x_{10}	Positive
		Centralized treatment rate of sewage (%)	x_{11}	Positive
		Ratio of air AQI index reached to the second level per year (%)	x_{12}	Positive

3.3.3 *Data source of energy-saving evaluation index*

Following the selecting principle of energy-saving indexes, 12 specific indexes are selected, including Power consumption per GDP, GDP power consumption decrease rate, Wind power accounted for the proportion of electricity use, and so on. The data comes from official documents such as "Environmental State Bulletin of Fujian Province" and "Pingtan Comprehensive Experimental Zone National Economic and Social Development Statistics Bulletin" from 2015 to 2020, as shown in Table3-2, and the indexes sorted out by this official document can indicate the development goals of Pingtan and target the problems of Pingtan City.

3.4 Weight method selection of the index in evaluation system

The choice of the weighting mechanism for the index will have an immediate impact on the evaluation's outcome when determining the individual subsystems' development levels. The evaluation will produce errors if the procedure is overly subjective. Therefore, this paper introduces a principal component analysis method that can determine the principal component scores of the internal indicators of each subsystem, and synthesizes the weight indicators of each subsystem through the variance contribution rate of each components, and calculates the scores of each subsystem of the evaluation system to comprehensively evaluate the subsystem and improve the accuracy of the evaluation by this way.

Table 3-2. Data of energy-saving evaluation index in Pingtan

Year	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}
2020	356.00	−1.385	214.62	42.00	4.25	2144.31	32.43	97.24	16 640.89	99.95	99.00	98.90
2019	361.00	0.838	184.66	26.00	4.25	2190.92	32.77	98.26	17 002.65	99.77	97.50	98.40
2018	358.00	−1.105	100.98	24.00	4.15	2237.53	33.11	99.28	17 364.41	98.87	92.40	95.90
2017	362.00	0.556	82.75	25.00	4.00	2284.14	33.45	100.29	17 726.17	97.50	91.00	93.90
2016	360.00	0.279	57.55	27.16	3.50	2330.75	33.79	101.30	18 087.93	96.50	89.00	96.30
2015	359.00	6.845	55.88	28.00	3.40	2358.82	33.79	101.30	18 259.57	96.00	88.00	96.40

The basic principle of Principal Component Analysis is to combine the original indexes of the evaluated object into new comprehensive indexes, so that they can express as the relationship of linear function, then calculate the proportion of the variance of a comprehensive index, accounted for the total variance of all original indexes and the weight is judged by the ratio. The steps are as follows:

- Establish the original data matrix of the index system. Observed above 16 indexes, aimed at the level of energy-saving for the low-carbon industrial development of Pingtan over the years, marked as $x_1, x_2, \ldots, x_p$ and established a data matrix X .

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{pmatrix}$$

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{pmatrix}$$

- Standardization of evaluation index. To avoid the effects due to the different dimensions of variables standardized the original data $X_j \ (x_{1j}, x_{2j}, \ldots, x_{nj})^T$, so that the average value of each variable is 0, and the variance is 1. Here is the formula for transformation:

$$Z_{ij} = \frac{(X_{ij} - \overline{X}_j)}{S_j} \quad (i = 1, 2, \ldots, n; \quad j = 1, 2, \ldots, p)$$ (

Where Z_{ij} is the standardized the variable of original variable X_{ij} .

$$\overline{X}_j = \frac{\sum_{i=1}^{n} |\overline{X}_{ij}}{n}$$ (

$$S_j = \sqrt{\frac{\sum_{i=1}^{n}(X_{ij} - \overline{X}_j)^2}{n-1}}$$ (

- Calculating correlation matrix R through the standardized data. Calculating correlation matrix R of the evaluation indexes which have standardized, where the correlation matrix R of $Z_j = (Z_{1j}, Z_{2j}, \ldots, Z_{nj})^T$

is:

$$R = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1p} \\ r_{21} & r_{22} & \cdots & r_{2p} \\ \cdots & \cdots & \cdots & \cdots \\ r_{p1} & r_{p2} & \cdots & r_{pp} \end{pmatrix}$$

- Its element r_{ji} represents the correlation between the original variables x_j and x_i .

$$r_{ji} = \frac{\sum_{k=1}^{n}(X_{ki} - \overline{X}_i)(X_{ki} - \overline{X}_j)}{\sqrt{\sum_{k=1}^{n}(X_{ki} - \overline{X}_i)}\sqrt{\sum_{k=1}^{n}(X_{ki} - \overline{X})}} \quad (i, j = 1, 2, \ldots, p) \tag{4}$$

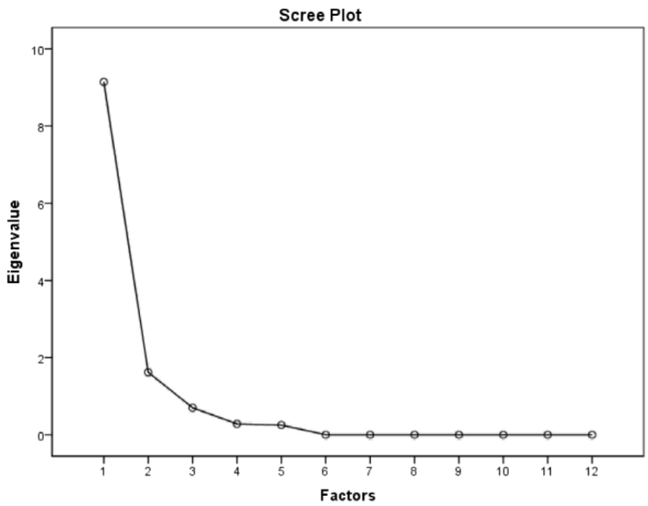


Fig. 3-2. The Scree Plot of energy-saving evaluation index in Pingtan.

Extract principal component, namely calculated the eigenvalue of the correlation matrix R, and then determined the corresponding eigenvectors R and the number of principal components. Doing characteristic equation R λE 0, calculate the eigenvalue λ; If λ1 ⩾ λ2 ⩾⩾ λn ⩾ 0, then to determine the number of main components m, according to the contribution rate of cumulative variance which is greater than 85, and ak (ak1, ak2, . . . , akm) is the eigenvector corresponding to λk (k = 1, 2, . . . , m), and ak = √λk is the principal

component of No. k, that is fitting to λk , where pk is the vector of variable Z1, Z2, . . . , ZP after standardized.

Calculate the principal component scores; it is the scores of each main component on the subsystem, which reflects the influence of the subsystem on the main system.

Calculate the total score of comprehensive indexes and then calculate the proportion of the principal component scores, accounting for the total score of extensive indexes， which reflects the industries that are currently primarily influencing the current state of energy efficiency. The larger proportion the more vital ability of the extended index to represent the original index， which means the higher the influence of the industry in the development of low carbon industry in Pingtan.

Some of them have negative main component scores, as determined by the model. The negative score shows that the subsystem's competitiveness is lower than the average level of the examined area, not that the subsystem is less competitive than it should be. The major factor score is favorable, which shows that the subsystem is more competitive than the norm. The explanation of total variance is shown in Table 3-3. The variance of the first two principal components accounts for 89.689% of the variance of all principal components.As can be seen, the first two principal components contain almost all of the information contained in the original variables, making them sufficient to replace them.

According to the eigenvalues of principal component factors, the distribution of eigenvalues of 12 principal components is calculated, as shown in Figer. 3-2. It is clear that the second eigenvalue marks a significant turning point.

3.5 Conclusion

The growth of low-carbon industries involves a variety of coordinated efforts in the areas of energy use, emission control, technology, and so forth. This paper proposes an energy-saving evaluation system for the development of low-carbon industries with energy consumption as the core, emission reduction as the goal, and technology as the means, and takes it as an evaluation index for the development of energy-saving in Pingtan industry on the basis of the reality of the Pingtan Comprehensive Experimental Zone.There has a fundamental practical significance of the evaluation system to optimize the industrial structure layout of Pingtan, promote the transformation and upgrading of traditional industries, accelerate the pace of low-carbon industries development, and improve resource utilization efficiency and purposefully solve the problems and development direction of low-carbon industry in Pingtan.

The development of low-carbon industrial is a unity of coordinated action, which is involved to energy consumption, emission reduction, technical, and so on. On this basis, combined with the reality of Pingtan Comprehensive Experimental Zone, this paper puts forward an energy-saving evaluation system for the development of low-carbon industries with energy consumption as the core, emission reduction as the goal, and technology as the means, and takes it as an evaluation index for the development of energy-saving in Pingtan industry. There has a fundamental practical significance of the evaluation system to optimize the industrial structure layout of Pingtan, promote the transformation and upgrading of traditional industries, accelerate the pace of low-carbon industries development, and improve resource utilization efficiency.

Table 3-3. Explanation of total variance for energy-saving evaluation index in Pingtan

Component	Initial eigenvalues			Extraction of sum of squares loaded		
	Total	% of variance	% Cumulative	Total	% of variance	% Cumulative
1	9.143	76.189	76.189	9.143	76.189	76.189
2	1.620	13.500	89.689	1.620	13.500	89.689
3	.702	5.850	95.540			
4	.283	2.356	97.895			
5	.253	2.105	100.000			
6	5.043E−016	4.203E−015	100.000			
7	3.039E−016	2.532E−015	100.000			
8	2.036E−016	1.696E−015	100.000			
9	8.238E−018	6.865E−017	100.000			
10	−2.637E−016	−2.197E−015	100.000			
11	−3.772E−016	−3.143E−015	100.000			
12	−1.874E−015	−1.562E−014	100.000			

So far, we have completed the first step in the whole cycle of planning and design, which is the establishment of the energy saving index system. In the next step, we will further narrow down the scale of the research object, and conduct research from all stages of the planning cycle.

Chapter 4 Planning Compilation for Installment of Sensors for Smartification of Urban Spaces

In the previous chapter, we clarified the energy saving indicators in planning and design, visual simulation of the energy system consumption of the overall building space can reduce energy consumption in the planning, implementation and management stages. Established the first step in the whole cycle of planning and design, setting planning goals. Therefore, at this stage of this study, the spatial scale of the research object is further reduced, and we enter the underground space in the urban space. In a low-carbon society, most of the underground space belongs to the public business field. The same thing as urban space is that it belongs to urban space and also includes smart service system and smart infrastructure system. At this stage, we have carried out specific planning and design for the intelligentization of underground space in urban space.

4.1 Introduction

This paper clarifies the sensor types and corresponding parameters for smart sensing scenes by analyzing the needs of different types of underground space scenes. Based on the sensor parameters and acquired data required by the underground space smart sensing platform system, the sensor installation guidelines are formed accordingly.

This study needs to clarify types of underground spaces, and we can refer to the laws and regulations of underground spaces in each country. Japan has a perfect legal and management mechanism for underground spaces , such as the “Act on Special Measures concerning Public Use of Deep Underground”, which clarifies the specific problems and technical measures for underground space utilization. Meanwhile, for different types of underground spaces, there are different technical standards and construction regulations , such as “Standard Specification for Tunneling” and so on. The “State Lands Act” and “Land Acquisition Act” clarify the classification basis and ownership of underground spaces, and the "Common Services Tunnels Act" and others have introduced new technical requirements for different underground spaces. There are also different technical standards and construction procedures in different underground space classifications such as "Railway applications Fixed installations Electric traction overhead contact lines". In the United States, there is also a relatively complete legal and management mechanism for underground space [6], and state laws such as "Laws of Minnesota for 1985 Mined Underground Space" and "Oklahoma Statutes Property" have clarified the technical measures in the development and use of underground space according to the characteristics of each state. There are also different technical standards and construction procedures in different underground space types, such as "Underground Electric Distribution Standards Manual" and "Underground Construction (Tunneling)". Similar to the United States, the United Kingdom also has a comprehensive legal and regulatory mechanism , such as the "London Underground Act 1992", which proposes measures to deal with various problems in different areas of London's underground space. The United Kingdom also has different technical standards and construction regulations in different underground space types, such as "The Road Tunnel Safety (Amendment) Regulations". Through these laws and regulations, the classification of underground space can be clarified .

From the location of the underground space, it requires arterial energy from facilities such as water, electricity, transportation and data flow , and waste water and waste disposal through veins , while the underground space contains the infrastructure that ensures the function and operation of urban infrastructure and is the "lifeline" that combines the arteries and veins of the city in addition to the services and facilities that bring benefits and taxes from commercial operations and provide commercial value to the city . Therefore, the planning of underground spaces also emphasizes the actual equipment , and smart sensing of underground spaces can improve the responsiveness of equipment and thus the efficiency of the city's arteries and veins . As a basic component of smart construction, the installation of sensors (including model selection, location selection, combination mode, etc.) is an important part of smart work .

Based on the existing design guidelines in Japan, such as "Facility Construction Safety Construction Technical Guidelines" and "Civil Engineering Work Safety Construction Technical Guidelines", it is clear in Table 4-1 that the requirements for equipment in underground spaces in the traditional Japanese design guidelines are mainly reflected in the types of equipment, the general location of equipment and the occasions of use of equipment. The existing regulations and guidelines basically do not involve smart devices, sensors and other new equipment content. This problem is common in the design guidelines for underground spaces in all countries. From the devices used in the current underground space in Japan, we can also see in Table4-1 that these devices consume more energy and have a lower degree of smartness, and most of them are universal and do not select devices for the characteristics of different types of underground spaces.

Table4-1. Summary of the requirements of the existing guidelines for underground space devices and the devices commonly used in the current underground space.

The Types of Equipment Mentioned in the Guidelines	**Rules for Equipment Requirements Mentioned in the Guidelines**	**Current Use of the Devices**
Lighting Equipment	1. Requirements on the installation of lighting equipment in three cases: a. Lighting equipment renewal (completely renewed, mixed old and new); b. Lighting equipment operation next to the air exchange fan. 2. Precautions for wiring installation of lighting equipment. 3. Precautions for installation of lighting equipment itself.	LED tunnel light
Air Ventilation Equipment	1. The air exchange equipment is mainly tunnel fans. 2. The location of the anchor for the fan is determined and installation precautions. 3. Precautions for installation of the fan itself. 4. Post-installation testing precautions.	Tunnel jet fan
Dust Countermeasure Equipment	1. Application of air ventilation equipment in the dust response phase. 2. Specific content of dust concentration measurement. 3. Precautions for the use of respiratory protective equipment in emergency situations.	Tunnel jet fan, dust concentration detector
Noxious Gas Response Equipment	1. Requirements for exhaust devices.	Tunnel jet fans, alarms or emergency bells, Automatic fixed combustible gas alarms, Automatic power cut-off devices

	2. Requirements for alarm devices (including implementation of monitoring equipment). 3. Response when the critical value is reached (automatic power cut). 4. Requirements for evacuation equipment.	
Alarm & Rescue Equipment	1. Clarify the investigation content of the prior investigation. 2. The use of rescue equipment. 3. The use of alarm equipment.	Alarm or emergency bell, automatic fixed combustible gas alarm, smoke detector
Disaster Response Equipment	To deal with rain, wind, snow, lightning, earthquakes and other natural disasters	Alarm or emergency bell, automatic fixed combustible gas alarm, automatic power cut-off device
Structure Monitoring Equipment	Mainly construction auxiliary equipment.	Earth pressure meter (vibrating string type earth pressure meter), pore water pressure meter, static level, displacement meter, in-clinometer, pillar pressure meter, reinforcement meter/anchor force gauge, concrete strain gauge
Environmental Monitoring Equipment	1. Measures for places with poor ventilation conditions. 2. Measures to deal with the cramped environment during mechanical construction. 3. Measurement required for operating environment.	Automatic fixed combustible gas alarm, smoke detector, thermometer, hygrometer, dust concentration detector

Source: compiled based on Facility Construction Safety Construction Technical Guidelines and Civil Engineering Work Safety Construction Technical Guidelines.

In summary, countries have more complete laws and regulations for the infrastructure construction of underground space, but there is a lack of design guidelines for setting up smart sensing devices in the whole underground space . Therefore, this study starts from the design phase of underground space, and after clarifying the classification of underground space, according to the functional requirements of different scenes for sensors in underground space, the type parameters of sensors in each scene are clarified. According to the type and parameters of sensors, the attributes of the collected data are clarified. Finally, based on the classification of underground space, the basic framework of underground space intelligent sensing system design, the properties of sensors, and the properties of data, we propose the guidelines of sensor installation for smart scenes in underground space.

4.2 Theoretical Concept and Methodology

To meet the monitoring and early warning needs of maintenance management, this study considers that the guidelines for setting up sensors in underground spaces need to clarify the classification of underground spaces and also the properties of sensors such as communication methods, the properties of data and the basic framework of the sensing system, thus taking the following research steps to propose guidelines for setting up sensors for smart scenes in underground spaces:

Classify the underground space according to the classification standard of Japanese underground space and the functional characteristics of each type of underground space, and by clarifying the functional requirements of each type of underground space for sensors on the basis of the classification of underground space;

Based on the above-mentioned requirements for sensors in the underground space, the sensors are screened on the basis of the temperature and humidity applicable to the underground space, and the sensor types and parameters are selected to meet the smart scene and functional requirements of the underground space;

Based on the functional requirements met by the above sensors as well as the sensor types and parameters, the types of data acquired by each type of sensor and the data attributes are clarified;

Based on the classification of underground space, sensor attributes and data attributes in I, II and III above, clarify the data transmission methods and data flow between sensors of various types of data, propose the basic framework of smart sensing system in underground space and form the guidelines for setting up sensors for smart scenes in underground space.

4.3 Underground Space Classification and Scene Requirements Analysis

Since the stage of guideline preparation is in the stage before planning compilatin, it is necessary to consider the needs of scenarios in each stage from planning design - construction - operation and maintenance - monitoring, etc. Since different types of underground spaces will adopt different construction methods and different construction processes to achieve different spatial structures and spatial effects during the development and construction process, these factors will affect the needs of underground spaces for data acquisition, construction safety, disaster response and other conditions; at the same time, the design requirements and maintenance re-quirements also differ in the planning design and operation and maintenance phases according to the different functions of the space. Therefore, studying the character-istics of various types of underground spaces on the basis of underground space classification is an important prerequisite and basis for clarifying the needs of dif-ferent spaces for sensors.

Various types of underground spaces have different needs for sensors. Since the planning and construction of underground spaces in Japan is at an advanced level internationally, this study refers to the Japanese classification standard for under-ground space, which distinguishes between civilian land and public land, and classi-fies underground spaces according to the depth of various underground facilities in Figure 4-1.

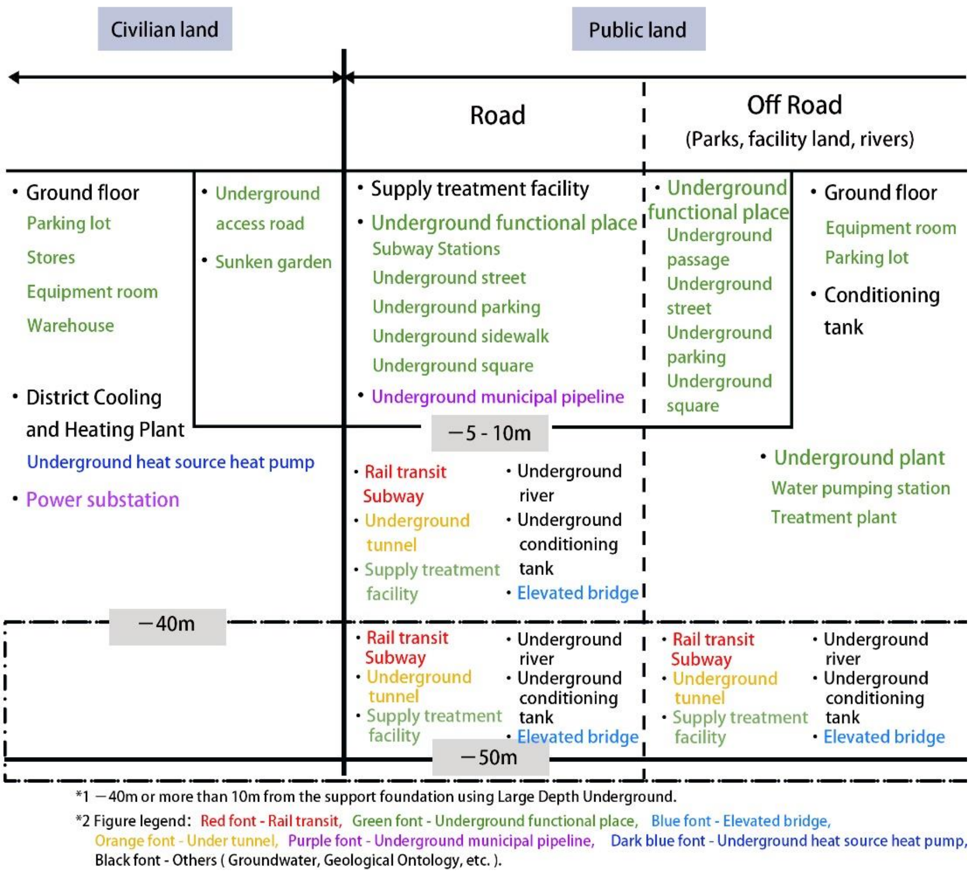


Figure 4-1. Classification of underground space in Japan.

Based on the Japanese classification standard for underground space, underground space can be divided into six types of underground infrastructure: rail transit, under-ground functional places (underground stores, parking lots, subway stations, etc.), elevated bridges, underground tunnels, underground municipal pipelines, and underground heat source heat pumps in Table 4-2.

Table 4-2. Classification of underground space and monitoring priorities.

Scene Type	**Maintenance and Management**		**Control-Warning**
	Daily Maintenance	**Disaster Prevention**	
Rail transit	Personal safety-fall, Personal safety-attention wake-up, obstacle monitoring, track status monitoring	Flooding disaster, fire evacuation, earthquake disaster	smart construction monitoring, disaster response (fire, flooding, earthquake, gas leak, tilt, subsidence, deformation)
Elevated bridge	Structural security monitoring		
Underground tunnel	Structural security monitoring	Tube sheet disease, tunnel flooding disaster, fire evacuation, earthquake disaster	
Underground municipal pipeline	Pipeline structure monitoring, pipe chamber environmental monitoring	Pipeline leaks (liquid/gas), underground voids	
Underground functional place	Underground space environmental monitoring	Underground space flooding disaster, fire evacuation, earthquake disaster	
Underground heat source heat pump	Underground heat source pollution monitoring		
Geological ontology	Surface monitoring, in-ground monitoring		Geological tilt, subsidence, deformation
Ground water	Groundwater level daily monitoring	Groundwater contamination monitoring	Groundwater level, water temperature, water quality abnormalities

Source: compiled based on Act on Special Measures Concerning Public Use of Deep Underground.

Different functions of the underground space are monitored differently during maintenance. Therefore, there are also differences in the requirements for sensor. Various spatial similarities are shown in Figure 4-2, mainly for the need of data acquisition and early warining & feedback: on the one hand, to obtain environmental data as well as image and structural data in space; on the other hand, for the early warn-ing and feedback of disasters such as fire, flooding disaster, earthquake, etc..

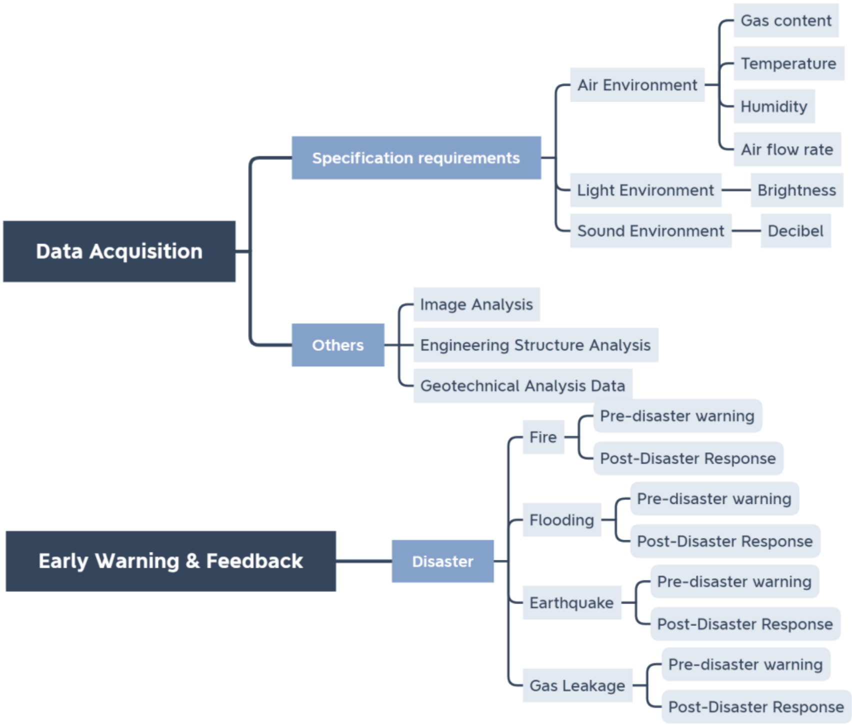


Figure 2. Maintenance phase monitoring content classification diagram.

As mentioned above, since the stage of guideline preparation is in the stage before planning compilatin, it is necessary to consider the needs of scenarios in all stages from planning and design - construction - operation and maintenance - monitoring. Different types of underground space in the development and construction process will use different methods, different construction processes to achieve different space structure and space effects, so in order to meet the construction needs, different types of space for the sensor needs also differ, need to be discussed based on the classification of underground space.

Underground spaces have different requirements for various types of sensors in different types of spaces, which are organized according to the Table 4-3 below.

Table 4-3. Summary of underground space requirements.

Smart Scene Type	Requirements	Purpose
Basic scenes (generic scenes)	Monitoring of natural and man-made disasters	Response before and after disasters, mainly natural disasters (flooding, earthquakes, extreme weather (extreme cold and

		heat, thunderstorms)) and man-made disasters (fire, equipment failure, construction personnel health)
	Monitor construction and operational environments	Monitoring and adjusting the air environment, sound environment, geotechnical environment, and light environment to make people feel comfortable
	Obtaining staff health information	Prevention of various types of emergencies in the underground space when affecting the health of staff, timely response
	Obtain equipment movement information	Prevent the loss of equipment in the underground space or loss of contact with the host
Rail transit	Obtain information on falling objects on the tracks	Prevent people from falling onto the track or objects from falling onto the track and affecting train operation
	Monitoring of platform doors for objects caught in them	Prevent damage to people or objects when platform doors are closed
	Emergency stop of trains	To guide trains to an emergency stop after an emergency situation to reduce damage
	Obtain track structure information	Prevent damage to the track structure from affecting operation
Underground functional place	Obtain operating environment data and make timely adjustments	To make the environment comfortable and convenient for various functions
Elevated bridge	Obtain bridge structure information	Reducing damage to bridge structures that may affect operations
	Obtain information on pillar structure	Prevention of collapse due to damage to the column structure
Underground tunnel	Obtain support structure information	Reduce the collapse potential caused by damage such as support cracks, and deal with cracks that have a greater impact in a timely manner
Underground municipal pipeline	Real-time monitoring of pipeline structure	Prevent the occurrence of liquid leakage and air leakage, and respond to liquid leakage and air leakage in a timely manner
Underground heat source heat pump	Obtain information on pipeline structure	Prevent fluid leaks and respond to them in a timely manner
	Obtain information on the structure of the exchange well	Reduce collapse hazards caused by cracks in exchange wells, etc., and promptly respond to cracks that have a large impact
	Monitoring the fluid in the well	Liquid temperature and water level should meet the specific requirements of the heat source heat pump and reduce the influence of the liquid itself on the efficiency of the heat source heat pump
	Obtain information on surrounding groundwater	Reduce the pollution of the surrounding groundwater by the liquid in the exchange well

Source: Compiled based on documents related to underground space issued by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

4.4 Underground Space Sensor Sorting

Based on the classification of the underground space, and the requirements of sensors for different underground space scenarios, the sensors on the market are screened on the basis of the temperature and humidity applicable to underground space, and the types of sensors and the corresponding parameters of sensors that can meet the needs of the scenario are obtained in Table 4-4. Also identified in Table 4-4 is whether the type of monitoring for each type of sensor is long-term monitoring or regular monitoring. Long-Term Monitoring refers to sensors that are turned on con-tinuously during the operation of the scenario (e.g. temperature and humidity sen-sors), while regular monitoring refers to sensors that are automatically/manually turned on at regular intervals to obtain periodic data.

Table4-4. Summary of underground space sensors.

Smart Scene Type	Sensor Type	Detection Principle (Component Equipment)	Data Monitoring Scope	Long-Term/Regular Monitoring
Basic scenes (generic scenes)	Infrared smoke sensor	Infrared 2 wavelength type, fluctuation type, CO_2 resonance radiation type	Exposure to smoke YES/NO	Long-term monitoring
	Gas sensors	Hot-wire type semiconductor type, contact combustion type, gas heat conduction type	0~100% LEL	Long-term monitoring
	Hydrogen sulfide sensor		0~50 ppm	Long-term monitoring
	Carbon monoxide sensor	Constant potential electrolytic type, diaphragm plus Varney cell type	0~250 ppm	Long-term monitoring
	Oxygen sensor	Constant potential electrolytic type, diaphragm plus Varney cell type	0~25 vol%	Long-term monitoring
	Noise detector1	Condenser electric microphone	28~141 dB	Long-term monitoring
	Flood sensor	Water contact sensor	Exposure to water YES/NO	Long-term monitoring
	Temperature and humidity sensor	Capacities temperature and humidity sensitive sensor	Temperature: −40~80 °C	Long-term monitoring

	Mobile environmental monitoring sensor	Constant potential electrolytic type, diaphragm plus Varney cell type	Humidity: 0~100%Rh Oxygen concentration: 0~25 vol%	Long-term monitoring
			Carbon monoxide concentration: 0~300 ppm	Long-term monitoring
	Laser distance sensor	Light reflection principle	0.05~100 m	Long-term monitoring
	RFID readers/tags	Light reflection principle	3–5 m	Long-term monitoring
	Dust sensor	Light scattering relative density meter	Exposure to dust YES/NO	Long-term monitoring
	Wind speed sensor	Rotor rotation speed	0~114 m/s	Long-term monitoring
Rail transit	Gas sensors	Hot-wire type semiconductor type, contact combustion type, gas heat conduction type, constant potential electrolytic type, diaphragm plus Varney cell type	0~100% LEL	Long-term monitoring
	Hydrogen sulfide sensor		0~50 ppm	Long-term monitoring
	Carbon monoxide sensor		0~250 ppm	Long-term monitoring
	Oxygen sensor		0~25 vol%	Long-term monitoring
	Construction monitoring radar	Light reflection principle	Collapse occurs YES/NO	Long-term monitoring
	Roll-off detection mat	Environment resistance obturation sensor, Drop test camera	Perceived pressure YES/NO	Long-term monitoring
	New-type PSD	Residual detection sensors (3D sensors, photoelectric sensors), proximity detection sensors (photoelectric sensors)	Perceived pressure YES/NO	Long-term monitoring
	Track material monitoring device	Configuration camera (distance image capture device)	Material Breakage YES/NO	Regular monitoring
	Orbit displacement monitoring device	Linear sensor camera (Intense and faint image photography device)	Orbital displacement YES/NO	Regular monitoring
	Image displacement measurement system	Laser displacement meter	Orbital displacement YES/NO	Regular monitoring
	Line equipment monitoring device	Digital camera, displacement meter, in-clinometer	Equipment breakage YES/NO	Regular monitoring

Underground functional place	Dust sensor	Light scattering relative density meter	Exposure to dust YES/NO	Long-term monitoring
Elevated bridge	Extensometer	Displacement sensor	6.5 ± 1 mm	Long-term monitoring
	Horizontally tiltometer	Tiltmeter	0–500 mm	Long-term monitoring
	Crack gauge	Crack gauge	5~40%	Long-term monitoring
	Light strain sensor	Light strain sensor, Strain gauge, Fiber optic measuring instrument	Sensing to strain YES/NO	Long-term monitoring
	Nature frequency gage	Nature frequency gage	50 kHz	Regular monitoring
Underground tunnel	Gas sensors	Hot-wire type semiconductor type, contact combustion type, gas heat conduction type, constant potential electrolytic type, diaphragm plus Varney cell type	0~100% LEL	Long-term monitoring
	Hydrogen sulfide sensor		0~50 ppm	Long-term monitoring
	Carbon monoxide sensor		0~250 ppm	Long-term monitoring
	Oxygen sensor		0~25 vol%	Long-term monitoring
	Construction monitoring radar	Light reflection principle	Collapse occurs YES/NO	Long-term monitoring
	Crack displacement meter	Crack displacement meter, remote wireless unit	5~40%	Long-term monitoring
	Fiber optic crack detection sensor	Crack detection accelerometer, crack detection adapter, data recorder TDS-530	5~40%	Long-term monitoring
	Fiber optic sensor	Fiber optic sensor	Cracking occurs YES/NO	Long-term monitoring
Underground municipal pipeline	Water leak detection service	Water leak detection sensor	Water leakage occurs YES/NO	Long-term monitoring
	Remote water leak monitoring system	Water leak detection sensor	Water leakage occurs YES/NO	Long-term monitoring
	Installation of tube lumen survey machine	Electromagnetic pulse radar, television cameras	Tube lumen breakage YES/NO	Regular monitoring
Underground heat source heat pump	Pressure type water gauge	Induction of hydro-static pressure in water bodies	0.05% F.S	Long-term monitoring
	Clinograph	Tilt sensor, electrolyte and conductive contacts	±330 micro-radius	Long-term monitoring
	Multipurpose water quality gauge	Voltage conductivity	PH value	Long-term monitoring
	Water leak detection sensor	Laser hydrostatic principle	0–50 m	Long-term monitoring

Source: Compiled based on the public information of the company: Tokyo Measuring Instruments Lab. (Kiryu Factory, Kiryu, Japan); SAKATA DENKI Co. Ltd. (Head Office & Factory, Tokyo, Japan); New Cosmos Electric Co. Ltd. (Cosmos sensor Center, Hyogo, Japan; Tokyo Factory, Tokyo, Japan); AIREC ENGINEERING Corporation (Head Office & Factory, Tokyo, Japan); TOBISHIMA Corporation, Keyence Co. Ltd. (Head Office & Factory, Tokyo, Japan); Kyosan Electric Mfg. Co. Ltd. (Head Office & Factory, Yokohama, Japan; Zama Factory, Kanagawa, Japan); Japan Railway Track Consultants Co. Ltd. (Head Office & Factory, Tokyo, Japan); Kyowa Electronic Instruments Co .Ltd. (Kofu Kyowa Dengyo Co. Ltd., Yamanashi, Japan; Yamagata Kyowa Dengyo Co. Ltd., Yamagata, Japan) where each type of sensor is located.

4.5 Underground Space Data Sorting

Based on the functional requirements of the underground space for sensors, sensor types and parameters, the attributes of the data acquired by various types of sensors are clarified, including data transmission methods and data monitoring scopes. The final results will be classified based on data types and attributes to form a data summary table (Table 4-5). Among the data transmission methods both wired and wireless transmission methods are collated. Except for some specific sensors in rail transportation scenarios, each sensor basically has two or more different transmis-sion methods to choose from.

Table 4-5. Sensor-based data summarization in underground spaces.

Smart Scene Type	Sensor Type	Data Monitoring Scope	Monitoring Indicator	Data Transmission Method
Basic scenes (generic scenes)	Infrared smoke sensor	Exposure to smoke YES/NO	Smoke, thermal infrared	ZigBee/Bluetooth
	Gas sensors	0~100% LEL	Hydrogen concentration, sulfur dioxide gas concentration, carbon dioxide gas concentration	ZigBee/Bluetooth
	Hydrogen sulfide sensor	0~50 ppm	Hydrogen sulfide gas concentration	ZigBee/Bluetooth
	Carbon monoxide sensor	0~250 ppm	Carbon monoxide gas concentration	ZigBee/Bluetooth
	Oxygen sensor	0~25 vol%	Oxygen concentration	ZigBee/Bluetooth

	Noise detector	28~141 dB	Noise intensity	WiFi/Bluetooth
	Flood sensor	Exposure to water YES/NO	Flooding depth	WiFi/Bluetooth
	Temperature and humidity sensor	Temperature: −40~80 ℃ Humidity: 0~100% Rh	Temperature & Humidity	WiFi/Bluetooth
	Mobile environmental monitoring sensor	Oxygen concentration: 0~25 vol% Carbon monoxide concentration: 0~300 ppm	Oxygen concentration, Carbon monoxide gas concentration	WiFi/Repeater/Bluetooth
	Laser distance sensor	0.05~100 m	Distance of mobile devices from the perimeter	Repeater-Bluetooth
	RFID readers/tags	3–5 m	Location, trajectory	WiFi/Bluetooth/USB
	Dust sensor	Exposure to dust YES/NO	Dust concentration (PM2.5 mainly)	WiFi/Repeater/Bluetooth
	Dust sensor	Exposure to dust YES/NO	Dust concentration	WiFi/Repeater/Bluetooth
	Wind speed sensor	0~114 m/s	Wind speed	WiFi/Repeater/Bluetooth
Rail transit	Gas sensors	0~100% LEL	Hydrogen concentration, sulfur dioxide gas concentration, carbon dioxide gas concentration	
	Hydrogen sulfide sensor	0~50 ppm	Hydrogen sulfide gas concentration	WiFi/Bluetooth
	Carbon monoxide sensor	0~250 ppm	Carbon monoxide gas concentration	
	Oxygen sensor	0~25 vol%	Oxygen concentration	
	Construction monitoring radar	Collapse occurs YES/NO	Construction safety (construction environment)	Repeater-Bluetooth
	Roll-off detection mat	Perceived pressure YES/NO	Orbital drop	Fiber optic
	New-type PSD	Perceived pressure YES/NO	Rail platform gap	Fiber optic
	Track material monitoring device	Material Breakage YES/NO	Track material	Repeater
	Orbit displacement monitoring device	Orbital displacement YES/NO	Orbital displacement distance	Repeater

	Image displacement measurement system	Orbital displacement YES/NO	Orbital displacement distance	Repeater
	Line equipment monitoring device	Equipment breakage YES/NO	Wires on the track	Repeater
Underground functional place	Dust sensor	Exposure to dust YES/NO	Dust concentration	WiFi/Repeater/Bluetooth
Elevated bridge	Extensometer	6.5 ± 1 mm	Bridge support displacement distance	Repeater-WiFi
	Horizontally tiltometer	0–500 mm	Inclined amount of bridge	Repeater-WiFi
	Crack gauge	5~40%	Crack width of bridge body	Repeater-WiFi
	Light strain sensor	Sensing to strain YES/NO	Bridge strain variables	Repeater-WiFi
	Nature frequency gage	50 kHz	Vibration characteristics of the bridge	Repeater-WiFi
Underground tunnel	Gas sensors	0~100% LEL	Hydrogen concentration, sulfur dioxide gas concentration, carbon dioxide gas concentration	
	Hydrogen sulfide sensor	0~50 ppm	Hydrogen sulfide gas concentration	WiFi/Bluetooth
	Carbon monoxide sensor	0~250 ppm	Carbon monoxide gas concentration	
	Oxygen sensor	0~25 vol%	Oxygen concentration	
	Construction monitoring radar	Collapse occurs YES/NO	Construction safety (construction environment)	Repeater-Bluetooth
	Crack displacement meter	5~40%	Tunnel support cracks	Repeater-WiFi
	Fiber optic crack detection sensor	5~40%	Tunnel support cracks	Repeater-WiFi
	Fiber optic sensor	Cracking occurs YES/NO	Tunnel support strain variables	Repeater-WiFi
Underground municipal pipeline	Water leak detection service	Water leakage occurs YES/NO	Pipeline liquid leakage	Repeater-WiFi
	Remote water leak monitoring system	Water leakage occurs YES/NO	Pipeline liquid leakage	Repeater-WiFi
	Installation of tube lumen survey machine	Tube lumen breakage YES/NO	Pipeline structure	Repeater-WiFi
Underground heat source heat pump	Pressure type water gauge	0.05% F.S	Heat source heat pump feed well water level, water temperature	Repeater-WiFi

Clinograph	±330 micro-radius	Sliding surface depth, sliding direction and movement of heat source heat pump feeder wells	Repeater-WiFi
Multipurpose water quality gauge	PH value	Water quality changes in heat source heat pump drainage wells	Repeater-WiFi
Water leak detection sensor	0–50 m	Location and flow conditions of groundwater fluidized bed of heat source heat pump	Repeater-WiFi

Source: Compiled based on the public information of the company: Tokyo Measuring Instruments Lab. (Kiryu Factory, Kiryu, Japan); SAKATA DENKI Co. Ltd. (Head Office & Factory, Tokyo, Japan); New Cosmos Electric Co. Ltd. (Cosmos sensor Center, Hyogo, Japan; Tokyo Factory, Tokyo, Japan); AIREC ENGINEERING Corporation (Head Office & Factory, Tokyo, Japan); TOBISHIMA Corporation, Keyence Co. Ltd. (Head Office & Factory, Tokyo, Japan); Kyosan Electric Mfg. Co. Ltd. (Head Office & Factory, Yokohama, Japan; Zama Factory, Kanagawa, Japan); Japan Railway Track Consultants Co. Ltd. (Head Office & Factory, Tokyo, Japan); Kyowa Electronic Instruments Co. Ltd. (Kofu Kyowa Dengyo Co. Ltd., Yamanashi, Japan; Yamagata Kyowa Dengyo Co. Ltd., Yamagata, Japan) where each type of sensor is located.

4.6 Basic Framework of Underground Space Smart Sensing Platform

Based on the analysis of underground space classification and scene requirements, sensor attributes and data attributes, the framework of underground space smart sensing platform (smart sensing system control) is proposed in Figure 4-3. Based on the summarized data transmission methods, the basic architecture model of the underground space intelligent sensing platform is obtained. It is mainly divided into four parts: smart monitoring module (various types of sensors or sensing systems), network transmission module, forecast and warning module and data report genera-tion visualization module. The framework of the underground space intelligent sensing platform is also the basis for determining the data transmission method and data flow of the sensor-acquired data, with the aim of establishing an underground space intelligent sensing system based on it.

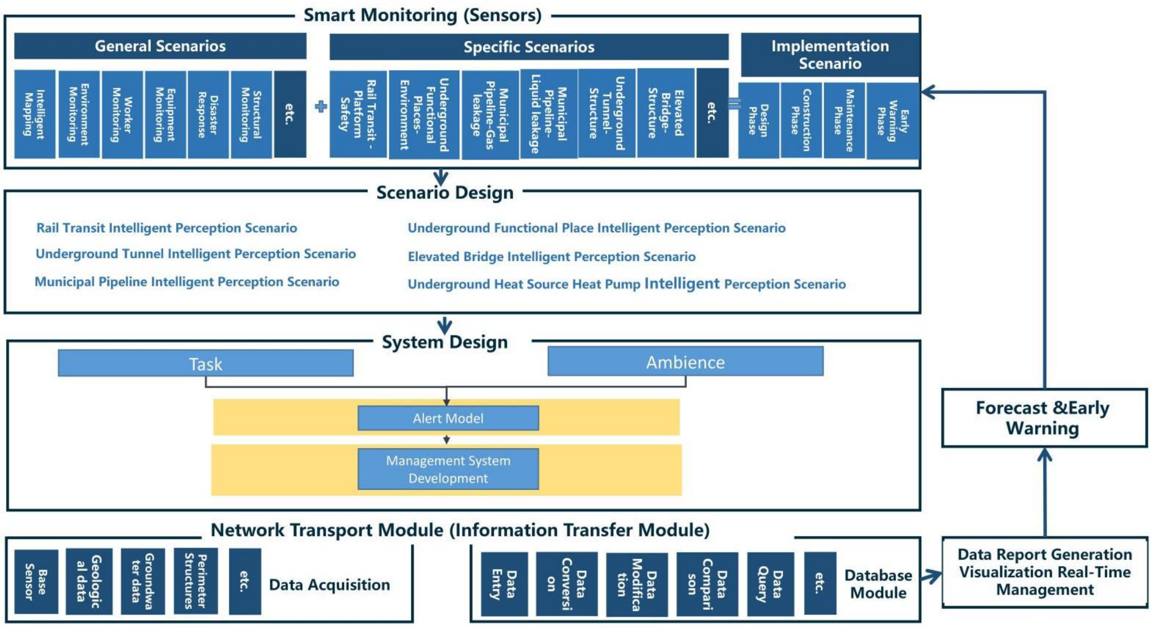


Figure 4-3. Basic framework of underground space smart sensing platform.

Based on the data transmission methods and data flow between sensors in the underground space, the data flow of the sensing platform is clarified in Figure 4-4: smart monitoring devices (sensors) acquire data Multiple sensors are combined to form smart scenarios The data acquired by each sensor is integrated as task (or the data acquired by each scene as Ambience), through the central processor and the database data for comparison, through the network transport module to the database module (update data without problems) or data report generation visualization real-time management module (problem data for feedback) feedback to smart monitoring equipment (alarm device) through forecast and early warning module with problematic data.

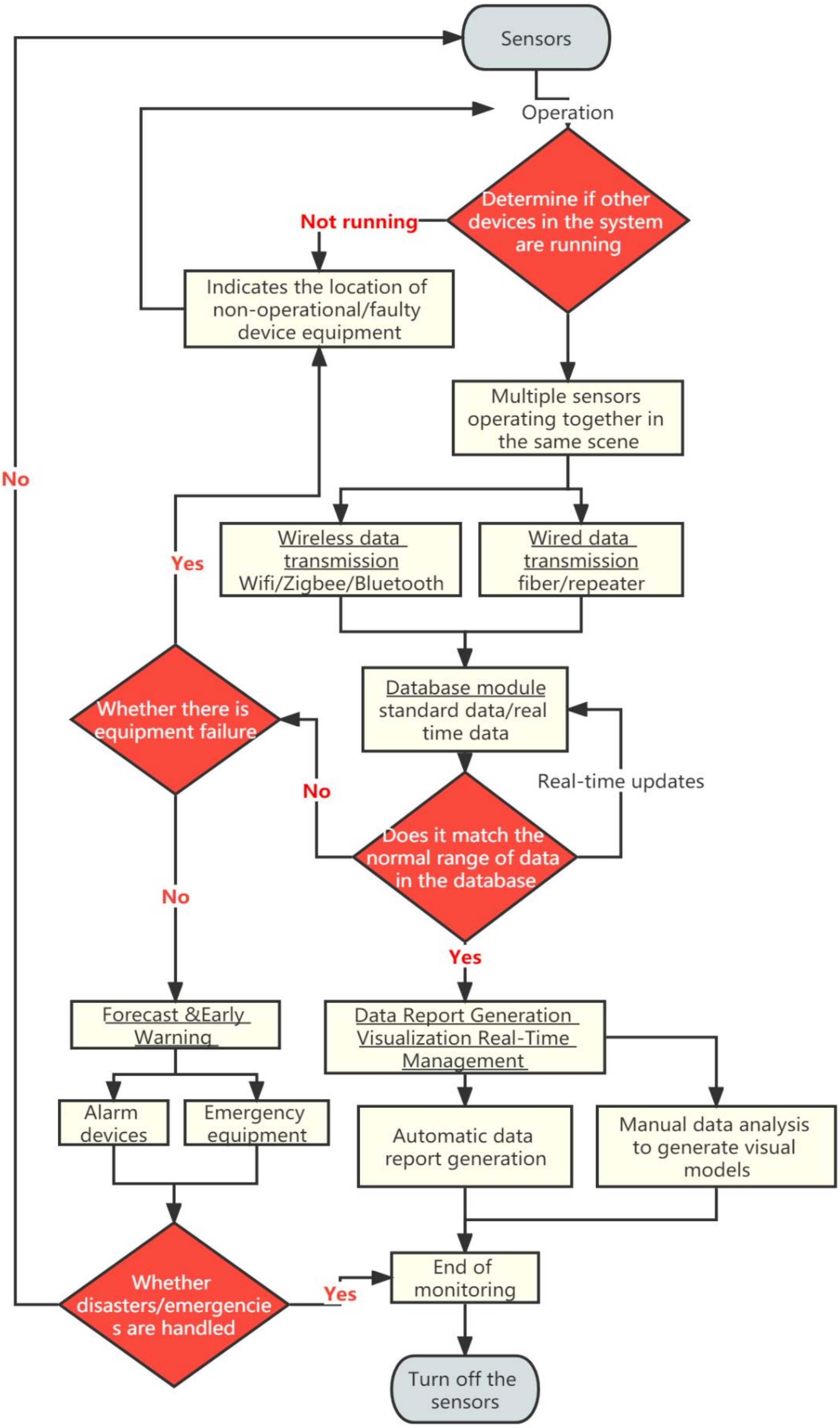


Figure 4-4. Smart perception platform UML.

7. Production of Sensor Installation Guidelines for Underground Space

In this paper, we make a summary analysis of the requirements of different underground space types to clarify the types of underground space sensor requirements as well as the parameters of the sensors and the monitoring data of the underground space to form the sensor installation guidelines in the underground space smart sensing platform. To facilitate the designers to carry out the design work related to the underground space smart, we will finally form the sensor design and installation guidelines table (Table 6) and the installation location schematic according to the characteristics of the sensors used in different scenarios (Figures 5–16). The guide-line table is mainly from the type of smart devices - smart devices to achieve the function - smart device installation scenarios and specific location - smart device installation methods - post-installation testing requirements of these parts of the content to sort out. On the one hand, the installation location diagram corresponds to the table in a diagrammatic way to determine the scenario and specific location of smart device installation; on the other hand, it clarifies the way of interaction be-tween various smart devices and users in each scenario, including the specific types of devices involved in the system and the specific process of their work.

Table 4-6. Sensor installation guidelines.

Smart Scene Type	**Smart Scene Function**	**Sensor Type**	**Suitable Installation Location**	**Installation Method**	**Testing Requirements**
Basic scenes (generic scenes)	Real-time monitoring of the operating and construction environment	Gas sensors	Support left and right wall, place left and right wall/column	Excavation: the amount of excavated soil and the amount of soil transportation (earth calculation) need to be clarified; Retaining support construction: thoroughly check excavation depth, soil quality, groundwater level, working soil pressure, etc., including installation of measuring equipment.	Earth calculation after excavation in construction (excavation volume, discharge and excavation volume, construction progress (excavation depth)); Trial run: power test, lighting test, various equipment operation test, environmental suitability test.
		Hydrogen sulfide sensor	Support left and right wall, place left and right wall/column		
		Carbon monoxide sensor	Support left and right wall, place left and right wall/column		
		Oxygen sensor	Support left and right wall, place left and right wall/column		
		Noise detector	Support left and right wall, place left and right wall/column		
		Temperature and humidity sensor	Support left and right wall, place left and right wall/column		

		Mobile environmental monitoring sensor	Staff members wear them everywhere		
		Dust sensor	Support left and right wall, place left and right wall/column, construction site floor		
		Wind speed sensor	Support left and right wall, place left and right wall/column		
	Monitor all kinds of emergencies	Flood sensor	Vertical safety distance of support/side wall from the ground		
		Infrared smoke sensor	Top of support, top of place safety distance of support/side wall from the ground		
	Get device movement information	Laser distance sensor	Placement with mobile devices		
		RFID readers/tags	Readers: Placement with mobile devices; Tags: Top of support/place		
	Real-time construction monitoring	Construction monitoring radar	Ground (near construction site)	Underground diaphragm wall method: prevention of excavation wall collapse, attention to the construction environment geotechnical structure. Weathervane work method: after the structure confirms the foundation support by foundation endurance test, it fills the concrete filled in the working chamber in a dry environment.	
	Response to falling rail accidents	Roll-off detection mat	Both sides of the track		
		Drop test camera	Top of the wall directly above the platform door		
Rail transit	Response to platform door accidents	New-type PSD	Both sides of the platform near the train		1. Electricity test after the dentsu project (electric communication security); 2. Track commissioning test.
	Orbital structure information acquisition	Track material monitoring device	Mounted with the bottom of the train		
		Orbit displacement monitoring device	Mounted with the bottom of the train		
		Image displacement	Mounted with the bottom of the train		

		measurement system		Shield construction method: excavation is carried out using an excavator, and then a block called a section is installed on the wall to construct a tunnel, and the excavation and discharge of sand and soil is carried out continuously.	
		Line equipment monitoring device	Mounted with the bottom of the train		
Underground functional place	Obtain and adjust operational environment data	Dust sensor	The left and right walls/columns of the place, the ground of the personnel gathering area can be placed separately	Same as basic scenes	Earthwork calculation after excavation; Trial run is based on environmental suitability test. There are differences in the requirements of the commissioning equipment according to the function.
Elevated bridge	Obtain bridge structure information	Extensometer	Contact part between column and bridge body	Ground drilling method: mainly soft foundation. As a general local piling construction method is the auger construction method; Shell method: mainly hard foundation. Swing and press into the outer cover hose within the full length of the pile. Mainly need to prevent the foundation from collapse.	Same as basic scenes
		Horizontally tiltometer	Mounted on the column		
		Crack gauge	Vulnerable points on columns/bridge deck		
		Light strain sensor	Bridge side (side wall)		
		Nature frequency gage	Contact part between column and bridge body		
Underground tunnel	Real-time construction monitoring	Construction monitoring radar	Ground (near construction site)	Shield construction method: continuous excavation and	Same as basic scenes

	Obtain information on support structures	Crack displacement meter Fiber optic crack detection sensor Fiber optic sensor	Support sidewalls (near sidewall lines) Support sidewalls (near sidewall lines) Support sidewalls (near sidewall lines)	discharge of sand and soil is required; Earth cutting: to prevent subsidence, groundwater protrusion and inflow of soil and sand into the end well, reinforcement and improvement of the soil around the cavern ring are required; Soil cutting volume: the cutting soil and sand must be discharged exactly in line with the amount of excavation; 4. Equipment: the shield machine has the feature that it can only enter but not retreat, so pay attention to the construction status of the shield machine.	
Underground municipal pipeline	Real-time monitoring of pipeline structures	Water leak detection service Remote water leak monitoring system Installation of tube lumen survey machine	Liquid pipeline vulnerability point (turning point) Liquid pipeline vulnerability point (turning point) Inside the liquid pipeline	For PC grouting, grout mixers, grout pumps, flow meters (grout flow meters) and, in some cases, grouting equipment are used.	There are various tests such as PC grouting temperature measurement, chloride ion content, compressive strength, archeology test, etc.
Underground heat source heat pump	Obtain information about the structure in the exchange well	Clinograph	Exchange well interior side wall	1. Pipeline part. ① Confirmation of pipeline paths for misconnection.	Trial run: thermal response test, pipe wall temperature test, exchange well temperature and humidity test, flow

② checking the test, power test, depth of buried pipeline; water pressure test

③ implementing water pressure test.

④ laying of buried marker plate.

⑤ setting buried markers on the ground surface.

⑥ Confirming the construction around the header.

2. Heat exchange well section.

① Capture geological information Record in excavation.

② Simultaneous setting confirmation of water tension in the underground heat ex-changer, proper reloading, and thermometer setting at insertion.

Monitoring of water quality in fluid exchange wells	Multipurpose water gauge	Liquid in the well
	Pressure type water gauge	Liquid in the well
Real-time monitoring of pipeline structures	Water leak detection service	Liquid pipeline vulnerability point (turning point)
Get information on surrounding groundwater	Water leak detection sensor	Groundwater borehole after

Self-painted by the author.

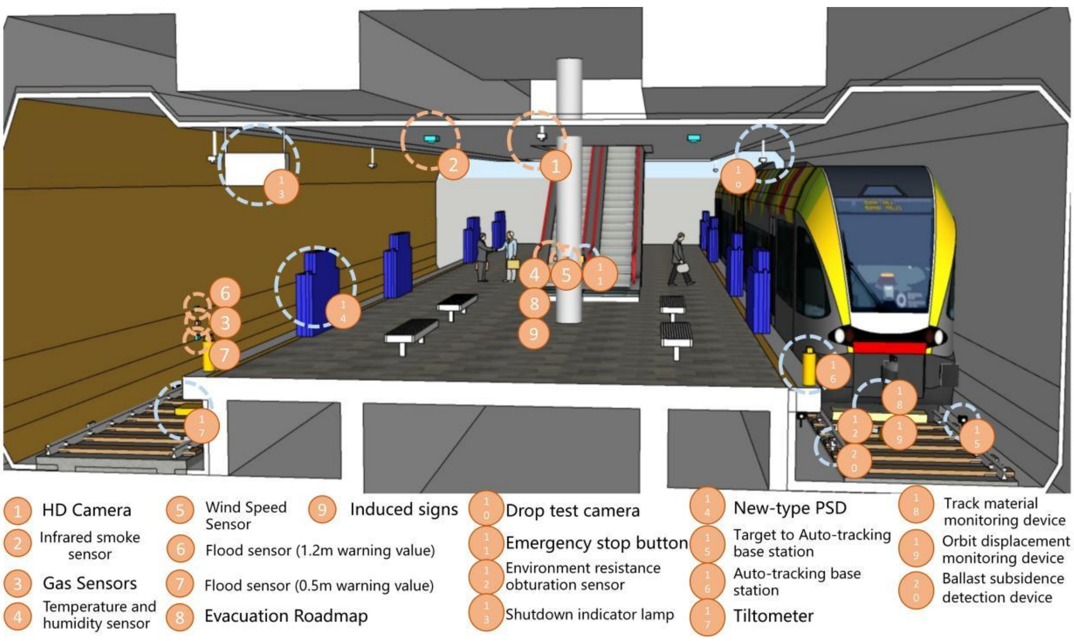


Figure 4-5. Rail transit sensor installation schematic.

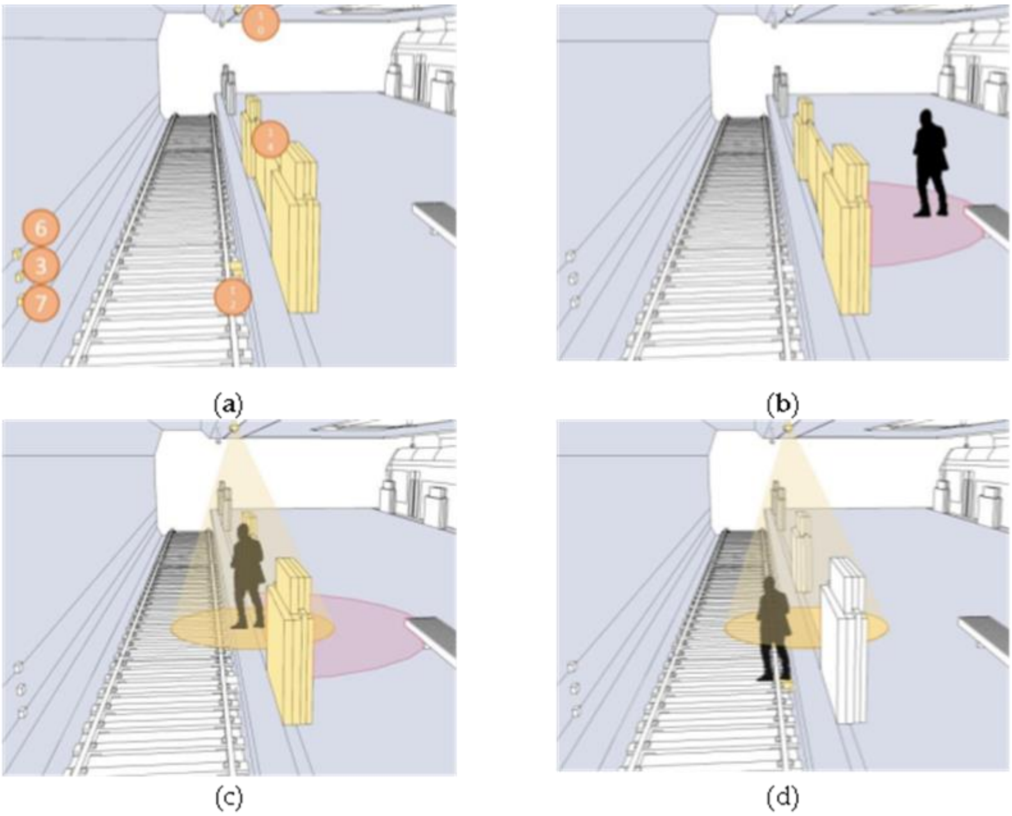


Figure4- -6. Smart interaction function for rail transit. Figure

(a): Various types of devices in smart interaction scenarios. Including environmental monitoring devices and accident response devices. Figure (b): User access to the detection range of new-type PSD. Figure (c): The door opens automatically after entering the detection range of new-type PSD, after which drop test camera opens and the user enters the detection range of drop test camera. Figure (d): When the user falls off the track, environment resistance obturation sensor will sound an alarm. He or she will remain in the detection range of drop test camera. At this time, drop test camera will determine the location of the fall accident and upload it.

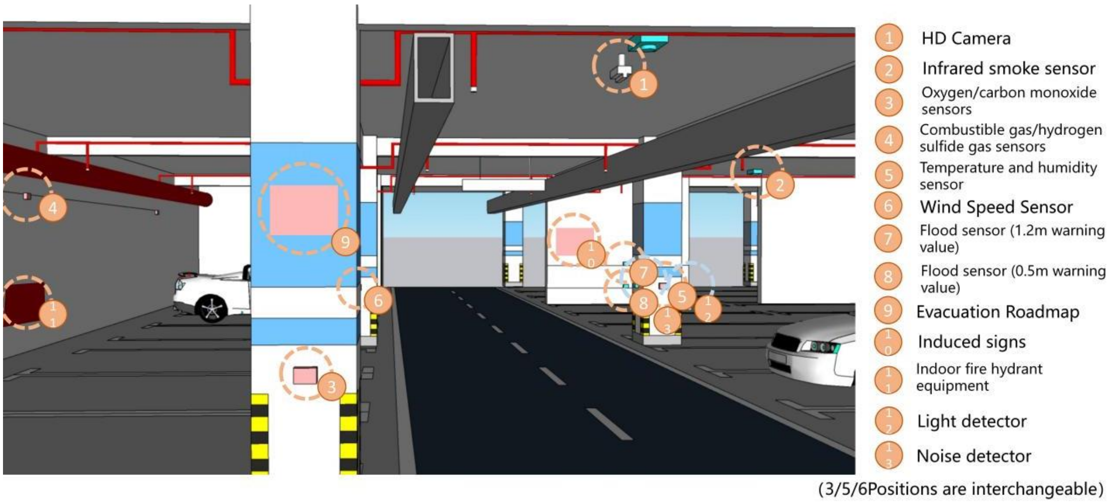
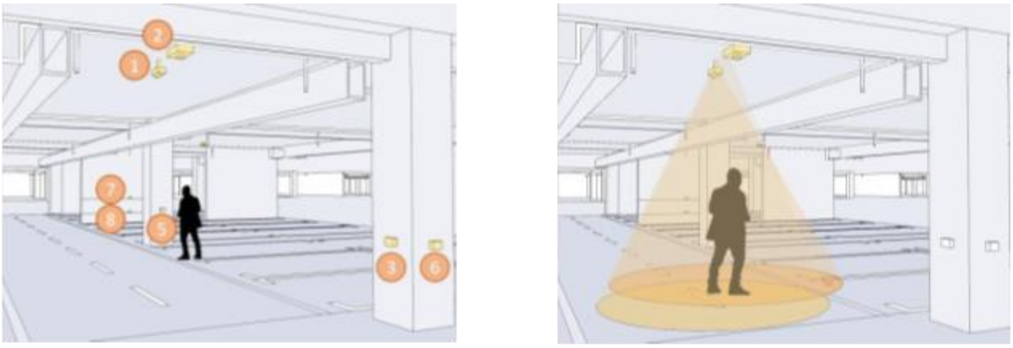


Figure4-7. Underground functional place sensor installation schematic.



(a) (b)

Figure 4-8. Smart interaction function for underground functional place.

Figure(a): Various types of devices in smart interaction scenarios. Environmental monitoring equipment is the main focus. Users can read basic environmental information at temperature and humidity sensor. Figure (b): When a user is detected to be in the monitoring range, the devices mainly in HD camera are automatically turned on.

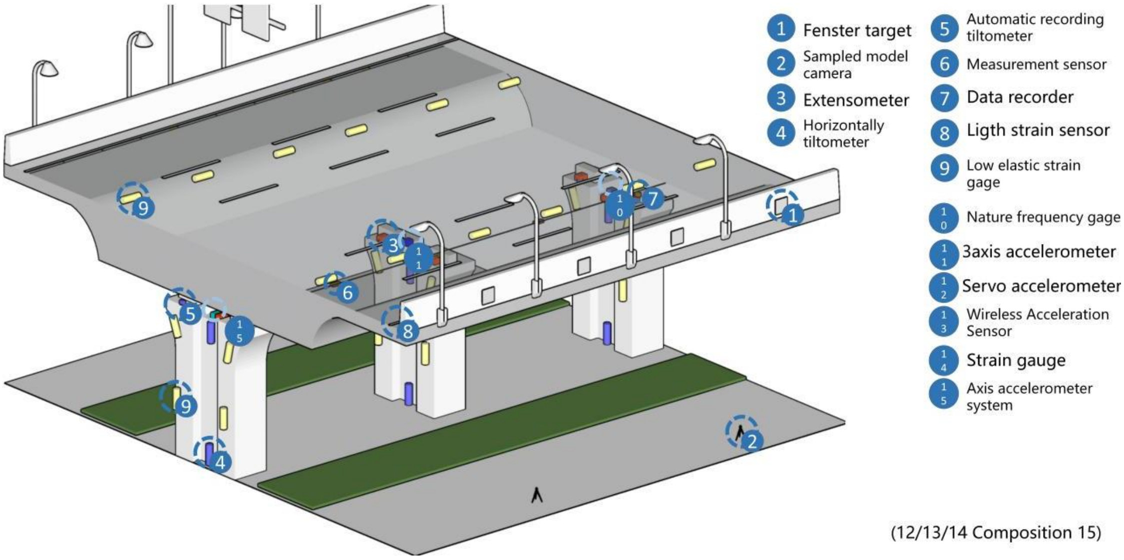


Figure 4-9. Elevated bridge sensor installation schematic.

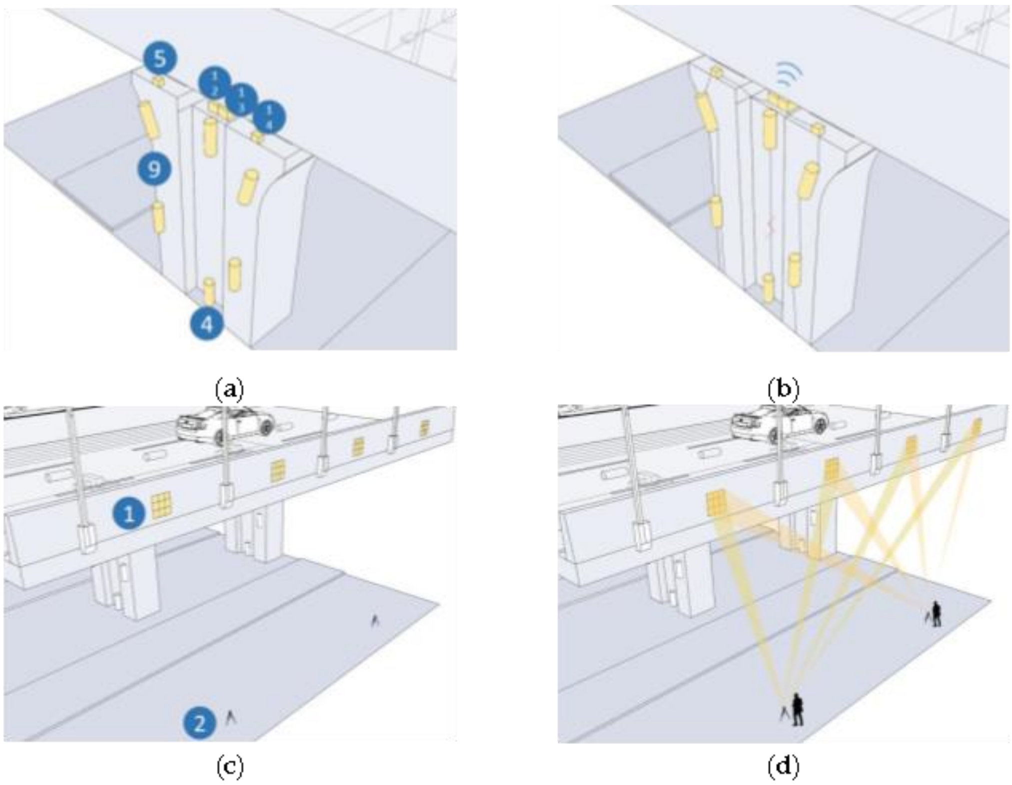


Figure 4-10. Smart interaction function for elevated bridge.

Figure (a): The monitoring devices are mainly column structure monitoring devices. Figure (b): The various devices are linked by optical fibers, and when cracks appear/structure damage, electrical signals are conducted from measurement sensors/horizontally tiltometer to 3-axis accelerometer system and uploaded by 3-axis accelerometer system via optical fibers. Figure (c): Bridge structure monitoring equipment is the main focus. Figure (d): The user captures the location of multiple fenster target's by sampled model camera and determines if the bridge is deformed by comparing it to the indicator.

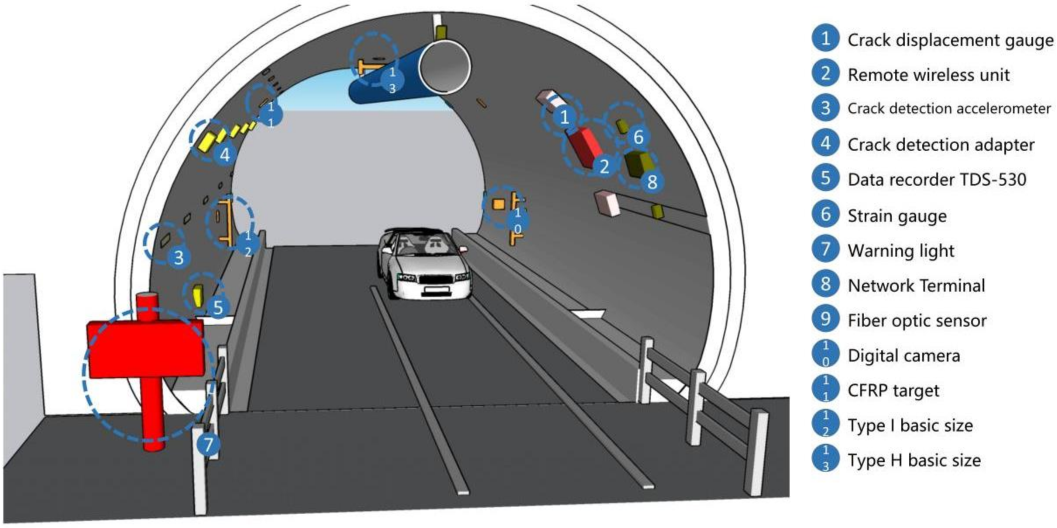
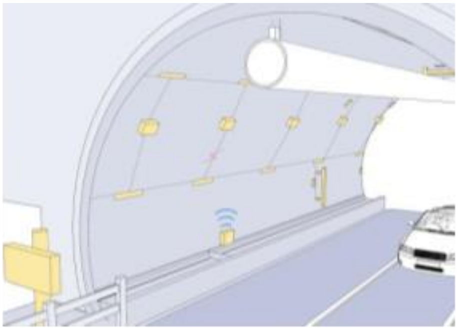


Figure 4-11. Underground tunnel sensor installation schematic.

(a)



(b)

Figure4-12. Smart interaction function for underground tunnel.

Figure (a): The smart devices are mainly tunnel support structure monitoring devices. Figure (b): Various devices are linked by fiber optics. When a crack/structure breakage occurs in the support, the electrical signal from the sensor is stored to data recorder via optical fiber and uploaded by data recorder.

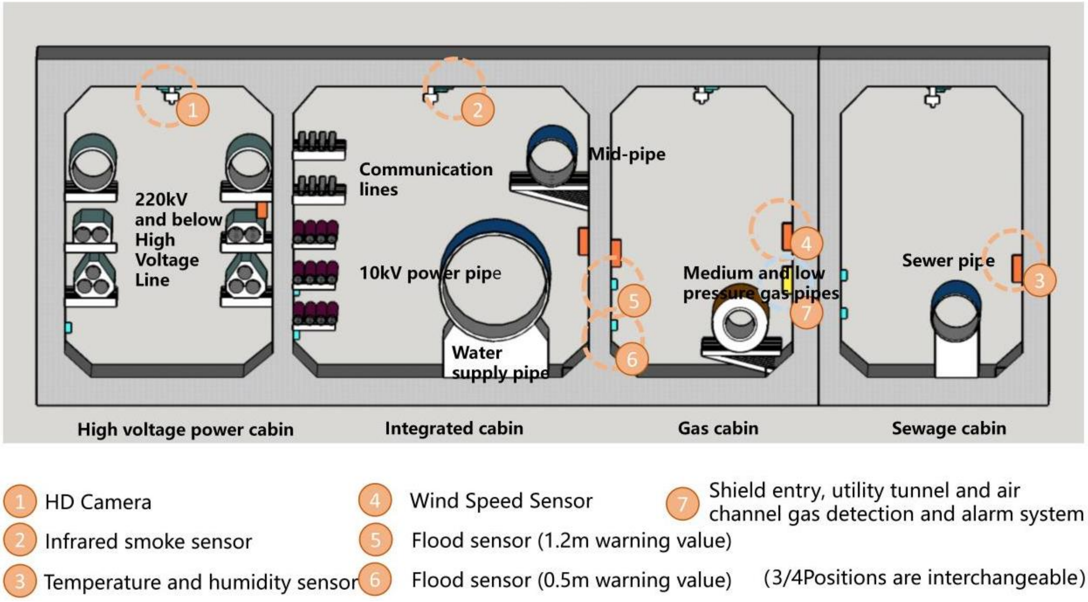


Figure 4-13. Underground municipal pipeline sensor installation schematic.

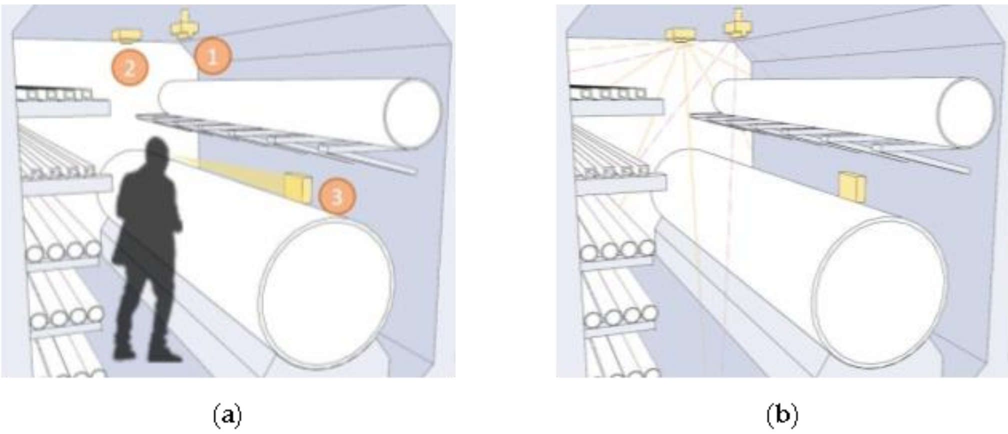


Figure 4-14. Smart interaction function for underground municipal pipeline.

Figure (a): The smart devices are divided into environmental monitoring devices and pipe corridor structure monitoring devices. Users can read basic environmental information from temperature and humidity sensor on the walls of the corridor. Figure (b): The monitoring range of environmental monitoring devices covers the entire corridor space.

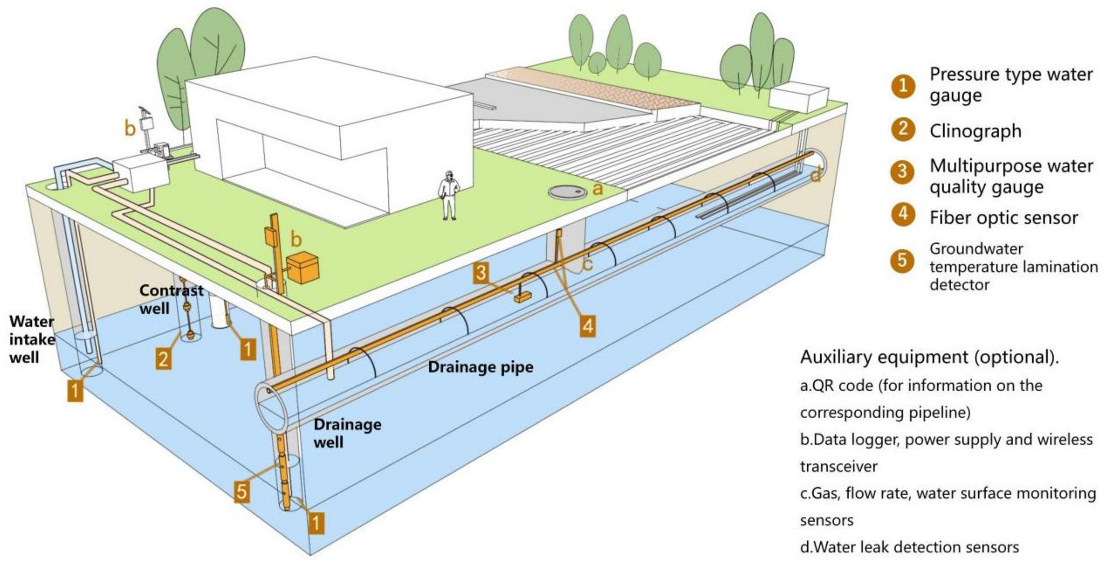
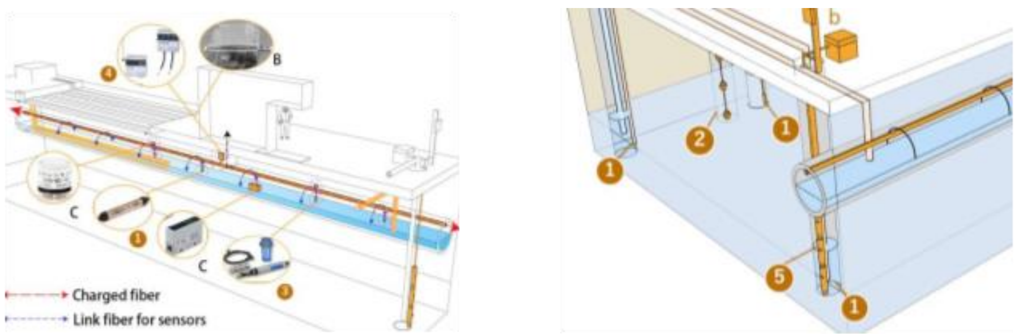


Figure 4-15. Underground heat source heat pump sensor installation schematic.



(a) (b)

Figure 4-16. Smart interaction function for underground heat source heat pump.

Figure (a): Smart devices in drainage pipes. Water monitoring devices and pipeline structure monitoring devices are the main focus. All kinds of devices are linked by optical fiber, and the electrical signal is transmitted to the data recorder and wireless transceiver after water quality problems or structural problems, and uploaded by the wireless transceiver. Figure (b): Smart devices in comparison wells, intake wells and drainage wells. Water quality monitoring devices and well structure monitoring devices are the main focus.

4.7 Conclusions

In this paper, we analyze the requirements of different types of underground space scenes and clearly establish the sensor types and corresponding parameters for smart sensing scenes. Based on the sensor parameters and the acquired data, we propose a system design for smart sensing platform in underground space and form the sensor installation guidelines accordingly. The guidelines are mainly divided into two parts: installation guideline table and installation schematic, and the purpose of set-ting the guidelines is to guide the work related to the construction of smart scenes in underground space. In general, this study determines the guidelines for sensor installation in underground space, forms a guideline table and installation schematic, and realizes the determination of smart device installation guidelines in the planning and design process before planning and design preparation, as well as the practice of planning and design based on smart devices in the planning and design process; this study is also This study is also the practice of installing smart devices in urban and architectural spaces in technological application, and for the research object of this study, it is mainly the practice of installing smart devices in underground space scale. Meanwhile, this study establishes an intelligent sensing system for under-ground space, which helps to realize smartification integrated with uban spaces.

The study of requirements in this paper focuses largely on maintenance management. The next step will be to refine the process of developing and constructing smart scenes in underground spaces, and to propose different development proposals and guidelines at different phases according to the refined process.

At this stage, we have carried out specific planning and design for the intelligentization of underground space in urban space. At present, although there are certain laws and regulations on underground space and construction-related laws and regu-lations in various countries in the world, there is a lack of relevant legal basis and design guidelines for the growing intelligent underground space construction. Laws and regulations are the cornerstone of system construction. The whole cycle of plan-ning and design must be based on policies, regulations, and planning, so that there is evidence to follow. Therefore, this study further clarifies the intelligent design guidelines including the underground space, including the type of equipment, installation location, specific installation method, maintenance management after installation, and planning and design of the intelligent perception system. In the planning and design stage, accurate simulation control is carried out for the building materials, equipment usage, location, and installation stage to be used in the later specific construction stage, so as to achieve zero waste as much as possible, so as to achieve the goal of energy saving and visualization in the design and planning stage.

This chapter clarifies the sensor types and corresponding parameters for smart sens-ing scenes by analyzing the needs of different types of underground space scenes. Based on the sensor parameters and acquired data required by the underground space smart sensing platform system, the sensor installation guidelines are formed accordingly.

This chapter is the basis for planning formulation and planning implementation. In the next step, we will conduct research on the architectural environment control of urban space and architectural space, which will be the basis for planning implementation and evaluation in the whole cycle of planning and design.

Chapter 5 Visualization of Planning Compilation using Energy Consumption Simulation on HVAC System of Smart building

In this chapter, we will discuss about the visual simulation of the energy system consumption of the overall building space can reduce energy consumption in the planning, implementation and management stages. This chapter as the basis for planning implementation and management, this chapter further narrows down the spatial scale of the study and enters into the interior of specific buildings in urban space and underground space. By research about the Energy Consumption Simulation and Design Phase Evaluation on Air-Conditioning System of The Intelligent and Healthy Building to clarify how to apply the HAVC technology before planning implementation. Realize how to simulate and verify the energy saving effect through visualization during the implementation and maintenance management phase.

5.1 Introduction

Global environmental issues like worldwide warming must be resolved on a global scale due to the continued rise in energy consumption, and energy scarcity has emerged as a significant challenge to the current economic and social development. Continuous non-renewable energy consumption reduction, increased primary energy efficiency, and strong new energy source development have all become vital human endeavors. The development of the construction sector, which can assist mankind in achieving the Sustainable Development Goals, is greatly impacted by the ongoing advancement of the Internet, artificial intelligence, big data, and other technology. As a fundamental carrier of human activities, the concepts of intelligent building, green building, and healthy building have consistently emerged. Shen Z. et al. investigated the idea and development of smart buildings.

The share of society's overall energy consumption that is accounted for by buildings' consumption is steadily increasing year after year as a direct result of the steady expansion of the built environment. The energy consumption of public buildings accounts for a relatively large proportion of the total energy consumption of buildings, and the energy consumption of office buildings, which are an important component of public buildings, accounts for approximately 20% of the energy consumption ratio of public buildings. The field of urban and building environment places a significant emphasis on the topic of energy-saving.

During the constructing of smart cities, the planning and design processes are carried out with the intention of reducing energy consumption. Additionally, the simulation of energy consumption occurs during the design stage of the planning compilation process. This allows for reasonable adjustments to be made to the project prior to the implementation of the planning.

Office buildings have been the major contributors to building energy consumption due to their large loads and relative concentration of air conditioning systems. Furthermore, the energy consumption of air conditioning systems accounts for the majority of the energy consumption of office buildings, which presents a promising future for energy savings.

Bagci and Bariset et al. discovered, through the course of performing an energy audit on a typical office building, that the majority of the building's energy usage was due to the building's lighting and air conditioning systems. Kajsa et al. examined the factors that affect energy consumption in office buildings. The findings showed that the most important thing for energy savings is to control the amount of fresh air and the area of glass windows, while on the other hand, it is also essential to reduce the energy consumption of lighting and office equipment. For this reason, it is crucial to simulate and conduct an analysis of the energy consumption of air conditioning in office buildings during the design and compliance stages in order to realize significant energy savings. The simulation of a building's energy consumption is one of the essential tools for the design of environmentally friendly buildings and for the rehabilitation of existing structures in order to save energy.

To give a theoretical foundation for attaining energy-saving in intelligent and healthy buildings, this study explores the main influencing elements of air conditioning energy consumption in office buildings and evaluates energy consumption in the planning compliation stage. We constructed an energy consumption model with the help of the Sketchup plugin in Openstudio. Next, we used Openstudio to simulate and analyze the amount of energy required to power the air conditioning in an office building located in the Sapporo region of Japan. An evaluation into the elements that affect the amount of energy used in an office building is carried out by modifying various parameters within the building. During the design phase of the planning and compliance process, an assessment of the intelligent and healthy building's overall energy usage was carried out and analyzed.

5.2 Research Methodology

In this research, a 3D model of the office building was created using the Sketchup plugin in Openstudio, after which the building layout was loaded into the Openstudio model and the working schedule information about the HAVC system was supplemented.

There are essentially three phases to the simulated energy consumption.First, the energy consumption model is established, which does not emphasize the design part and focuses on the energy consumption factors in the building. The energy proportion of each factor in the building is adjusted and calculated after specifying the energy consumption factors of the building, and then the parameters of the tabs in the Openstudio application, such as weather information and building information, are set; finally, the model is run, and the resulting Energy consumption results are analyzed to reveal the factors that affect the energy consumption of the building.

During the design phase of the planning and compliance process, the rationality of the building model for saving energy is evaluated based on the results of any model simulations that have been run.

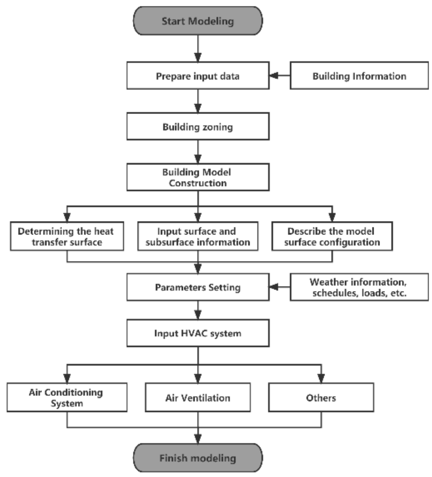


Figure 5-1. Research Route.

5.3 Designing the building model

5.3.1.1 Build the building geometry model

Construct a building in Microsoft Visio Drawing that has one level and a total area of around 176 square meters, as directed by the floor plan. The interior of the building contains a total of seven rooms that may be broken down into the following categories: lobby, restroom, lounge, conference room, and open office. As can be seen in the Figure each location features a ceiling, a floor, walls, and both doors and windows.as shown in the Figure 5-2.

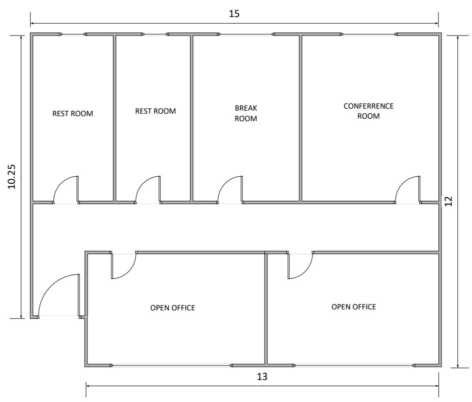


Figure 5-2. Building Plan.

After finishing the floor plan, the Sketchup plug-in application was used in Openstudio to construct a 3D model of the building, which could then have its individual components modified. The 3-dimensional modeling may be seen in Figure

3, which demonstrates the result. The model uses different colors to label the components: yellow for the walls, dark maroon for the roof, and gray for the floor.

Users of the Sketchup application have the ability to name spaces in the model and edit surfaces while they are working in the program. If the user selects to examine the model through boundary condition, the model will display blue as its primary color, while the components that are located inside the building will be represented in green. The color blue indicates that the surface being exhibited is immediately exposed to the outside environment, whereas the color green indicates that the wall or door being shown is located on the interior of the building. Because heat may be transferred across walls from one room to another, energy estimates can be made more accurately and sensibly, at least to some extent.

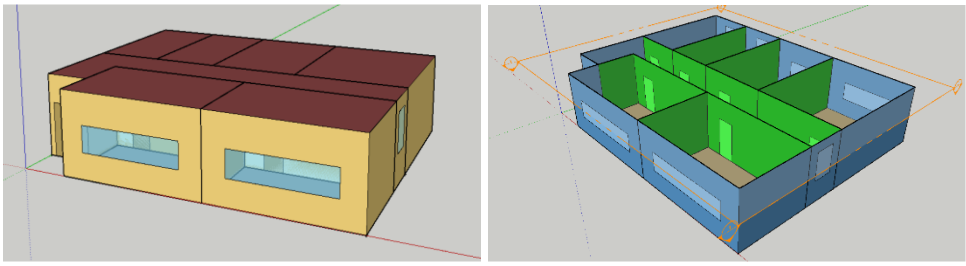


Figure 5-3. Building Geometry Model.

5.4 Building Zoning

To render a [Surface type] means to determine the model's surface, and to render a [Boundary Condition] means to aid in adjusting the heat transfer across surfaces. The Sketchup add-on for Openstudio provides two visualization options for the model: Thermal Zone and "Space Type".

5.4.1 *Space Type*

When rendering using [Boundary Condition], the user is able to observe how the model is partitioned into spaces, with each color denoting a predefined category of space. As for the colors, ochre is used for common areas and beige is employed for conferences in this research. Openstudio Inspector can define different [loads] and [schedule sets] for each space during the power simulation, allowing the user to flexibly assemble the space types to describe different activity scenarios.

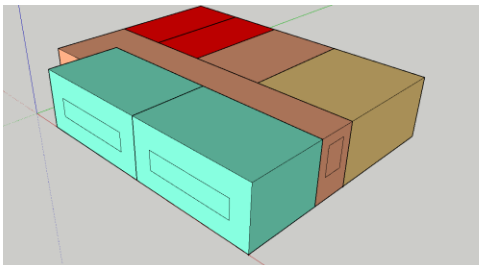


Figure 5-4. Building Geometry Model(Boundary Condition).

5.4.2 *Thermal Zone*

The Openstudio energy simulation model can depict a building's interior by "thermal zone," where distinct regions receive their heating and cooling from separate systems. Because thermal zones are made up of individual regions, their individual shapes affect how those zones are laid out. The entire structure can be regarded as a single thermal zone consisting of a single space; different thermal zones are indicated by different colors serving as representative markers; and two distinct types of spaces can be integrated into a single thermal zone. As shown in the figure below, the hot zone of an open office is labeled in gray, the hot zone of a lounge is labeled in pink, the open office and the restroom are labeled in the same color, and the same thermostat and equipment are used for the same hot zone.

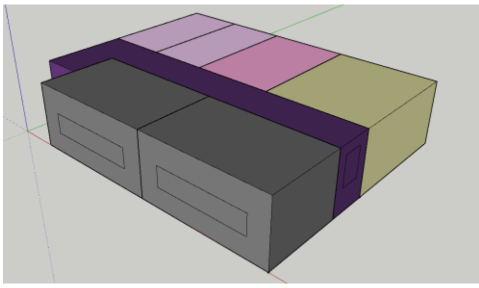


Figure 5-6. Diagram of thermal zone.

5.5 Openstudio model parameter setting

5.5.1 *Energy consumption parameter setting*

5.5.1.1 Site Sets

It is necessary to have energy models in order to mimic weather conditions, which have a significant impact on the transmission of energy between the interior and exterior of structures. The TMY (Typical Meteorological Year) is used to describe the general local climate. This method combines years of weather observations to represent the annual average weather and the range of extremes at a given location. Since the local weather is always changing, this method cannot accurately describe the local climate. This tab allows for the modification of the weather information.

A region in Sapporo, Japan was selected for simulation, and the weather file, which needed to be in EPW format, was obtained from the website that was appropriate for the software. In this study, typical metric year data was used to model the building, the year information was set to "first day of the year", and the "daylight saving time" option extended the traditional summer daylight hours.

Table 5-1. Weather File & Design Days settings table.

Starts Time	2009/04/01
Latitude	43.05°
longitude	141.33°
Elevation	19
Time Zone	9

In addition to the EPW data file, the Sapporo DDY (design day) file was downloaded from the same website mentioned above for this study. This file covers weather information useful for energy modeling, such as the extreme weather conditions that can be expected at a particular location, and can be used to size HVAC systems to ensure that buildings can remain comfortable under extreme heating, cooling, humidification, and dehumidification conditions. In OpenStudio models containing auto-sized HVAC systems, at least one design date needs to be imported for error-free simulation.DDY files typically contain several different heating and cooling design points. Only a subset corresponding to 0.4% of the summer design days and 99.6% of the winter design days are imported in OpenStudio, which means that only 0.4% of the time during the summer the actual temperature is higher than the design temperature, whereas the design temperature is exceeded 99.6% of the time during the winter.

5.5.1.2 Consruction Sets

Each surface in Openstudio is related with a construction of a particular type. A top-level construction set that is applicable to the entirety of the structure can be specified by the user, while each construction set outlines the typical building procedures for a specific category of surface or subsurface, such as walls, roofs, windows, doors, and etc. A construction set is a group of construction assemblies applied to a building. This set of constructions for the office includes constructions for the outer surfaces of the building.

[Mass Climate Zone] is used for the outside walls, floors, and roof. Interior walls, flooring, and ceilings, as well as any other necessary supporting framework, make up the interior construction. The components of a structure are described by the constructions that make up the set. They could be utilized over an entire structure or just an isolated area.

The Construction tab displays the construction assembly, which consists of stucco, concrete, wall insulation, and gypsum. These materials are applied in layers, each with its own thermal conductivity properties. When calculating the thermal conductivity and heat transfer characteristics of this building assembly, these properties are taken into consideration. The layers are first applied to the exterior of the building, followed by the stucco and then the plaster, and last they are applied inside the building.

Table 5-2. Materials settings table.

Roughness	Smooth
Thickness	0.0127 m
Conductivity	0.16 W/m*k
Density	784.9 kg/ m^2
Specific Heat	830 J/kg*k
Thermal Absorptance	0.9
Solar Absorptance	0.4
Visible Absorptance	0.4

5.5.1.3 Loads Sets

Space load definitions are entered on the loads tab and fall into several categories, including all heat, electric, gas, and steam loads in the building.

First, lighting loads may include individual table and desk lamps, emergency exit lighting, etc. The definition of light may be specified based on power, power per floor area, or power per person. Wattage per space floor area is used to define lamp usage for each space. When specifics regarding the lighting scheme are lacking, this method is often used to quantify loads. Openstudio considers the usage of daylight controls to counteract the energy use of the electrical lighting, as explained in the site tab section, and these calculations are incorporated into the simulation.

In comparison, individual desk lamps may be best expressed in watts per person. If a detailed audit reveals the exact number of specific types of luminaires, lighting can be specified in terms of the power rating consumed by individual units. It's also possible to customize the degree of radiant light, the degree of visible light, and the level of effect on the HVAC system's return air.

Table 5-3. Lights Definitions settings table.

Watts Per Space Floor Area	8 W/ m^2
Fraction Radiant	0
Fraction Visible	0
Return Air Fraction	0

Next is the definition of number of people, which represents the density of occupants located in the various spaces. People represent a very large heat load in a space, but are treated a bit differently than lighting or equipment. To determine these loads, we take into account both the total number of occupants and the average metabolic rate of those occupants. They figure out the amount of carbon dioxide released and the proportion of radiant heat. Occupancy rates can be specified in a few different ways: by total number of people, by total number of persons per floor space, or by total floor area per person.

As shown in the table below, we use persons per floor area to define the number of persons in each space, while people are expressed as a percentage of the radiant energy they contribute to the space. Openstudio can automatically determine the percentage of sensible and latent heat gain from occupants based on normal metabolic rates, factoring in the quantity of waste heat, for the remainder of the heat they reject.

Table 5-4. People Definitions settings table.

People per Space Floor Area	0.5 people/ m^2
Fraction Radiant	0.3
Carbon Dioxide Generation Rate	0.000038 L/s*W

The definition of electrical appliances is stated at last. Electrical plug loads include appliances like coffee makers, toasters, microwaves, refrigerators, laptops, televisions, hair dryers, etc. Similar to how Openstudio does not depict every single light fixture in a room, it also does not depict every single electrical, gas, steam, or other device present in the area. Most people would be outraged if their preferred coffee maker was suddenly replaced with a microwave oven, both are merely appliances that use power and emit heat into the atmosphere.

The maximum amount of power consumption, the working schedule (for more information, see the following subsection), and the mechanism by which heat is transferred into the space are the only ways to differentiate an electric kettle from a blender. As with lighting, devices can be quantified in terms of power per unit, floor space, people, etc. Power consumption is measured in watts per square foot of floor space. Because equipment, unlike light bulbs, can use a variety of fuels (electricity, gas, steam, etc.), the simulation results are broken down by fuel type.

The carbon dioxide emission rates from gas appliances can be specified for air pollution studies, while the use of less common fuel types like propane and fuel oil can be chosen for other appliances. When it comes to equipment that consume water, the water in a room that is used for things like taking showers, cooking, and washing clothes, etc. However, the focus here is solely on electrical energy use, therefore gas and steam appliances are not included.

Table 5-5. Electric Equipment Definitions settings table.

Watts Per Space Floor Area	25 W/ m^2
Fraction Radiant	0
Fraction Latent	0
Fraction Lost	0

5.5.1.4 Schedule Sets

The individual loads in a space are in most cases a strong function of occupancy, which varies with time of day and day of the week. This means that occupancy, lighting, and equipment schedules need to be captured in order to reasonably describe energy use and associated heat loads.

As shown in the figure below, this is the type of schedule often used for energy modeling of lighting in office buildings. This particular schedule is "fractional," meaning that it varies from 0 to 1 and is used as a multiplier on the maximum expected occupancy in the space to create a time-varying number of people.A similar schedule is used to regulate the total power consumption of lighting and electrical equipment. Also shown below is the air conditioning setpoint schedule for cooling. The building operates 24 hours a day, 7 days a week, 365 days a year. This schedule is set back at night to save energy, as is the case with conventional buildings. During the day, the building is actively cooled, and the cooling system is basically shut down at night. As Figure shows, the day starts at 7:00 AM and ends at 8:00 PM.

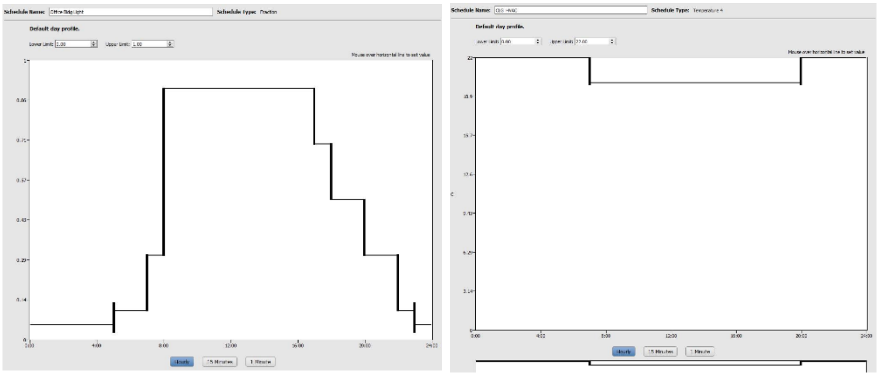


Figure 5-8. Openstudio model design Schedule sub-tab setting .

5.6 HVAC system parameter setting

As mentioned before, HVAC accounts for the majority of energy consumed in buildings, which is an acronym for heating, ventilating, and air conditioning, and is collectively referred to as air conditioning. HVAC systems are designed to regulate their internal environmental conditions. In addition to heating and cooling, these systems provide outdoor fresh air ventilation to dilute CO2 and other pollutants emitted from building occupants, activities, or materials. OpenStudio's model is segmented into Spatial, where a space is defined as a collection of surfaces and subsurfaces that surround a volume of air, and where each space has its own internal load.

5.6.1 *Air Conditioning System*

As discussed for thermal zones part, they are provided by the HVAC system and consist of one or more spaces. In other words, a heat zone is the collection of all surfaces and subsurfaces surrounding all spaces in a zone and all internal loads contained within those spaces.

At each simulation time step, Openstudio performs a heat balance calculation for each heat zone. Depending on the thermal boundary conditions, heat flows into or out of the thermal zone through the surface. Openstudio generally assumes that all air in a Heat Zone is well mixed.

Air systems are used to simulate ventilation systems configured in the HVAC Systems tab and OpenStudio's Zone HVAC equipment is a family of components designed to represent a preconfigured HVAC system, with exactly one thermal zone. It is intended to provide service to exactly one thermal zone.

Cooling system includes fans, cooling coils, and heating coils. Other subcomponents, such as backup heating coils and humidifiers, can be added as long as the zone-specific HVAC components are not preconfigured to include those subcomponents. The right-hand panel displays all detailed properties and subcomponent properties, which contains the properties and parameters of the PTAC or other zone equipment.

As for heating system, baseboard Convective Electric is used in each thermal zone except the lobby, and convection heaters are the most basic type of baseboard heaters, which functionally consists of a heating element. An internal electric coil heats it like a coil in a toaster. Given that the thermostat for this type of heater might be found either on the heater or on the wall, the simulation results were adjusted to 700 watts during auto-sizing.

5.6.2 *Ventilation Systems*

For the ventilation system, we will try to use an air system, although zone HVAC equipment could be used to add fans to the model for ventilation. While zone HVAC equipment is helpful, it can only be used in one specific temperature zone.

Therefore, it is not practical to use zone HVAC heating and cooling equipment in thermal zone 1 and thermal zone 2. Since both of these thermal zones are not a single thermal zone, Thermal Zone 1 includes two open office spaces and Thermal Zone 2 includes two restroom spaces, which affects the accuracy of the energy simulation compared to reality.

The building ventilation system contains DOAS - Dedicated outdoor air system, including one exhaust fan (located adjacent to the outdoor air system exhaust node), one air supply fan (located below the outdoor air system), one heating coil for preheating, a setpoint manager to control the heating coil, and the outdoor air system required for the ventilated system. In order to incorporate outdoor air, a component can be added to the system directly below the external air intake. As seen, this upper section represents the supply side.

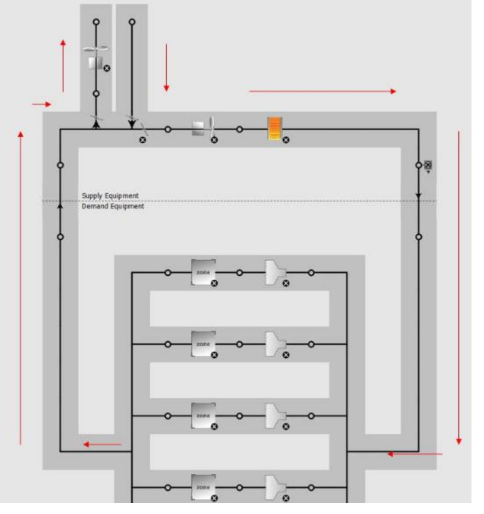


Figure 5-9. Openstudio model design Ventilation System setting.

The table below shows the specification of the thermal zone sizing parameters, which are default parameters in Openstudio. These are defined in the Thermal Zone tab and specify the primary air supply conditions for the air terminal serving each thermal zone. Knowing the thermal zone air supply conditions, EnergyPlus can determine the airflow required to achieve the set temperature for each thermal zone for a given heat load. Total flow rates for all thermal zones plus air loop sizing parameters equal the supply-side airflow that must be accommodated by the air loop. The air loop's supply air conditions (those provided by the system before the air terminal) are defined by these sizing parameters.

Table 5-6. Openstudio default parameters table.

Air loopHAVC	Design Return Air Flow Fraction of Supply Air Flow	1
Sizing: System	Hard size	1
	Preheat Design Temperature	7
	Preheat Design Humidity Radio	0.008
	Precool Design Temperature	12.8

	Precool Design Humidity Radio	0.008
	Central Cooling Design Supply Air Temperature	12
	Central Heating Design Supply Air Temperature	17
	Central Cooling Design Supply Air Humidity Radio	0.0085
	Central Heating Design Supply Air Temperature	0.008
	Cooling Design Air Flow Rate	0
	Heating Design Air Flow Rate	0
Fan: ConstanVolume	Fan Total Efficiency	0.7
	Pressure Rise	250
	Motor Efficiency	0.9
	Motor In Airstream Fraction	1.0
Setpoint Manager:SystemNode Temperature	Offset Temperature Difference	0
	Maximum Limit Setpoint Temperature	20
	Minimum Limit Setpoint Temperature	5

5.7 Analysis and evaluation of simulation results

Since Sapporo, where the model runs its climatic simulations, experiences a significant temperature swing between summer and winter, it is projected to consume considerable amount of energy to remain warm during the winter. This energy model's simulation findings are useful for estimating the building's monthly energy consumption and operational costs, particularly for the air conditioning system.

Figure below shows the building's zone temperatures throughout the year: room temperatures do not exceed 88 degrees Fahrenheit (about 31 degrees Celsius); they remain stable at about 20 degrees Celsius (67 degrees Fahrenheit). This energy simulation model system's thermal zones are adequately managed and respond to the hours of heating and cooling demands. The building's interior room temperatures were more comfortable throughout the year, and the system was better at sustaining specified temperatures.

Figure5-10. Year-round regional temperature map.

In the HVAC Load Profile and Zone Conditions report, we observe the discrepancy between the amount of energy consumed on heating and cooling and the outdoor dry bulb temperature. A dry bulb thermometer, which is protected from both moisture and radiation, is used to determine the air's temperature. The graph below demonstrates that the building's heating costs increase as the exterior dry bulb temperature drops. As the outdoor dry bulb temperature increases, the amount of electricity used for cooling also increases. Combined with the climate of Sapporo and the year-round regional temperature map of the building model, it is clear that the model is operating normally and the description of the temperature is more reasonable.

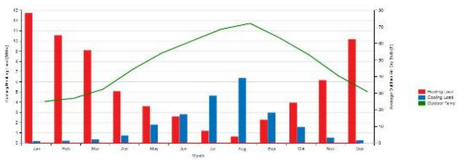


Figure 5-11. HVAC load and zone conditions diagram.

The results of the run show that the total energy consumption of the building model for one year is 169,403 kBtu . The consumption of gaseous energy is not a part of this study because it is only concerned with the consumption of electrical energy; hence, the result presented here is the total amount of electrical energy that was consumed by the building model.

Table 5-7. Table of building summary.

Data	Value
Building Name	Office Building
Total Site Energy	169,403 kBtu

Total Building Area	1,900 ft^2
Total Site EUI	89.17 kBtu/ ft^2

Table 5-8. End Use- view table.

End Use	Consumption(kBtu)
Heating	67,883
Cooling	22,226
Interior Lighting	27,023
Exterior Lighting	0
Interior Equipment	45,002
Exterior Equipment	0
Fans	7,270
Pumps	0

Due to Sapporo's very cold climate in the fall and winter, the building model consumes a significant amount of energy for heating, accounting for approximately 55% of the HVAC system's energy consumption. The heating process consumes the most energy, accounting for 19% of the lighting system and 25% of the electrical equipment energy consumption.

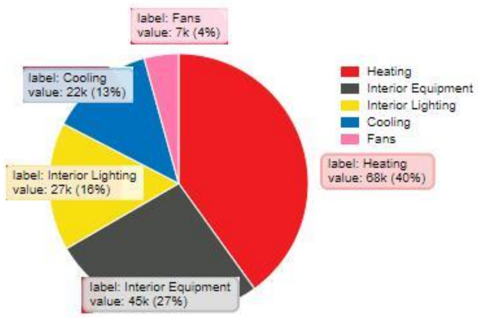


Figure 5-12. Diagram of building energy consumption ratio.

5.8 Conclusion

This study use OpenStudio software to build the energy consumption model of the building and details the parameter settings related to the energy simulation processes .

After running the model, the data of the building's energy consumption for the whole year were obtained, and the energy-saving degree of the building in the design stage was focused. The following conclusions were drawn.

Firstly, the air conditioning system accounts for most of the energy consumption, with the heating process accounting for a relatively large amount. The study showed that greenhouse gas emissions in the environment can be mitigated by reducing the energy consumption of the building's air conditioning system. In addition to the energy consumption of air conditioning equipment, lighting and electrical equipment also occupy a high percentage of energy consumption, 15% and 25%, respectively. Therefore, reducing the energy consumption of these two devices can be considered in a intelligent building, and the devices can functionally complement each other.

Secondly, clarifying the energy consumption of smart buildings in the planning compilation process helps designers to identify the deficiencies of building systems in the design phase and improve energy efficiency. Compared to traditional buildings, intelligent health buildings integrated with smartification management can be better utilized in the design phase by reasonably evaluating the functions of the system and the way the equipment is utilized. There is a growing trend toward intelligent and healthy buildings, with automation and control systems that can use sensor data to improve building efficiency. Outstanding energy-saving measures in intelligent health buildings allow electronic sensors and small processors in each room to automatically regulate room temperature, light sources, heating and cooling, ventilation, etc. With its outstanding technical features, the intelligent and healthy building can make a significant contribution to greenhouse gas reduction and environmental protection initiatives. The efficient use of energy in high-rise buildings can not only significantly reduce electricity consumption, but also reduce building costs, which contributes to energy-saving.

With more and more high-rise buildings in large cities today becoming the main consumers of energy demand, the efficient use of energy in buildings is urgent. The increasing urban population necessitates more effective use of available resources in order to lessen the burden on the environment caused by excessive energy consumption and carbon emissions. Intelligent and healthy buildings not only improve energy efficiency, but intelligent placement of sensors and actuators can continuously monitor and adjust lighting and air quality to ensure an optimal working environment and increase productivity. However, the systems in the intelligent and healthy building can be so complex that even minor problems can cause major disruptions to the operation of the entire building, requiring further research in this area.

According to the results of the HVAC load curve electrical energy consumption graph, it can be seen that the energy consumption is much higher in winter than in summer, i.e. heating consumes more electrical energy than cooling in summer, and the weather in Sapporo also influences the results to some extent. Both cooling and heating equipment consume more energy, so it is important to conserve electricity in both systems in order to save energy. Saving electricity in daily life, especially in office buildings, is directly related to reducing the strain on the electrical supply system. If high-rise buildings do not incorporate intelligent energy savings into their design phase before implementation, it will result in a huge waste of energy, especially in large cities.

The results of this study show that air conditioning consumes a relatively large amount of electrical energy in buildings, about 50%, compared to lighting energy and electrical equipment energy consumption. However, there is a lack of further in-depth research on other energy use in smart and healthy buildings, and the simulation of building energy consumption in this study focused on the building's electrical energy. Therefore, additional research into precisely estimating building energy usage during the design phase is required in the future. In addition, only the conventional air conditioning system was considered in the simulation study of the energy part, and the inclusion of new energy sources such as solar energy and natural gas can be considered in the future.

After the system simulation of the environment of the building space, we will enter the next step, the visual simulation of the individual control of the building environment.

Chapter 6 Simulating Intelligent Control of Temperature and Heat Environments in Office Environment of Smart Building for Energy Consumption before planning implementation

In this chapter we will discuss about the energy visualization simulation of air conditioning consumption in a built environment. Serve as the basis for the last step in the planning lifecycle management (planning evaluation). Planning evaluation is not only the management of the smooth implementation of planning and design, but also an important method and means for predicting and early warning of urban and architectural space utilization.

6.1 Study background

In recent years, environmental problems caused by urbanization, such as global warming and the heat island phenomenon, have been highlighted as issues that need to be addressed internationally. In Japan, these problems are caused by anthropogenic heat emissions from buildings and vehicles in cities and carbon dioxide emissions from primary energy consumption in urban activities. The item that accounts for the largest share of primary energy consumption in Japan is electricity generation through burning fossil fuels, and Japan's per capita CO2 emissions are second only to those of the United States, South Korea, and Russia among major countries.

In the field of architectural design, recent technological advances have enabled the visualization of the architectural design process in a virtual space and the simulation of the analysis and optimization of construction to improve efficiency.The example of actual architectural design using virtual space presented in UnityTechnology's "Unity Japan Office Project" implements the design solutions to simulation and other sample problems needed. In addition, when applied to VR and AR, design intent can be communicated not only to the designer, but also to all parties involved in the building project. Although BIM data and component data can be visualized in this way, there are few examples of visualizing interior environments and their digital information, and their visualization methods have not yet been established.

The energy efficiency of Task and Ambience air conditioners can be determined through energy consumption calculation simulations and operational data analysis. However, it is impossible to know the energy savings in the design phase because there is no method to visualize the heat load of such air conditioning equipment again, and there are no guidelines for assuming up-to-date air conditioning in conventional simulation software in the design phase. Therefore, it is necessary to develop design guidelines to account for the energy consumption of energy-efficient air conditioners. This study focuses on the Task-Ambience area, and aims to estimate the thermal load by comparing various temperature and humidity patterns with conventional temperature and humidity settings to create a design guide to give guidance to the design phase of office air conditioning installations.

6.2 Study methodology

(1) The study organized existing air conditioning design guidelines, surveyed existing studies and literature on office worker comfort, and organized the necessary air conditioning environmental conditions based on these studies, and the obtained air conditioning environmental conditions created combinations.

(2) Estimation of heat loads using heat load calculation formulas based on the obtained air conditioning environmental conditions created combinations.

(3) Development of visualization tools for design guidelines using a game engine to create a 3D model of the target space and construct a virtual space.

(4) Outputting the heat load obtained in step (2) based on the creation of a combination of air conditioning environmental conditions as a csv file and creating a program to read this CSV file in the virtual space of step (3) through the game engine.

(5) creating an option interface of environmental conditions based on step (1) in the virtual space of step (3) through the game engine, creating a heat load visualization program based on step (4), specifying the total heat load of Task and total heat load of Ambience under different environmental conditions, and analyzing the total heat load

of Task-Ambience area in comparison with the total heat load of Task-Ambience area without using Ambience area to analyze the energy saving effect.

(6) Propose design guidelines for intelligent control of temperature and heat environment and energy consumption based on the visualization results of step (5).

6.3 Thermal comfort, thermal load and the necessity of design guidelines

An inspection of primary energy consumption by each sector shows that the business and household sectors are growing significantly more than other sectors; for office buildings and other in non-residential buildings, primary energy consumption standards have been established and implemented in Japan for renovation, new construction and construction of buildings with high energy performance. In this context, a quarter of primary energy consumption in the breakdown of primary energy consumption in the business and other sectors in 2016 was for air conditioning (the sum of cooling and heating); lighting and electricity were the second most important items in need of improvement.

The control of primary energy is not only about making buildings more energy efficient, but also about ensuring the comfort of the people in those building spaces. According to the Japan Productivity Center, Japan's hourly labor productivity was two-thirds of the U.S. level in 2016, the lowest of the seven major industrialized countries since 1970. On the other hand, declining production due to a declining workforce remains a reality. Considering the maintenance of Japan's current GDP, per capita productivity needs to increase to approximately 2.8 times the current per capita when calculated by 2060, implying the need to create a workplace where everyone can maximize performance. In addition, guidelines for the introduction of Cool Biz/Warm Biz air conditioning systems in government facilities were established in 2009, and ZEB (Net Zero Energy Building) design guidelines were established in 2008 to begin promoting super energy efficiency in building environmental equipment and ensuring a comfortable indoor environment. In this context, study on energy-efficient air conditioning, including Task-Ambience air conditioning aimed at improving the comfort of individual workspaces, has been conducted in the air conditioning systems of office buildings. However, this method of evaluating and planning for energy-efficient air conditioning has not been established in the guidelines for installation of air conditioning systems or in the ZEB design guidelines. Therefore, there is a need to organize information on energy-efficient air conditioning and to prepare new design guidelines.

At the same time, energy saving assessment in the planning compilation stage is an important element to achieve energy saving in the city and built environment, so it is necessary to assess thermal comfort and heat load, and to forecast energy consumption and heat load in buildings and built environment on the one hand; on the other hand, it is necessary to develop design guidelines to describe energy consumption for energy-saving air conditioning.

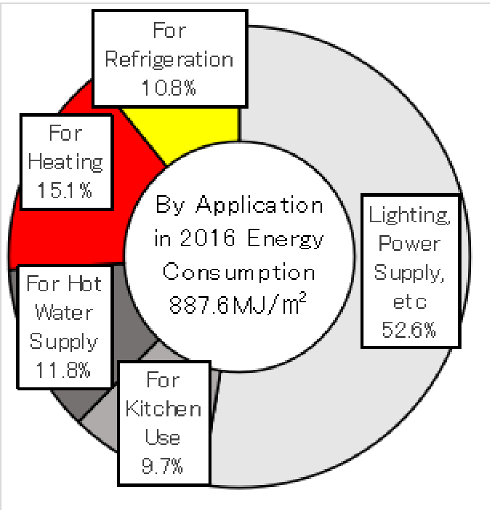


Figure 6-1. Primary energy consumption breakdown for operations and other sectors in 2016.

6.4 Task-Ambience Air Conditioning System

The Task-Ambience Air Conditioning System (hereinafter referred to as the TAC system) is an air conditioning system in which the environmental conditions are planned by dividing the space into the vicinity of the occupants (Task area) and their surroundings (Ambience area). By setting the ambient conditions (temperature, humidity, and wind speed) to avoid excessive use of air conditioning in the Ambience area, where occupants spend less time, and to increase intellectual productivity in the Task area, where they spend more time, the TAC system can maintain a balance between energy savings in the Ambience area and comfort in the Task area. A typical example of such a TAC system is floor-blown air conditioning. In an office, it is simpler to create an efficient environment around a desk by installing air vents on the floor near the desk than by having air conditioning throughout the area. Additionally, by allowing each individual to control the airflow, individuals' comfort is improved through ease of operation.

There are various existing studies that have shown the energy savings of relaxed environmental settings when Task-Ambience air conditioners are installed. However, these energy savings were verified during the demonstration and operation phases, and no efficiency savings were shown during the design phase.

Meanwhile, in Japan's "Guidelines for Cooling/HVAC Systems in Government Facilities" released in July 2009, regarding the elaboration of the relationship between the elements of the thermal environment in conventional air conditioning and cooling/heating air conditioning systems, the results show that it is difficult to ensure that the thermal environment in office areas is the same as the conventional environment by addressing only one element of the thermal environment index.

As for the study of air conditioning control considering comfort, existing studies have shown that air conditioning control can improve comfort by considering air conditioning control from the traditional temperature-centered control to the comfort evaluation method, PMV-centered control, when the influence of solar radiation is high. It was found that comfort can be improved when the influence of solar radiation is significant. However, the balance between peripheral and internal air conditioning power was lost due to misjudgment of the adjustment of blowing air temperature and airflow speed in the design stage. Therefore, it is necessary to understand the heat load of the air conditioner at the design stage.

6.5 Thermal comfort of occupants and its evaluation method

6.5.1 *Six elements of the thermal environment.*

According to the Ministry of Environment's Atmospheric Environment Report, the elements that define the thermal environment are: (1) metabolic rate: the metabolic rate is the energy expenditure associated with human activity and is expressed in met. The criterion1 met is a metabolic rate of 58.2 W/m^2 in a static position seated in a chair. The heat balance of the human body is expressed per unit body surface area and takes into account differences in body size; (2) clothing wear: the clothing wear is the thermal resistance of the clothing, expressed in clo. Winter clothing wearing condition is 1clo, where 1clo is 0.155℃m²/W; (3) air temperature; (4) thermal radiation (average radiation temperature); (5) airflow (wind); and (6) humidity.

6.5.2 *Comfort assessment method.*

In this study, office worker comfort was assessed using an index called predicted mean vote (PMV) to set appropriate temperature and humidity levels.PMV is a thermal index designed by Fanger that expresses human comfort in a given thermal environment on a seven-point temperature/coolness scale. It is based on the equation of heat balance when the human body feels comfortable, and the corresponding index is calculated and obtained from the comfort equation using the six variables affecting human thermal comfort (metabolic rate, clothing wear, air temperature, thermal radiation, relative humidity and airflow) as previously described, and how far the thermal environment is from the comfort conditions. PMV has been adopted by ASHRAE and ISO 7730 as an evaluation criterion for comfort environments. The PMV control equation for air conditioning shows the relationship between the percentage of dissatisfaction and PMV through experiments on subjects.The percentage of dissatisfaction can be calculated as the predicted percentage of dissatisfaction (PMV).The PPD is represented by a variable PMV, which is 5 even if PMV is 0. indicating that one out of every 20 people feels dissatisfied.

Table 6-1. Comfort evaluation method and evaluation index table.

Scope of application of PMV		PMV's 7-stage evaluation index	
PMV	-2<PMV<+2	+3	Hot
Metabolic rate	0.8～4met	+2	Warm
Clothing wear	0～2clo	+1	Slightly warm
Air temperature	10～30℃	0	Moderately
Average radiation temperature	10～40℃	-1	Slightly cool
Air flow	0～1m/s	-2	Cool
Humidity	30～70%	-3	Cold

6.6 Calculate the indoor heat load of air conditioning

The heat load is the amount of heat required to maintain a constant indoor temperature and humidity, and the magnitude of the heat load determines the performance of the required air conditioning equipment. In this study, since the focus of the study is on interior design, the estimation of thermal load is mainly focused on indoor load and outdoor air load caused by ventilation. The outdoor air load is part of the air conditioning load, but is included as part of the heat load calculation in the "Air Conditioning Manual". When performing heat load calculations, a maximum heat load calculation is required to determine the capacity of the air conditioning system and an annual heat load calculation is performed to predict and evaluate energy savings. In this study, the maximum heat load calculation was used to estimate the heat load to measure the approximate heat load in the Task/Ambience area. In reality, the heat load is assumed to be non-stationary, i.e., varying over time, but in this study, the heat load is assumed to be steady-state because it was estimated by hand calculations using Excel, without the use of simulation software, etc. This study deals with the items with "○" in the table below.

Table 6-2. Heat load classification and content summary table.

Classification of heat load		Content of heat load	Whether this study involves
Room heat load	Surface heat load	Flux heat load of window glass	×
		Solar heat load from window glazing	×
		Heat load from exterior walls and roofs	×
		Heat load from ceilings, floors and interior walls	×
		Heat load from floor walls	×
		Moisture permeability of walls	×
	Indoor heat load	Heat load from heat generated by the human body	○
		Heat load from lighting	○
		Heat load from equipment generation	○
	External air heat load	Heat load from intermittent air conditioning	×
		Heat load due to ventilation	×
Other		Outdoor air load due to ventilation	○

Room heat loads (heat generated indoors) can be broadly classified into three categories.

Surface heat load: Surface heat load include the flow-through and solar heat loads of window glazing, the heat loads of building components such as exterior walls, roofs and ceilings, and the moisture permeability of walls. To calculate these, different values are treated for different components and locations, such as the thermal transmittance and shielding coefficients of components, standard solar heat gain rates, and effective temperature differences, so these are not treated in this study.

Indoor heat load: Indoor heat load includes heat load due to human body, lighting and equipment.

External air heat load: External air heat load is a general term for the heat load resulting from the introduction of "outdoor air" with a temperature difference from the room. Here it is assumed to be the total load caused by ventilation. The formula for the outdoor air load due to ventilation is as follows.

$$Q[W] = 0.33 \times V\left[\frac{m^3}{h}\right] \times \triangle H\left[\frac{kJ}{kg(DA)}\right]$$

(1)

Q: Dry − Total heat load$[W]$,

V: External air volume $\left[\frac{m^3}{h}\right]$,

$\triangle H$: Enthalpy difference between internal and external $\left[\frac{kJ}{kg(DA)}\right]$.

Regarding the specific enthalpy difference between internal and external in the equation: In general, the calculation of air conditioning heat load (including outdoor air heat load) involves the use of a wet air diagram to set the air conditioning performance. However, for more accurate data in this study, the actual equations given in (1) - (4) below will be used to calculate the required values.

（1）Method to determine saturated water vapor pressure [Pa]: The common method to determine saturated water vapor pressure based on temperature is Wechsler's formula.

t: Dry − bulb temperature[℃], T: Absolute temperature[K],

Ps: Saturated water vapor pressure[Pa], P: Water vapor partial pressure[Pa],

Φ: Relative Humidity[%], x: Absolute humidity[kg/kg(DA)],

$Patm$: Atmospheric pressure[Pa], h: Specific Enthalpy of Heat[kJ/kg(DA)].

In contact with liquid water (above 0.01° C):

$$\ln(Ps) = -0.58002206 \times \frac{10^4}{T} + 0.13914993 \times 10 - 0.48640239 \times 10^{\{-1\}T} + 0.41764768 \times 10^{\{-4\}T^2} - 0.14452093 \times 10^{\{-7\}T^3} + 0.65459673 \times 10 ln(T)$$

· (2)¶

（2）Method of determining the water vapor partial pressure [Pa]: The water vapor partial pressure can be calculated simply by dividing the saturated water vapor pressure determined above by the relative humidity.

P: water vapor partial pressure [Pa], ϕ: relative humidity [%].

$$P = Ps \times \phi / 100 \tag{3}$$

（3）Method of determining absolute humidity [kg/kg']: Absolute humidity can be calculated by the water vapor partial pressure.

P: water vapor partial pressure [Pa], *x*: absolute humidity [kg/kg'], *Patm*: atmospheric pressure [Pa].

$$x = 0.622 \times P / (Patm - P) \tag{4}$$

（4）Method of determining enthalpy [kJ/kg']: Specific enthalpy can be calculated from temperature and absolute humidity.

t: dry - bulb temperature [° C], *x*: absolute humidity [kg/kg'], *h*: specific enthalpy [kJ/kg'].

$$h = 1.006t + (1.86t + 2501)x \tag{5}$$

6.7 Development of visualization tools for design guidelines using game engines

6.7.1 *Creating a 3D model of the target space and constructing a virtual space.*

In this study, the 3D modeling software "Sketch Up Make 2017" from Trimble and the game engine software "Unity" from Unity Technologies were used to build the virtual space and visualize the data. Sketch Up was used to create a 3D model of the virtual space. sketch Up has a function to export the created 3D model as a dae file, which we used to export the 3D model and import it into Unity as a new asset. in the next section, the virtual space built in this section will be used to design a system that uses the equations mentioned in chapter 3 to The formula mentioned to visualize the heat load data.

6.7.2 *Visualizing the heat load with the game engine*

6.7.2.1 Creating a program to read CSV files.

In this section, the heat load data calculated by the formula in Chapter 3 is saved in a csv file in Unity, and a system is designed to visualize the data on the plane of virtual space. Regarding the Assets folder in the Unity project, the necessary scripts and data files were added to this folder. The first step was to create a Resources folder in the Assets folder and add the database .csv file that stores the heat load data. the DataInformation script consists of two main functions. The function CsvReader() reads the data information from the csv file and stores it in the variable Database as an array of string type. The function Init() stores the data information stored in the variable Database in a defined variable to be processed by other scripts.

6.7.2.2 Creating an Options Screen for Environmental Conditions.

In this section, an option screen for environmental conditions is created in order to set temperature and humidity conditions for office workers. First, a Canvas is added to the hierarchy to create a DropDown, which is an object of the user interface (action screen or method, UI) displayed on the PC screen with the ability to display options when clicked. A parent object for adding a DropDown-like UI; as shown in the figure, six Task temperature and humidity conditions are set up for the DropDown to display the selected conditions. These conditions are the same as those specified in Chapter 3. As shown in the figure, DropDown is placed near the seat. The four ambient temperature and humidity conditions were also set to the same settings as in Chapter 3. In the next section, a program was created to read the data corresponding to the selected conditions from the CSV file read and stored in the previous section by selecting the ambient conditions on this screen and displaying it on a separate heat load display screen.

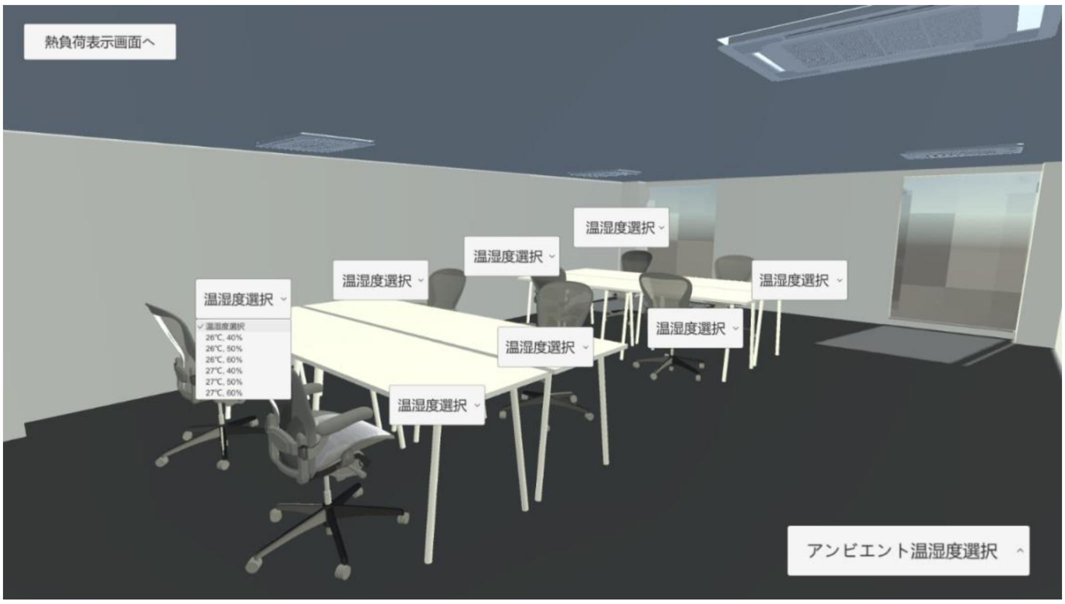


Figure 6-2. Options screen for environmental conditions.

6.7.2.3 Creating the Heat Load Visualization Interface.

In this section, interfaces are created to display the heat load on the virtual space plane. The heat load display interface consists of three display panels: a panel that displays the Task total heat load, a panel that displays the Ambience total heat load, and a panel that displays the total heat load. First, a panel showing the Task total heat load is created. This display panel shows the required area of the Task area in red and also shows the total heat load of the Task in the center of the seat. This display panel was duplicated to match the number of seats and was positioned to match the location of each seat. the Ambience total heat load display panel was also positioned to fit the floor area of the virtual space and displayed the Ambience total heat load corresponding to the environmental conditions selected in the previous section. Then, in the panel displaying the total heat load, the total Task total heat load, the Ambience total heat load, and the total heat load summed are displayed. In the next section, after selecting the environmental conditions created in the previous section, a program is created to display them on this heat load visualization screen.

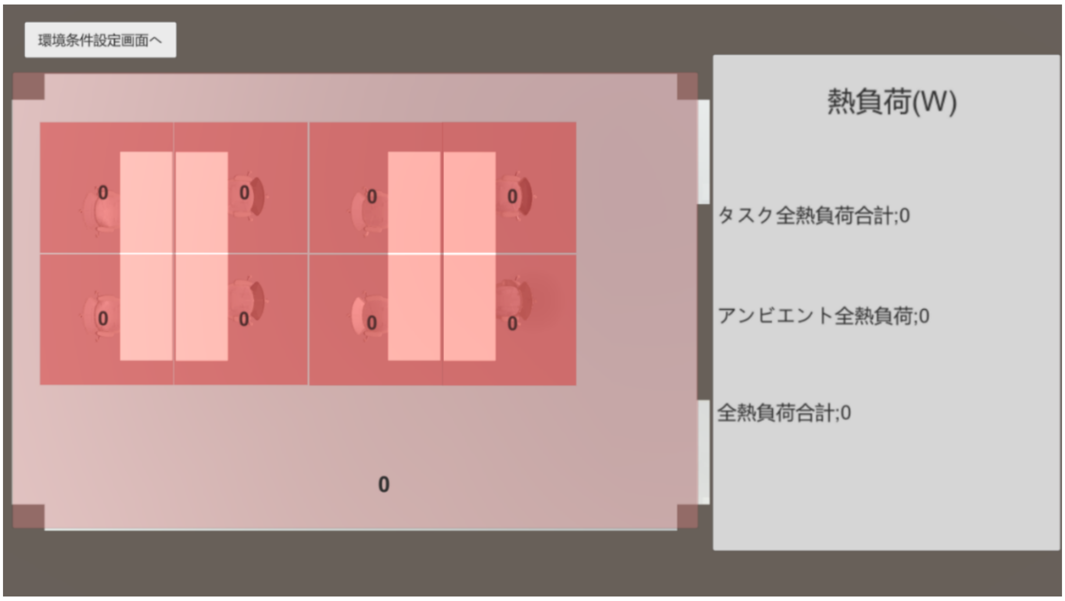


Figure 6-3. Heat Load Visualization Interface.

6.7.2.4 Creating a Heat Load Visualization Program.

In this section, create a program to display the heat load based on the heat load visualization interface created in the previous section. First, the parent object

TextBackGround is added to the Text component and the TaskHeatLoad.cs script is attached to it. On the script, the variable TheatLoadText is made [SerializeField] so that the text component can be stored on the Unity inspector. In the function Start(), the DataInformation class of the DataInformation script is stored in the variable dataInfo, and the CSV data is read and stored in this variable. In the function TaskChangeValue(), when the DropDown created in section 2 is checked, the total Task hotload stored in the CSV data is *converted* to a text type and assigned to the variable TheatLoadText. then, a text component showing the total Task hotload is attached to the inspector. Finally, the corresponding DropDown is attached. if this is done for eight seats, the total Task heat load will be displayed separately on the plane of the virtual space when the system is running and the environmental conditions are selected.

The Ambience total heat load display program is created in the same way as the Task total heat load display. First, the parent element TextBackGround is added to the Text component and the AmbientHeatLoad.cs script is attached to it. On the script, the variable *AHeatLoadText* is made to [SerializeField] so that the text component can be stored on the Unity inspector. In the function Start(), the DataInformation class of the DataInformation script is stored in the variable dataInfo, and the CSV data is read and stored in this variable. In the function AmbientChangeValue(), when the DropDown created in section 2 is selected, the total Task heat load stored in the CSV data is converted to a text type and assigned to the variable HeatLoadText. then, a text component showing the total Task heat load is attached to the inspector. Finally, the corresponding DropDown is attached. now, when the system is running and environmental conditions are selected, the total Task heat load is displayed separately on the virtual space plane.

This section ends with creating a program to display the sum of all total heat loads. First, the *necessary* text components are added to the hierarchy: in the SumHeatLoad.cs script, the variables are made to [SerializeField] so that the text components can be stored on the inspector, adjusting and selecting the corresponding text components. In the function SumChangeValue(), the data of string type is obtained from the text components attached to TaskTexts, converted to numeric type and added together. At the same time, the string type data of Ambience's total heat load is also obtained and converted to a numeric type. All heat load data converted to numeric type is then added together and displayed in the text part of the total heat load. The program allows to check the value of the total outdoor heat load by setting the temperature and humidity conditions in the Task and Ambience areas in the virtual space.

The figure 6-4 shows the screen for executing the total heat load display program created in *this* section with the Task temperature and humidity conditions and the ambient temperature and humidity conditions set.

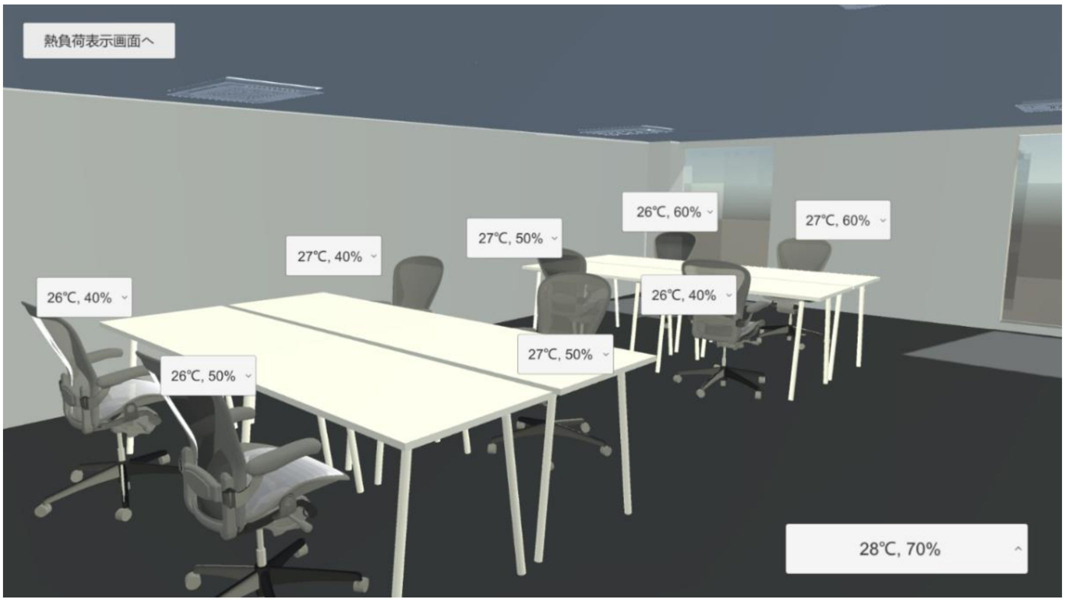


Figure 6-4. Environmental conditions selection interface.

If you then switch from the environmental conditions selection screen to the heat load visualization screen in the above figure, the respective Task total heat load, Ambience *total* heat load and their totals are displayed, referring to the Task and Ambience environmental conditions selection in Figure 4, the corresponding heat loads are shown in the figure.

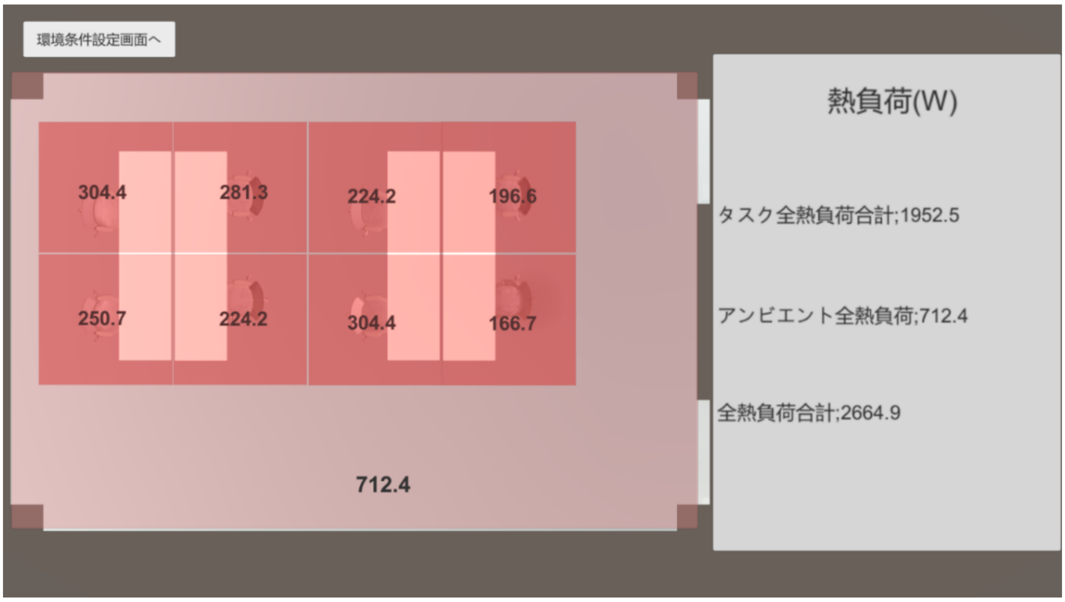


Figure 5. Thermal load visualization screen after selecting environmental conditions.

6.8 Case Study - Design Phase Analysis of Energy Savings in Task-Ambience area

6.8.1 *Case study setup*

In this *study*, a database of CSV files was created to estimate the heat load in the Task/Ambience area and visualize it in a game engine, targeting a planning and design studio rather than an office in the Natural Science 2 building of Kanazawa University. The size of the room was assumed to be about the same as a small office with an area of 73.5 m2 (7000 mm in length and 10500 mm in width). The required ventilation and personnel will be set up accordingly. The number of attendees was set at 8. The outside air temperature was set at 30° C and the humidity at 70%.

6.8.2 *Design Guidelines for Task and Ambience areas*

In this *section*, the total heat load calculation method identified in Chapter 3 is used to calculate the total heat load for the Task-Ambience area: first, the absolute temperature, saturated water vapor pressure, partial pressure of water vapor, absolute humidity, and specific enthalpy of the outdoor air conditions are obtained, which are necessary to calculate the total heat load for the Task and Ambience areas. According to the visualization tool development process in Chapter 4, the virtual space of the case studio is created and the total heat load of the corresponding environment in the Ambience-Task area is calculated in the virtual space. The final result is the following design guidelines for intelligent control and energy consumption of the temperature and heat environments in the Task and Ambience areas.

Table 6-3. Setting of environmental condition values.

Item	Absolute temperature	Saturated water vapor pressure	Water vapor partial pressure	Absolute humidity	Specific enthalpy
Unit	K	Pa	Pa	kg/kg(DA)	kJ/kg(DA)
Value	303.15	4246.03	2972.221	0.018797	78.23976

Table 6-4. Total heat load in Ambience area.

Ambience Settings							
Temperature	**Humidity**	**Absolute temperature**	**Saturated water vapor pressure**	**Water vapor partial pressure**	**Absolute humidity**	**Specific enthalpy**	**Total heat load**
℃	%	K	Pa	Pa	kg/kg(DA)	kJ/kg(DA)	W
28	40	301.15	3782.207	1512.883	0.009428	52.23804	2481.5
28	50	301.15	3782.207	1891.103	0.01183	58.37	1896.291
28	60	301.15	3782.207	2269.324	0.01425	64.54878	1306.613
28	70	301.15	3782.207	2647.545	0.016688	70.77493	712.4143

Table 6-5. Total heat load in Task area.

Task Settings							
Temperature	**Humidity**	**Absolute temperature**	**Saturated water vapor pressure**	**Water vapor partial pressure**	**Absolute humidity**	**Specific enthalpy**	**Total heat load**
℃	%	K	Pa	Pa	kg/kg(DA)	kJ/kg(DA)	W
26	40	299.15	3363.132	1345.253	0.008369	47.49202	304.4026

26	50	299.15	3363.132	1681.566	0.010497	52.91604	250.7048
26	60	299.15	3363.132	2017.879	0.012639	58.3768	196.6433
27	40	300.15	3567.312	1426.925	0.008885	49.82838	281.2727
27	50	300.15	3567.312	1783.656	0.011145	55.59652	224.1681
27	60	300.15	3567.312	2140.387	0.013423	61.40614	166.6528

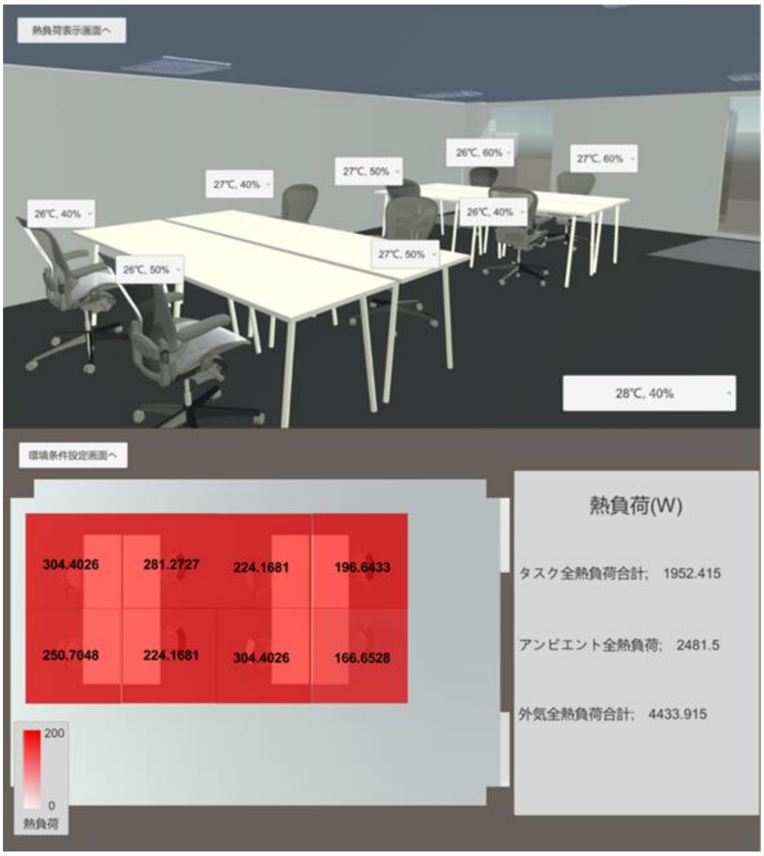


Figure 6-6. Ambience-Temperature 28° C humidity 40% corresponding to the environmental conditions selection interface and thermal load visualization interface.

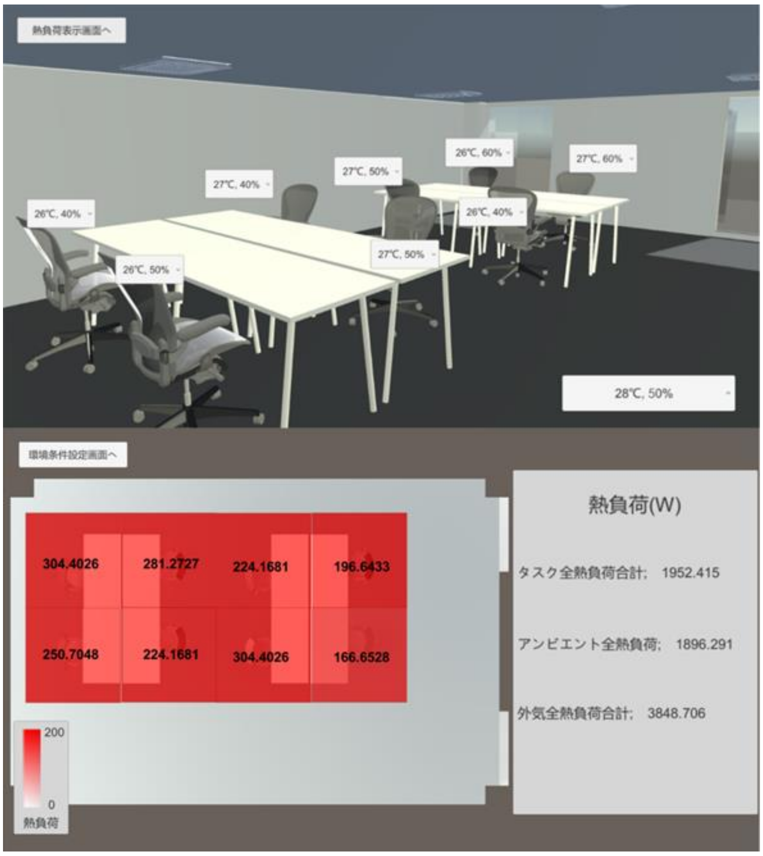


Figure 6-7. Ambience-Temperature 28° C humidity 50% corresponding to the environmental conditions selection interface and thermal load visualization interface.

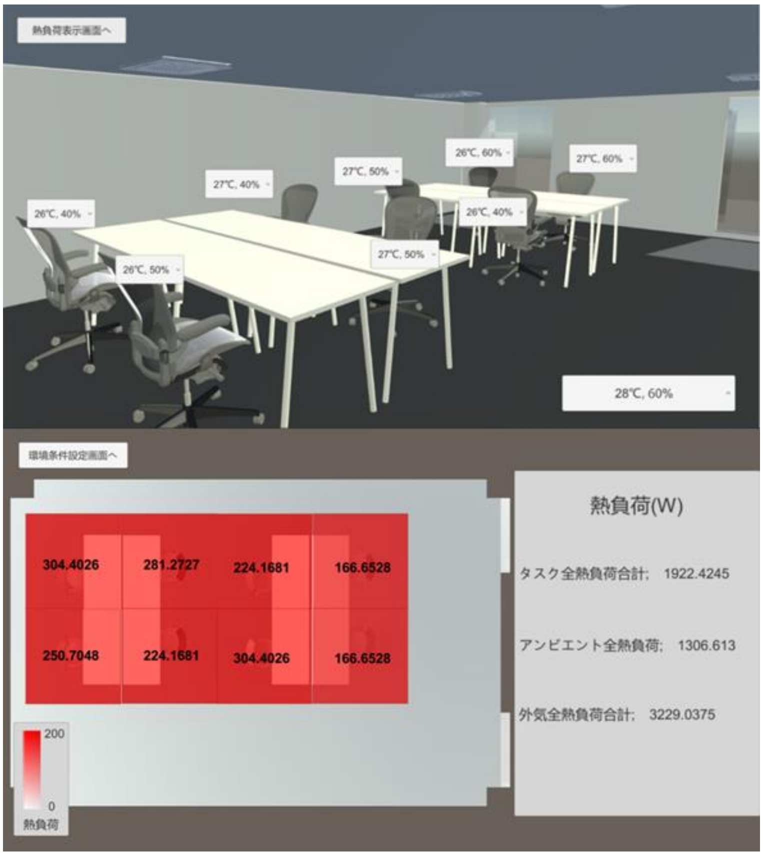


Figure 6-8. Ambience-Temperature 28° C humidity 60% corresponding to the environmental conditions selection interface and thermal load visualization interface.

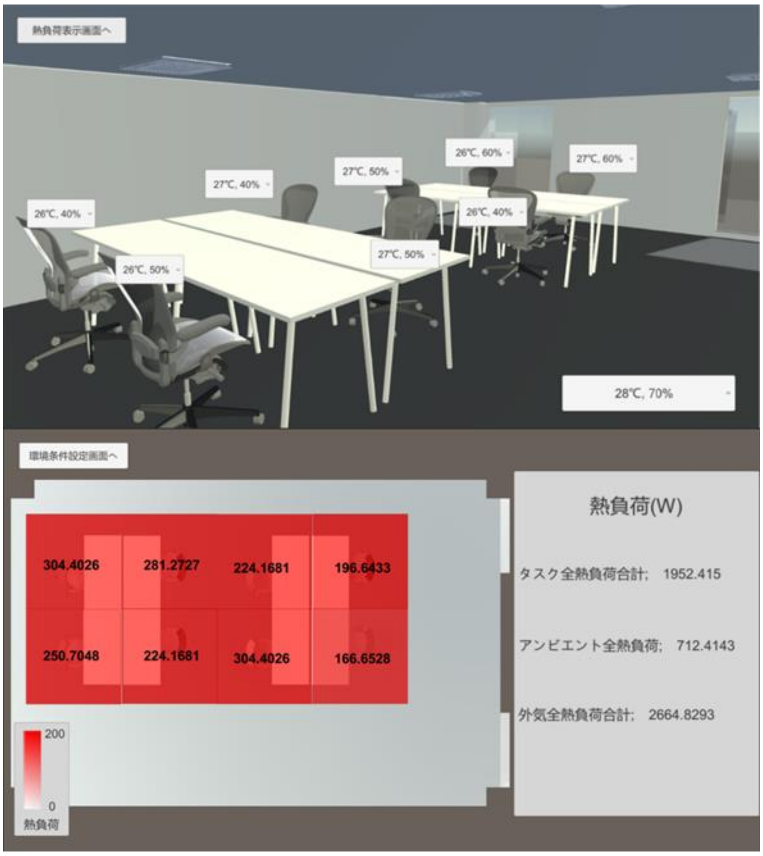


Figure 6-9. Ambience-Temperature 28° C humidity 70% corresponding to the environmental conditions selection interface and thermal load visualization interface.

6.8.3 *Comparison of energy consumption with and without the use of design guidelines in the Task and Ambience areas*

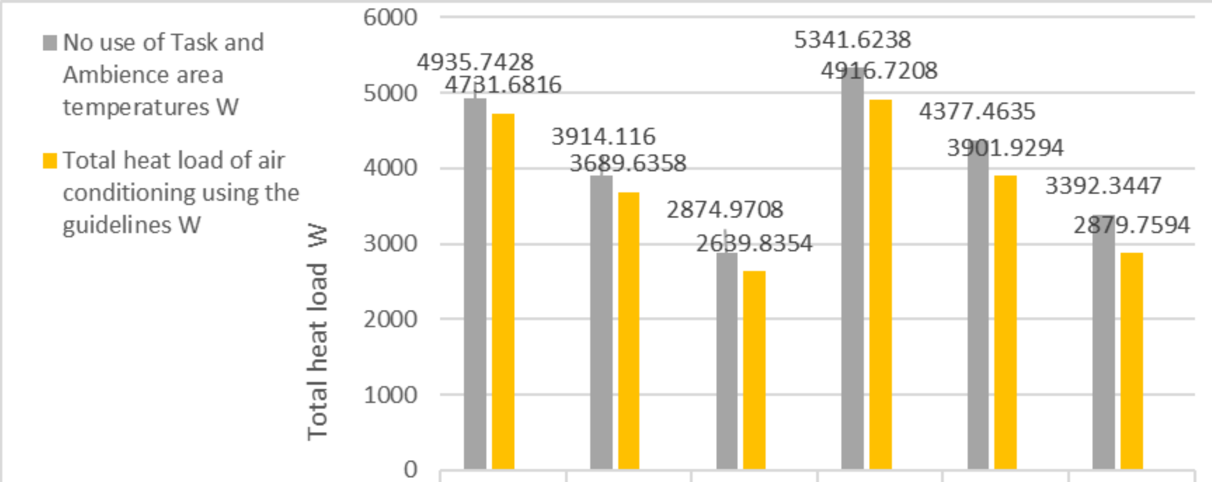
Table 6-6. Energy consumption without using the Task and Ambience area design guidelines.

Temperature	**Humidity**	**Absolute temperature**	**Saturated water vapor pressure**	**Water vapor partial pressure**	**Absolute humidity**	**Specific enthalpy**	**Total heat load**
℃	%	K	Pa	Pa	kg/kg(DA)	kJ/kg(DA)	W
27	40	300.15	3567.312	1426.925	0.008885	49.82838	4935.7428
27	50	300.15	3567.312	1783.656	0.011145	55.59652	3914.1160
27	60	300.15	3567.312	2140.387	0.013423	61.40614	2874.9708
26	40	299.15	3363.132	1345.253	0.008369	47.49202	5341.6238

26	50	299.15	3363.132	1681.566	0.010497	52.91604	4377.4635
26	60	299.15	3363.132	2017.879	0.012639	58.3768	3392.3447

Table 6-7. Energy consumption using Task and Ambience area design guidelines Energy consumption using Task and Ambience area design guidelines.

Temperature	**Humidity**	**Absolute temperature**	**Saturated water vapor pressure**	**Water vapor partial pressure**	**Absolute humidity**	**Specific enthalpy**	**Total heat load**
℃	%	K	Pa	Pa	kg/kg(DA)	kJ/kg(DA)	W
A:28, T:27	40	301.15	3782.207	1512.883	0.009428	52.23804	4731.6816
A:28, T:27	50	301.15	3782.207	1891.103	0.01183	58.37	3689.6358
A:28, T:27	60	301.15	3782.207	2269.324	0.01425	64.54878	2639.8354
A:28, T:26	40	301.15	3782.207	1512.883	0.009428	52.23804	4916.7208
A:28, T:26	50	301.15	3782.207	1891.103	0.01183	58.37	3901.9294
A:28, T:26	60	301.15	3782.207	2269.324	0.01425	64.54878	2879.7594



Personal work area Temperature + Humidity	27℃, 40%	27℃, 50%	27℃, 60%	26℃, 40%	26℃, 50%	26℃, 60%
No use of Task and Ambience area temperatures W	4935.7428	3914.116	2874.9708	5341.6238	4377.4635	3392.3447
Total heat load of air conditioning using the guidelines W	4731.6816	3689.6358	2639.8354	4916.7208	3901.9294	2879.7594
Percentage reduction in total heat load with than without %	4.13	5.74	8.18	7.95	10.86	15.11

Figure 6-10. Difference in energy consumption between using the Task and Ambience areas design guidelines and not using them.

The difference between the energy consumption using the design guidelines for Task and Ambience areas and the energy consumption without using the design guidelines shows that the energy consumption using the design guidelines for Task and Ambience areas is on average about 8% less than the *energy* consumption without using the design guidelines, with the same temperature (Task temperature) and humidity in the individual workplace; the results also show that the temperature and humidity settings of the air conditioner The greater the difference between the temperature and humidity of the air conditioner and the room temperature, the higher the energy savings from using the design guidelines for the Task and Ambience areas.

6.9 Conclusion

In terms of content, after organizing information about energy-efficient air conditioners, this study finally chose to control the office environment through Task-Ambience air conditioners; however, the current study shows that the energy-saving effect of Task-Ambience air conditioners is verified in the demonstration and operation stages, and the energy-saving effect is not shown in the design stage, while there are few examples of visualizing the indoor environment and its digital information, and the method of visualization has not been established yet.

This study identifies design guidelines for smart control of temperature and heat environment and energy consumption based on Task-Ambience air conditioning, and realizes the prediction of energy consumption and heat load at the scale of the building environment in the pre-compilation stage of the full planning cycle, as well as the practice of planning and design based on smart devices in the building environment in the pre-planning stage; this study is also the practice of energy This study is also a technical practice of simulation and visualization of energy in the design phase, and a practice of intelligent management using computer systems. At the same time, this study establishes a simulation system to visualize energy consumption according to individual zones and work styles, not only based on energy schedules and building floor plans.

Therefore, this study first uses Unity, a game engine, to develop a visualization tool that calculates the total thermal load of the Task-Ambience area according to the formula for outdoor air load based on preset environmental conditions and displays it on the visualization interface as the energy consumption of the Task-Ambience air conditioner; relying on this visualization tool, this study conducts a study of the Based on this visualization tool, this study investigates the case studio and finally integrates the design guidelines for intelligent control of thermal environment and energy consumption in the Task and Ambience areas. Calculations show that the use of the design guidelines reduces energy consumption by an average of about 8% compared to no use, and that the use of Task-Ambience air conditioning and energy consumption design guidelines can effectively reduce the energy consumption of air conditioning in offices.

Finally, in the *planning* and design stage, prepare for the planning and design evaluation, and simulate the energy saving effect of the building environment through virtual visualization. Through the design of Application of virtual reality to visualize the design guidelines for intelligent control of temperature and heat environments and energy consumption in office environments, the purpose is to clarify how to apply the task and ambient air condition for building environment before planning implementation.

Chapter 7 Conclusions

This research is based on the full-cycle management of planning and design, through the visualization simulation of urban space and building space intelligent energy saving, in order to achieve different spatial scales, how to reduce energy consumption through visualization in each stage of planning and design .

Firsr through the planning and Design of a Smart Visiting Service Management System in Order to Integrate Tourism Management into an Isolated Island

Previous works are focused on the development of different kinds of tourism information services for tourism organizations, and claim that by using big data analysis and processing means, researchers can improve practices in tourism businesses and serve tourists better. In this paper, we proposed a management system using virtual reality for tourism services, and took the Huangguan smart island project as a case study in order to figure out how to design the visiting service system in the island space, and how to collect personal information for smart visiting service management.

We suggest the infrastructure monitoring system and the smart service system for smart visiting management on the island. Personal information collected in the island space is a relatively small database that can be organized in one integrated database in this system; it is also easy to integrate the database of smart services as one visiting management system for cooperation between the service providers. Personal information collected in the island space is complicated, due to different service providers collecting different personal data for various business purposes. Personal information is collected by the sensors not only in personal mobile devices, but also in smart LoT facilities deployed in the buildings of the urban space. Thus, the smart visiting service management system is able to share the personal information for integration of all separated smart visiting services.

Also , we discuss the principles of personal information collection. The personal information is supplied by different providers, which usually makes it impossible to share this information between them, thus, it is unreasonable to identify an individual person for protection of non-public personal information, if there is no integrated database. Besides the non-public personal information, public personal information can be shared between smart service systems, and there is also a kind of smart device that will not collect personal information. As a result, we can divide personal information into three types: public, non-public personal information, and non-personal information.

Different smart services require different types of personal information, so it is important to organize smart devices in building spaces. In further research, we investigate what kind of personal information is necessary for different types of smart services, and then we can further discuss the standards of planning and design for smart devices in the smart city constructions.

The above is the basis of the following research in this paper, the first step in the whole cycle of planning and design, and the largest range of spatial scale in this research.

In the second step, we will set planning and design objects and goals, and establish an energy-saving index system. The development of low-carbon industrial is a unity of coordinated action, which is involved to energy consumption, emission reduction, technical, and so on. On this basis, combined with the reality of Pingtan Comprehensive Experimental Zone, this paper puts forward an energy-saving evaluation system for the development of low-carbon industries with energy consumption as the core, emission reduction as the goal, and technology as the means, and takes it as an evaluation index for the development of energy-saving in Pingtan industry. There has a fundamental practical significance of the evaluation system to optimize the industrial structure layout of Pingtan, promote the transformation and upgrading of traditional industries, accelerate the pace of low-carbon industries development, and improve resource utilization efficiency.

In the third step of this research, we will clear planning and design guidelines are the basis for planning compilation and planning implementation. we analyze the requirements of different types of underground space scenes and clearly establish the sensor types and corresponding parameters for smart sensing scenes. Based on the sensor parameters and the acquired data, we propose a system design for smart sensing platform in underground space and form the sensor installation guidelines accordingly. The guidelines are mainly divided into two parts: installation guideline table and installation schematic, and the purpose of setting the guidelines is to guide the work related to the construction of smart scenes in underground space.

Especially focuses largely on maintenance manage-ment. The next step will be to refine the process of developing and constructing smart scenes in underground spaces, and to propose different development proposals and guidelines at different phases according to the refined process.

Furthermore, Energy visualization simulation of air conditioning consumption in a built environment. Serve as the basis for the last step in the planning lifecycle management (planning evaluation). Planning evaluation is not only the management of the smooth implementation of planning and design, but also an important method and means for predicting and early warning of urban and architectural space utilization.

Therefore, we established the energy consumption model of the building and details the parameter settings related to the energy simulation model . After running the model, the data of the building's energy consumption for the whole year were obtained, and the analysis of the building's energy consumption was focused. The following conclusions were drawn.

one of the results is the air conditioning system accounts for most of the energy consumption, with the heating process accounting for a relatively large amount. The study showed that greenhouse gas emissions in the environment can be mitigated by reducing the energy consumption of the building's air conditioning system. In addition to the energy consumption of air conditioning equipment, lighting and electrical equipment also occupy a high percentage of energy consumption, 15% and 25%, respectively. Therefore, reducing the energy consumption of these two devices can be considered in a intelligent building, and the devices can functionally complement each other.

Besides， clarifying the energy consumption of intelligent buildings helps designers to identify the deficiencies of building systems in the design phase and improve energy efficiency. Compared to traditional buildings, intelligent health buildings can be better utilized in the design phase by reasonably evaluating the functions of the system and the way the equipment is utilized. There is a growing trend toward intelligent and healthy buildings, with automation and control systems that can use sensor data to improve building efficiency. Outstanding energy-saving measures in intelligent health buildings allow electronic sensors and small processors in each room to automatically regulate room temperature, light sources, heating and cooling, ventilation, etc. With its outstanding technical features, the Intelligent and Healthy Building can make a significant contribution to greenhouse gas reduction and environmental protection initiatives. The efficient use of energy in high-rise buildings can not only significantly reduce electricity consumption, but also reduce building costs, also in buildings that use a lot of electricity.

With more and more high-rise buildings in large cities today becoming the main consumers of energy demand, the efficient use of energy in buildings is urgent. With more and more people living in cities, the available resources need to be used more efficiently to reduce overall energy consumption and carbon emissions. Intelligent and healthy buildings not only improve energy efficiency, but intelligent placement of sensors and actuators can continuously monitor and adjust lighting and air quality to ensure an optimal working environment and increase productivity. However, the systems in the intelligent and healthy building can be so complex that even minor problems can cause major disruptions to the operation of the entire building, requiring further research in this area.

According to the results of the HVAC load curve electrical energy consumption graph, it can be seen that the energy consumption is much higher in winter than in summer, i.e. heating consumes more electrical energy than cooling in summer, and the weather in Sapporo also influences the results to some extent. Both cooling and heating equipment consume more energy, so it is important to conserve electricity in both systems in order to save energy. Saving electricity in daily life, especially in office buildings, is directly related to reducing the strain on the electrical supply system. If high-rise buildings do not incorporate intelligent energy savings into their design and operation, it will result in a huge waste of energy, especially in large cities.

Furthermore show that air conditioning consumes a relatively large amount of electrical energy in buildings, about 50%, compared to lighting energy and electrical equipment energy consumption. However, the simulation of this study for building energy consumption focused on the building's electrical energy, and there is a lack of more in-depth research on other energy consumption in intelligent and healthy buildings. Therefore, there is a need to further explore how to evaluate building energy consumption more accurately in the design phase in the future. In addition, only the conventional air conditioning system was considered in the simulation study of the energy part, and the inclusion of new energy sources such as solar energy and natural gas can be considered in the future.

Finally, as a basis for planning implementation and evaluation, this chapter will discuss about the implementation, management and maintenance of the architectural environment of the building space are simulated based on the smallest spatial scale of this study.After organizing information about energy-efficient air conditioners, this study finally chose to control the office environment through Task-Ambience air conditioners; however, the current study shows that the energy-saving effect of Task-Ambience air conditioners is verified in the demonstration and operation stages, and the energy-saving effect is not shown in the design stage, while there are few examples of visualizing the indoor environment and its digital information, and the method of visualization has not been established yet.

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