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Development and Assessment of Healthy Senior Workplace Index

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Abstract

The high statistical incidence of diseases in the elderly, particularly at the top ranks, includes cancer and tumors which accounted for 19.61%, circulatory system diseases for 15.72%, neurological system diseases for 14.63%, and respiratory system diseases for 14.03%. These diseases have a strong relation with VOC, $PM_{2.5}$, CO_2, air temperature and humidity which must be minimized. Thailand enters into an aging society therefore it is necessary to extend the working age in an alignment with Sustainable Development Goals (SDGs); Goal 3: ensure healthy lives and promote well-being for all ages and Goal 8.8: protect labor rights and promote safe and secure working environments. The technique of mixed-methods research was conducted with Analytic Hierarchy Process (AHP). Health problems of the elderly workers were studied according to the standards, laws, and the development of assessment models reflecting the Healthy Senior Workplace Index and simplified assessment concepts compliant with the elderly laws and workplace environments, utilizing WELL and fitwel standards focusing more on building the environments than others. A literature review on disease causes was conducted to construct a structured questionnaire with 97% index of item objective congruence. A survey was conducted online with fifteen qualified public health experts, employing a snowball sampling method and Likert scale (0-5) to assess the relationship between the environment and diseases. AHP reveals $PM_{2.5}$, temperature, VOC, and CO_2 accounted for 41.52% having higher importance weights than other factors, integrated to variables in the Healthy Senior Workplace Index. An assessment for office building environments for elderly workers was developed, achieving a Cronbach's Alpha Coefficient of 0.99 in reliability testing through an online survey distributed to thirty building inspection experts and engineers. Real-time IoT was combined with past physical environment records to facilitate efficient assessments.

Keywords: Disease prevalence; Senior worker; Workplace standards; Healthy Senior Workplace Index; Well-being

1. Introduction

The complete elderly society in Thailand (The Bureau of Registration Administration Department of Provincial Administration, 2020) has led to an expansion of their workforce aged over 60 years (Office of the Secretariat of the Cabinet, 2018), with flexible working hours, thereby necessitating improvements in workplace environments to enhance well-being, aligning with the Sustainable Development Goals (SDGs) (International Health Policy Program Foundation, 2021) regarding the society in the dimension of people, focusing on building the foundation for good health and promoting well-being for everyone across all ages, in accordance with SDGs Goal 3 and 8.8. Although Thailand enforces various laws and standards related to well-being, the statistics of disease prevalence among the elderly in Thailand remain high; for instance, cancer and tumors accounting for 19.61%, almost one fifth. The implementation of every requirement can result in significantly high costs, leading to duplication or incomplete execution. Monitoring and inspection are inconsistent. The fluctuations in indoor environmental conditions may result in illnesses due to Sick Building Syndrome (Zainal, *et al.,* 2019). High prevalence of diseases among the elderly, such as carcinogenic substances or formaldehyde are commonly found in furniture, synthetic wood, or certain types of paint in buildings, and small particle PM_{10}, $PM_{2.5}$ and along with diseases related to the circulatory system, diseases caused by nerve-damaging substances and cancer (Daoprasert, 2010). Moreover, physical conditions can lead to accidents, such as lighting, obstructions in walkways and ramps, or respiratory system diseases, such as allergies, inflammation of mucous membrane of nose, inflamed conjunctiva, and skin diseases due to inappropriate temperature and humidity. Moreover, airborne infectious diseases such as bacteria and legionella, which grow at temperatures of 25 - 42 ^{0}C, result in health problems which are obstacles to continuous work after retirement (Ritwichai, 2014).

Laws and standards are provided to support the elderly; for example, guidelines for managing the environment suitable for the elderly, specifying the characteristics of signs, ramps, elevators, handrails, stair dimensions, the size and number of parking spaces for the elderly, and the characteristics of bathrooms (Ministry of Public Health, Department of Environmental Health, 2015). Additionally, the Well-Being Building standards promote the universal design for national standards such as the Sook Building Standard (Thailand Green Building Institute, 2021). This standard emphasizes the concepts of Biophilia & Neighborhood, architectural design, interior design, and materials to prevent various pollutants such as volatile organic compounds (VOCs), and the environmental and engineering systems to ensure good indoor air quality and promote health innovations. International standards include fitwel which has a sub-standard specifically for the elderly, Fitwel Senior Housing (fitwel, 2022). This standard aligns with the Ministry of Public Health guidelines for managing environments suitable for the elderly but more considerations for building location and safe travel, gardens, natural light, natural views, indoor air quality testing. It also includes access to food and water, emergency planning, and staff trained to handle emergencies. This aligns with the WELL standard, which focuses on eleven aspects: air quality, water, food, light, movement, thermal comfort, sound, materials, mind, community, and innovation that promotes health and the environment (International WELL Building Institute, 2022). The LEED standard from the United States focuses on energy efficiency but includes standards for non-polluting materials and indoor air quality (U.S. Green Building Council Standard, 2022). Additionally, the CASBEE standard from Japan covers energy efficiency, resource use, local environment, and building environment, including a formula for calculating the Building Environment Efficiency (BEE) index (Japan Sustainable Building Consortium and the Institute for Building Environment and Energy Conservation, 2014). The BREEAM standard from the United Kingdom assesses and promotes environmental, energy, economic, and social sustainability, encouraging continuous improvement and innovative best practices (BRE, 2020). The DGNB standard from Germany focuses on environmental, economic, social, and usability aspects, ensuring comfort, satisfaction, and mobility within buildings. It can be seen that both laws and standards are aimed at designing and improving the built environment for everyone (German Sustainable Building Council, 2022).

This research focuses on controlling environmental factors that lead to a high prevalence of diseases in the statistics. The researchers study the health problems of elderly workers, investigate relevant standards and laws, and develop assessment tools to create the Healthy Senior Workplace Index. The researchers also propose ideas for developing continuous workplace environment assessment methods that could be conducted quickly and easily by building staff without the expense of hiring certified building inspectors. Additionally, it can monitor the workplace environment and improve indoor air quality. The researchers utilize empirical knowledge of disease prevalence and causes to infer factors contributing to disease prevalence, employ survey research tools to the opinion scale from qualified individuals and public health experts, and employ rank correlation statistical analysis to determine the importance of environmental factors in disease occurrence, enabling efficient management and control measures at the primary cause. The correlation used the analysis hierarchy process method, similar to the approach used by Sirisawat and Kiatcharoenpol (2020), Tansirikongkol (2014) and Kongsing and Choonil (2013). The research was in line with the sub-goals of SDGs: to reduce premature deaths from non-communicable diseases by preventing and supporting good living conditions, including reducing the mortality rates of individuals with heart disease and stroke, cancer, diabetes, or chronic respiratory diseases, as well as illness from hazardous chemical and toxic substances or air, water, and soil pollution, including indoor air pollution and planet with SDGs dimension of environmental aspects that need to prepare the environment in buildings.

2. Methodology

The research involves a mixed-methods approach. The research framework shows the relation of dependent variables and independent variables (Figure 1).

2.1 Sample preparation

The research involves a mixed-methods approach, employing qualitative research methodology to study literature related to the subject matter through relevant publications. It utilizes the Theory of Consolidated Meta-Analytical Approach – TEMAC, by searching for related research, managing data relationships, and reviewing evidence (Mariano *et al.,* 2019). Additionally, VOSViewer version 1.6.19 is used to identify keywords and connections to reflect of researchers' interest levels in similar topics and identify research gaps from previous studies about workplace environment suitable for elderly workers and inferring knowledge linked to factors contributing to disease occurrence, disease prevalence statistics among individuals over 60 years old, and mortality rates (Strategy and Planning Division Ministry of Public Health, 2020).

Relevant laws considered include the Elderly Person Act, regulations on facilities for disabled and elderly individuals, occupational health, environmental and safety laws, and the Building Act. The domestic and international building standards are considered according to the Ministry of Public Health guidelines

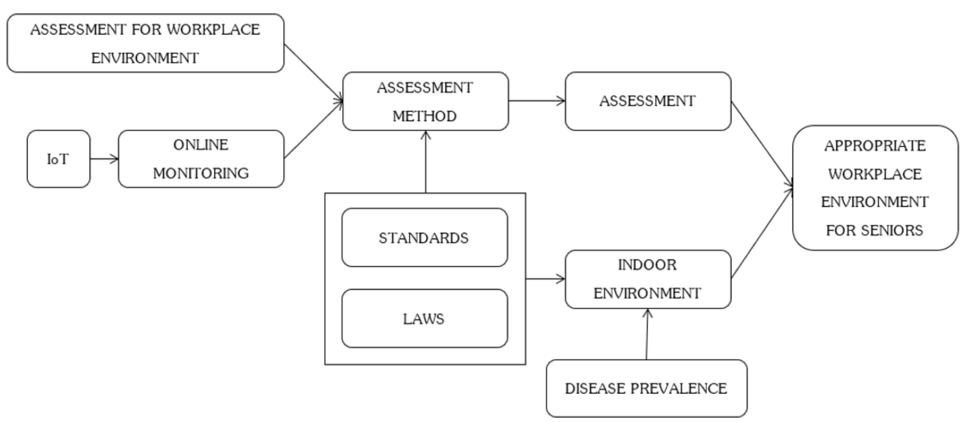


Figure 1. Conceptual framework

for managing the environment suitable for the elderly, Thai Green Building Institute standards, fitwel, WELL, LEED standards from the United States, German DGNB standards, Japan CASBEE standards, and BREEAM standards from the UK. Each concept of weight, its importance and key measures are considered. The method of qualitative research is employed to derive a structured questionnaire. Data were collected from qualified individuals and experts in public health, medicine, and nursing through a snowball sampling method. The survey conducted from July 1, 2023 to October 30, 2023 employed a Likert scale ranging from 0 to 5 to assess the relationship between the environment factors and disease occurrence, as well as the relationship between diseases. A score of 0 indicated no relationship, while 5 indicated the highest likelihood. The index of item objective congruence of the questionnaire was at 97 percent.

2.2 Sample analysis

The sample analyzed was conducted in accordance with age ranges and the causes of various diseases. The researchers applied a positivist philosophy, where knowledge led to conclusions and inferences regarding the environmental factors within buildings affecting disease prevalence. The standards, laws and disease prevalence were compared.

2.3 Statistical analysis

The survey results were analyzed according to the Analytic Hierarchy Process (AHP) method similar to the research conducted by Sirisawat and Kiatcharoenpol (2020). AHP was employed to analyze the influence of one disease on others and ranked the importance of environmental factors causing diseases. A matrix comparison method was used to compare problems. AHP was used to rank the importance of factors in the equation for assessing the building environment's suitability for elderly workers. These importance levels are then used to construct the Model Equation for the Healthy Senior Workplace Index (Equation 1) with a maximum total score of 110% including 10% extra points for emergency preparedness planning for the elderly.

$$\beta_1x_1+\beta_2x_2+\beta_3x_3+\beta_4x_4+\beta_5x_5+\beta_6x+\beta_7x_7 +\beta_8x_8+\beta_9x_9+\beta_{10}x_{10}+\beta_{11}x_{11}+\beta_{12}x_{12} +\beta_{13}x_{13}+\beta_{14}x_{14}+\beta_{15}x_{15}+EMP \rightarrow Y \quad (1)$$

β	weight of importance of each variable
x_1...n	physical environmental factor variables, the values between 0 not compliance and 1 compliance
EMP	Emergency Plan
Y	Senior Healthy Workplace Index

The workplace assessment was analyzed by comparing those with experience in inspecting buildings with those working in the buildings, using a comprehensive assessment form and a form aimed at reducing the prevalence of high-statistic diseases. The analysis was conducted using RStudio (2023), the R programming language to perform Pearson's Chi-squared test, One Sample t-test, and to examine the distribution of data between the first quartile and the third quartile.

2.4 Workplace assessment

An assessment questionnaire was developed based on the main disease prevalence factors identified through AHP analysis. There were comprehensive assessment form and a form aimed at reducing the prevalence of high-statistic diseases. The questionnaire contained fewer questions due to its strong focus on the causes of disease prevalence and was tested for reliability using Cronbach's Alpha Coefficient. Thirty subjects of building inspection experts and engineers were surveyed online. Their responses indicated a reliability coefficient of 0.99, demonstrating high reliability. In addition, to ensure that indoor air quality environment in the building remained consistently good at all times, IoT devices capable of continuously monitoring building air environments were selected with only high priority environmental factors based on AHP analysis. The sensors were their compared with standard parameters according to WELL. The sensor used was the Milesight model AM319, which measured temperature, $PM_{2.5}$ dust, TVOC, formaldehyde, humidity, and CO_2. It transmitted the data wirelessly with long-range signals (LoRaWAN) and stored it on a cloud server via a gateway server, model UG65 from Milesight.

2.5 Conduct a trial of the workplace assessment

The trial of the workplace assessment took place at Ramkhamhaeng University, specifically in room 401 and the Faculty of Engineering Graduate Studies Office on the 4th floor of the LTB building, with a total of 32 samples consisting of those with experience in inspecting buildings and those who work regularly in the buildings. The assessment was conducted from May 14 - 15, 2024. The workplace assessment forms, including both the comprehensive assessment and the form aimed at reducing the prevalence of statistically high diseases, along with IoT devices, were used during the survey.

3. Results and Discussion

Analysis using VOSviewer software revealed (Figure 2) that there were significantly common references regarding the work environment, with up to 513 articles from the EBSCO database between 1481 and 2023. The keywords are the elderly or the aged or the older or the elder or geriatric or senior AND employees, AND workplace, AND indoor, and AND environment. It was evident that there had been considerable emphasis on researching workplace environments over the centuries. Research connections extended to environmental issues within buildings, quality of life, elderly individuals, cleanliness, and workplace safety. There was substantial research on designing amenities workplace environments. But only a small number of research specifically addressed the work environment concerning elderly individuals, with minimal or insignificant linkages of research in this area. Furthermore, no research connections were found regarding indices evaluating suitable office environments for elderly employees.

3.1 Disease prevalence and current practices

A total of sixty research papers were reviewed, along with fourteen protocols. For instance, the research by Voordt and Jensen (2018) identified the measurement of building efficiency, both quantitative, such as CO_2 emissions compared to legal regulations or standards like BREEAM, LEED, or DGNB,

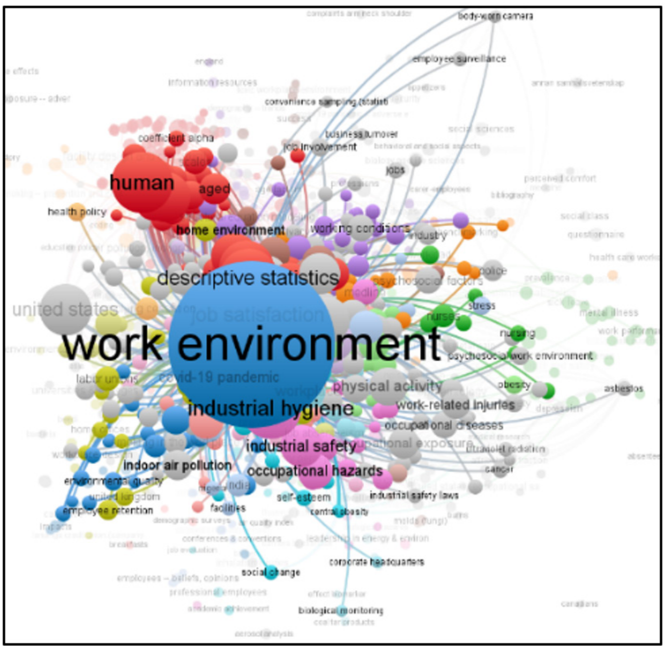


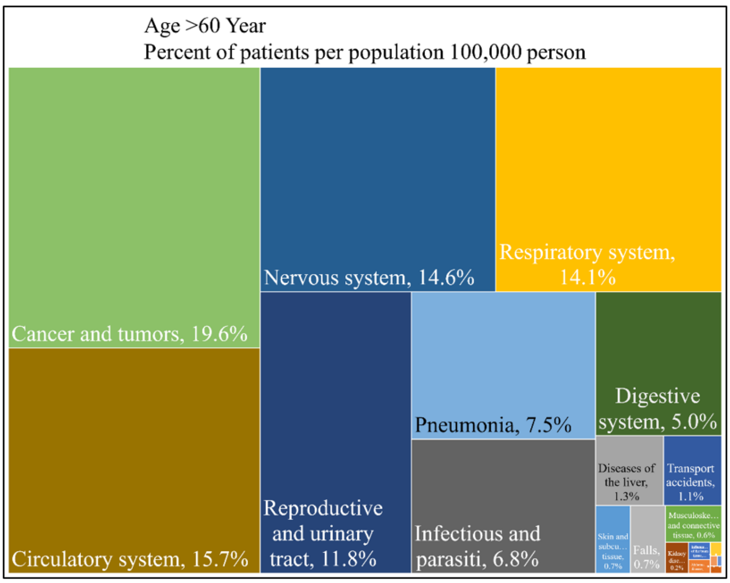
Figure 2. Co-occurrence map from VOSviewer

and qualitative assessments as satisfaction with office building usage. Furthermore, a review by Oberti and Plantamura (2022) summarized workplace requirements and their impact on work effectiveness, including mindfulness, control of various disturbances such as phone calls, meeting noises, space design necessitating privacy, or collaborative work, and different designs tailored to specific space functions. Additionally, other factors mentioned include ergonomics in the workplace, comfortable temperatures and lighting, air quality in buildings, occupational health and safety, and rest areas for rehabilitation from work fatigue. However, with every country aiming for higher GDP targets annually (PWC, 2017), leading to increased urbanization and people spending over 90% of their time indoors each day (Ritchie and Roser, 2018), it becomes imperative to improve building environments. From statistics, it's evident that disease prevalence and mortality rates were significantly higher among individuals aged over 60 compared to other age groups (Strategy and Planning Division, Ministry of Public Health Official statistics, 2020). The leading causes of illness, from highest to lowest disease prevalence were cancer and tumors, circulatory system diseases, nervous system diseases, respiratory system diseases, and less common diseases such as falls and drowning, skin and subcutaneous tissue diseases, and musculoskeletal and connective tissue diseases, respectively (Figure 3).

Therefore, preparing the workplace environment for the elderly should focus on preventing and reducing the prevalence of these diseases, starting from design control, construction, monitoring during building operation, legal compliance, and various preventive measures and practices according to standards that mitigated environmental factors directly influencing disease prevalence, enabling elderly workers to work collaboratively with others in a healthy manner.

3.2 Standards and laws for promoting Well-Being in buildings

From the SDGs and the 20-year National Strategy of Thailand (BE 2561-2580) there is a support to extend the working age and provide more opportunities for the elderly to work longer to cope with the labor shortage during the era of complete aging society. In this regard, both laws and building design standards and



Source: Strategy and Planning Division Ministry of Public Health. Official statistics 2020

Figure 3. Disease prevalence statistics among individuals over 60 years old

maintenance practices to promote well-being are enforced. For instance, according to the Ministry of Interior (2021) regulations of the facility of building for disabled or deformed and aged persons specified requirements for signs, characteristics, dimensions of ramps, and suitable lifts. Handrails, lift sizes, and lifts installation were mandated for buildings with two or more floors. The regulations also detailed the characteristics of staircases, parking spaces in appropriate proportions, along with pathways beside parking lots. Restrooms for the elderly were required to have at least one room per service point. Doors were to be sliding or have an opening angle of more than 90 degrees. Suitable sizes and positions of toilet bowls were specified, along with the installation of light and sound signaling systems to alert users outside in case of emergencies. Additionally, the Ministry of Social Development and Human Security (2017) established roles and responsibilities for stakeholders concerning the elderly, ensuring their protection, promoting and supporting various services, including suitable occupational activities and facilities and safety for the elderly within the building premises and other public service areas. The Ministry of Labor (2015) issued standards of management and operations on safety, occupation, and workplace environment regarding heat, light, and noise as to which light is suitable for each activity type without glare or direct sunlight. Temperature for light work conditions should not exceed an average temperature of 34 degrees Celsius or moderate work at 32 degrees Celsius and 30 degrees Celsius for heavy work. Sound with peak sound pressure levels for impact or impulse noise must be less than 140 dBA and for continuous steady noise less than 115 dBA. The Time Weighted Average (TWA) must not exceed the standards.

The Well-Being Building standard used both domestically and internationally was designed to ensure accessibility and mutual benefits for everyone through Universal Design principles. Thailand Green Building Institute (2021) issued The Sook Building Standard emphasizing Biophilia, Neighborhood and Architectural Design, Interior Design to prevent various pollutants such as volatile organic compounds (VOCs), and Environmental System & Engineering design for indoor air quality and supporting well-being innovation. Another standard aimed at well-being was fitwel (2022), a standard from the United States of America, focusing on building wellness for everyone to improve health and well-being of building users and surrounding communities through expert analysis, research, and standards suitable for each building usage type, such as fitwel Senior Housing or Multi-Tenant-Based Building. It emphasized the importance of building location, connectivity to mass transportation systems, passenger drop-off and pick-up points, bicycle parking, building accessibility, safe walkways, and employee shower facilities. Outdoor recreational spaces were equipped with central amenities such as directional signs, gardens, vegetable and fruit gardens, appropriate lighting systems, meditation rooms, breastfeeding rooms, rest areas, adjustable windows, inclusive bathroom designs, dining areas, including gym facilities, promoting natural light, and providing natural views from work areas. The emphasis was on promoting non-smoking policies, mitigating heat accumulation impacts such as planting trees, reducing paved areas, planting grass, conducting indoor air quality tests, and sharing information with employees, while avoiding the use of asbestos or lead-containing materials, and separating general ventilation systems from chemical storage rooms. Policies include sourcing and using environmentally friendly materials, integrated pest and weed management. The management was for both internal and external sources of noise within the building, as well as cleaning workspaces, operations, and building resource management. It also involved providing employees access to various health support programs, communication plans, conducting regular satisfaction assessments, providing water and food access, along with preparing plans and training personnel to handle emergency situations.

In addition to fitwel, the International WELL Building Institute (2022) WELL Building Standard was used worldwide for human health and well-being of both buildings and communities. It established good practices, measurements, and monitoring by using four principles of equities for diverse and disadvantaged or vulnerable people. This was based on proven standards and academic research from experts, literature reviews, design standards, laws, and continuous data updates, reviewed by third parties through document inspections, field performance testing, or recommendations from global practitioners. The emphasis was on eleven aspects including air quality, thermal comfort, noise, lighting, water, food, movement, materials, mind, and community. Health and innovation that promote health and environment were encouraged.

Additionally, there were standards that focused on health by controlling indoor air quality and efficient use of energy, such as the building standard from Japan Sustainable Building Consortium and the Institute for Building Environment and Energy Conservation (2014) CASBEE standard. They aimed at energy efficiency, resource usage, environmental aspects both inside and outside the building. It included a formula for calculating the Building Environment Efficiency Index (BEE). Also the U.S. Green Building Council (2022) LEED standard focused on energy efficiency and standards for materials and indoor air quality. Moreover, German Sustainable Building Council (2022) DGNB focused on environment, economics, society and Indoor comfort, satisfaction and easy movement of building users. Lastly, BRE (2020) BREEAM standard, with BREEAM In-Use International SD6063 - V6.0.0 was used internationally to evaluate and promote sustainability, energy, economy, society, and the built environment with innovative regulations and good practices with continuous efficiency improvement.

3.3 Disease prevalence and environment factors

Laws and standards had different requirements and assigned different importance weight factors. Specifically, WELL and fitwel standards emphasized more on the environmental aspect of buildings, building asset management, shared workspace, building access, and access to nutritious food. Bowornkitti and Loftus (1996) found that temperature and humidity influenced indoor air quality. Humidity above 70% promoted the growth of small organisms. Humidity below 20% could lead to skin dryness, irritation, and respiratory issues. Temperature affected the perception of indoor air quality, with a thermal comfort ranging between 20 - 26 degrees Celsius. Ritwichai (2014) mentioned several factors contributing to workplace stress from the physical environment. Inadequate or excessive lighting caused eye strain. Loud noises disturbed work. This led to a lack of concentration and ineffective communication. Extreme temperatures affected work productivity. Tähtinen et al. (2020) summarized health problems arising from indoor air quality and workplace environment, including discomfort from temperature, colds, dry or humid air, dry throat, headaches, eye and nasal irritation, fatigue, coughing, skin irritation, dust and unpleasant odors. Furthermore, Yoosuk (2009) summarized the safety of physical and chemical environmental factors such as volatile organic compounds, which could be toxic to the central nervous system and potentially fatal. Fine particulate matter $PM_{2.5}$ could cause lung inflammation, pulmonary impairment, and increase the risk of cancer or allergies. National Cancer Institute (2021) identified factors contributing to cancer, including consuming carcinogenic foods, exposure to ultraviolet radiation from sunlight, viruses, smoking, contact with chemicals, or toxins from mold exposure, contact with carcinogens, asbestos, or radiation, and smoke particles. Thupiro (2015) summarized details about disease prevalence related to high blood pressure from cholesterol, stress, lack of exercise, or circulatory system disease, diabetes, high blood sugar which caused blood vessels to be fragile and led to easy breakage. Neurological diseases could be caused by mosquito-borne viruses or fungal infections, virus infections from the environment, accidents, falls, excessive fat intake, or accumulation of free radicals. Respiratory diseases, could be caused by allergies to some substances such as molds, dust, virus infections, colds, dust mites, cigarette smoke, air pollutants, or environmental temperature changes. Reproductive and urinary tract diseases could be caused by bacterial infections, liver diseases from smoking, fatty foods, or food or water contaminated with viruses. Skin and subcutaneous tissue diseases were caused by excessive heat or humidity. Digestive system diseases arose from chronic irritation in the esophagus from hot drinks or smoking, consuming strongly flavored or toxic foods, and physical and mental stress. Musculoskeletal diseases were caused by accidents or repetitive movements such as prolonged sitting or standing, unnatural postures, or excessive exertion, stress, inadequate nutrition, protein deficiency, high vitamin and calcium intake, or by viral or bacterial infections. Therefore, environmental factors such as physical building conditions and indoor air quality could contribute to disease occurrence, and if one type of disease occurred, there was a risk of other types of diseases.

Thus, based on opinions from qualified individuals and experts regarding the relationship between disease and environmental factors in buildings, the results from the AHP analysis, from the perspective of public health experts regarding the importance level of disease causes, were shown in Table 1. It was observed that VOC, $PM_{2.5}$, and CO_2 had a significant effect on cancer and tumors, circulatory system, respiratory system, pulmonary edema, and nervous system. Temperature had a significant effect on infections and parasites, skin and subcutaneous tissue. Humidity had a significant effect on pulmonary edema including infections and parasites, while UV light had a significant effect on skin, subcutaneous tissue, cancer and tumors. Food and water were significant factors for the reproductive and urinary tract system, digestive system, and liver disease. Other physical factors such as light, stairs and slopes, restrooms, and transportation had impact on accidents and falls.

The relation to environmental factors of buildings with diseases as shown in Table 1 corresponded to the disease prevalence statistics in 2020, which included cancer and tumors, circulatory system diseases, nervous system diseases, and respiratory system diseases, collectively accounted for up to 63.99%. The main causes of these diseases could be indoor air conditions such as temperature, humidity, volatile organic compounds, and particulate matter, often found in workplaces. Additionally physical environmental conditions included indoor and outdoor pathways, slopes, handrails, stairs, facilities and clean water as well as nutritious food. Therefore, effective preventive measures against diseases required controlling the main causes leading to high disease prevalence and establishing continuous monitoring of the building environment.

3.4 Development of the healthy senior workplace index

The AHP analysis weighted the importance of environmental building variables that were major causes of disease prevalence as shown in Table 2. This information was used to create a linear regression model as demonstrated in Equation 1, resulting in the Healthy Senior Workplace Index with a maximum score of 110%. The index included fifteen environmental factors in the workplace that contributed to high disease prevalence and an additional 10% for an emergency plan. These factors were later used to create assessment guidelines for building environments for elderly workers (for buildings in operation), aiming to evaluate workplace environments and calculate a building health index level.

3.5 Development of assessment form and the utilization of IoT technology

This research developed an assessment form for evaluating the building environment and components for the elderly (for buildings during operation), covering factors that contribute to diseases, such as sound, lighting quality, $PM_{2.5}$, indoor humidity, temperatures, volatile organic compounds, CO_2, natural light, UV light, stairs and ramps, doors, fire escapes, elevators, buttons, bathrooms, food and water access, outdoor areas, shared spaces, transportation and parking areas including emergency plans. The form specified requirements and threshold values with the reference to the WELL standard.

The assessment scores were multiplied by the percent weight of importance of each factor, obtained from AHP analysis as shown in Table 2. The assessment utilized IoT to measure CO_2, $PM_{2.5}$, temperature, humidity, and formaldehyde online. Most physical environmental conditions remained unchanged after construction unless there were building modifications or damages such as to staircases, handrails, elevators, or ramps. With the full assessment form, it was able to create a quick assessment form aimed at reducing the prevalence of statistically high diseases.

Table 1. Level of significance of environmental factors in office buildings influencing the prevalence of diseases in the elderly

Environmental factors in office buildings influencing the prevalence of elderly diseases	Cancer and tumors	Circulatory system	Nervous system	Respiratory system	Reproductive and urinary tract system	Pulmonary edema	Infections and parasites	Digestive system	Liver disease	Transportation accidents	Skin and subcutaneous tissue	Falls and drowning	Musculoskeletal and connective tissue	priority
Elderly disease occurrence rate 2020	19.6%	15.7%	14.6%	14.1%	11.8%	7.5%	6.8%	5.0%	1.3%	1.1%	0.7%	0.7%	0.6%	
Weight of disease prevalence factors in elderly	24.1%	20.0%	21.2%	15.1%	11.0%	12.4%	16.5%	13.1%	12.2%	13.0%	10.8%	10.3%	12.9%	
1. Sound	2.3%	5.6%	9.6%	2.7%	2.8%	1.5%	1.6%	6.0%	3.8%	5.4%	2.4%	3.8%	2.3%	4.0%
2. Light	7.0%	5.6%	7.8%	2.0%	2.8%	1.5%	1.6%	5.1%	3.8%	9.3%	9.7%	10.7%	3.9%	5.5%
3. PM2.5	10.1%	9.8%	9.6%	16.7%	2.8%	12.2%	4.1%	5.1%	5.1%	8.5%	9.7%	3.8%	2.3%	8.1%
4. Humidity	2.3%	3.5%	3.6%	8.0%	5.6%	11.4%	11.4%	6.0%	8.9%	3.9%	9.7%	5.7%	3.1%	6.0%
5. Temperature	4.7%	9.1%	8.4%	7.3%	7.5%	9.9%	12.2%	10.3%	10.2%	4.7%	12.2%	5.7%	6.3%	8.2%
6. VOC	16.3%	12.6%	10.2%	14.7%	5.6%	13.7%	4.1%	6.9%	10.2%	6.2%	8.1%	4.4%	6.3%	9.8%
7. CO2	12.4%	14.0%	10.8%	14.7%	6.5%	13.7%	3.2%	6.9%	6.4%	9.3%	8.1%	5.0%	4.7%	9.4%
8. UV	9.3%	4.9%	4.8%	2.7%	3.7%	2.3%	3.2%	2.6%	2.5%	6.2%	11.4%	4.4%	6.3%	5.1%
9. Stair and Slope	6.7%	2.8%	3.0%	2.0%	6.7%	6.7%	6.7%	6.7%	6.7%	12.4%	6.7%	13.2%	14.1%	6.7%
10. Rest Room	6.7%	6.7%	6.7%	2.0%	14.0%	6.7%	9.7%	2.6%	6.7%	3.1%	0.8%	12.6%	8.6%	6.6%
11. Access to Food	6.2%	4.9%	3.6%	2.0%	4.7%	1.5%	8.1%	12.8%	14.0%	1.6%	1.6%	2.5%	7.8%	5.5%
12. Outdoor space	0.8%	2.1%	3.6%	5.3%	2.8%	3.8%	4.9%	5.1%	3.8%	7.0%	2.4%	10.1%	7.8%	4.2%
13. Working space, common area	6.7%	2.8%	5.4%	8.7%	5.6%	7.6%	8.9%	3.4%	2.5%	6.2%	1.6%	6.9%	7.8%	5.8%
14. Water	3.1%	7.7%	4.8%	4.7%	18.7%	2.3%	13.0%	14.6%	12.7%	0.8%	8.9%	3.1%	7.0%	7.4%
15. Transportation to work	5.4%	7.7%	8.4%	6.7%	10.3%	5.3%	7.3%	6.0%	2.5%	15.5%	6.5%	8.2%	11.7%	7.7%

Degree of relationship

Table 2. Summary of percent weight of each variable

Environment Factors	Variable	% weight of variables	
1. Sound	X_1	β_1	4.04%
2. Light	X_2	β_2	5.46%
3. PM2.5	X_3	β_3	8.09%
4. Humidity	X_4	β_4	6.00%
5. Temperature	X_5	β_5	8.20%
6. VOC	X_6	β_6	9.81%
7. CO2	X_7	β_7	9.42%
8. UV	X_8	β_8	5.10%
9. Stair and Slope	X_9	β_9	6.73%
10. Rest Room	X_{10}	β_{10}	6.58%
11. Access to Food	X_{11}	β_{11}	5.51%
12. Outdoor space	X_{12}	β_{12}	4.21%
13. Working space, common area	X_{13}	β_{13}	5.77%
14. Water	X_{14}	β_{14}	7.40%
15. Transportation to work	X_{15}	β_{15}	7.68%

The trial of the workplace assessment used the forms and model equation 1 to evaluate the workplace environment at the university. The results showed the sound and light quality within standard parameters. $PM_{2.5}$ ranged from 15-21 µg/m³, exceeding the standard of 15 µg/m³. The comfortable temperature ranged from 24 - 25 ⁰C, meeting the standard of 21-25 ⁰C. The indoor humidity levels were between 48 - 57%, meeting the standard of 30 - 60%. TVOC levels were within the standard limit of 500 µg/m3, but formaldehyde (HCHO) levels ranged from 53 - 60 µg/m³, slightly exceeding the standard of 50 µg/m³. CO_2 levels met the standard of 900 ppm. Most areas lacked natural light or outdoor views. Ramps and handrails were not compliant. The lift buttons were not appropriately positioned for elderly individuals, and there were no tactile indicators before and after the step area. The restroom sizes were not suitable for the elderly, and there were no handrails near restroom fixtures. Emergency plans for elderly illness or assistance were not prepared. There were inadequate parking spaces. The building provided sufficient drinking water and amenities. This assessment revealed a Healthy Senior Workplace Index of 63.9%. A very low score indicated the need for improvement in $PM_{2.5}$, HCHO, natural light, ramps, restrooms, parking availability, and emergency preparedness plans for the elderly.

To test whether the use of the quick assessment form in conjunction with IoT could be effectively utilized by building users, the assessment from a sample of 27 out of 32 people was analyzed. Pearson's Chi-squared test revealed a p-value of 0.08, leading to the rejection of the null hypothesis. It was concluded that the quick assessment form and the full assessment form provided results that were not significantly different at a 95% confidence level (p-value > 0.05). Similarly, the One Sample t-test indicated that both assessment forms had p-values greater than 0.05, so the null hypothesis could not be rejected. This suggested that the median of the sample group was not significantly different from the target value at a 95% confidence level. However, when analyzing the Box plot to compare the independent variable, RU Healthy Senior Workplace Index, it was found that the quick assessment form used by building users had less variation compared to the full assessment form.

4. Conclusion

The Fitwel, WELL, and SOOK Building Standards cover more dimensions than others, emphasizing biophilia, neighborhood, and architectural design to support indoor air quality and well-being innovation. Ministerial regulations set standards for building accessibility for persons with disabilities, including the elderly, and govern management, operations, safety, occupational health, and environmental conditions. Despite these policies, laws, and standards, disease prevalence statistics for 2020 showed that individuals aged over 60 remained highly affected, with over 60.99% suffering from various diseases. The prevalence of these diseases was attributed to environmental factors in buildings, particularly temperature, VOCs, $PM_{2.5}$, CO_2, humidity, UV light, food, and water. Other physical environmental factors, such as light, stairs and slopes, restrooms, and transportation contributed to accidents like falls, though their impact was less significant.

Fifteen weighted environmental factors associated with high disease prevalence were used to create a linear regression model, resulting in the Healthy Senior Workplace Index with a maximum score of 110%, plus an additional 10% for an emergency plan. These factors informed the creation of assessment guidelines for building environments for elderly workers (for buildings in operation). The quick assessment form, utilized with online IoT measurements, was found to be effective for building users.

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