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# Exploration of Healthcare Sensitive Systems and Services for Supporting Ambient Assisted Living of Diversified Social Groups in South Korea

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**Abstract**
Different social groups normally have specific sets of requirements and priorities in relation to their surrounding living environment. In our research, we conducted an extensive survey on the preferred conditions and demands for four different domains of daily life: healthcare, environment, activity, and information. Carefully composed sets of questionnaires were distributed to 800 people representing diversified social groups in South Korea classified by gender, age, occupation, co-residents, home location, housing style, economic level, and chronic disease. Their responses were collected and analyzed through cross-tabulation to identify characteristic preference patterns concerning their immediate housing unit, residential cluster, and close neighborhood environment and services. Based on the extracted socio-environmental preferences of the different social groups in South Korea, we developed a web-based information system called AALPSS (Ambient Assisted Living Pattern Support System), which includes a total of 100 selected healthcare-sensitive system/service patterns to support the optimum design and operation of artifacts and facilitate the promotion of a healthy silver life. Each pattern is organized based on Christopher Alexander's 'Pattern Language' format and can be browsed and rated by different online users with diverse social profiles. This information system, therefore, has the potential to evolve into a better-tuned healthcare-related system/service decision support system, enhancing social sustainability within a community.

*Keywords: social group, ambient assisted living, preferred life pattern, healthcare sensitive environment, online information system*

## 1. Introduction

In the context of extended life expectancy and the escalating need for elderly healthcare practices, Majumder et al. (2017) claimed the necessity of exploring affordable, pervasive, and simple-to-use healthcare solutions. They indicated that smart homes equipped with environmental and wearable transducers connected with high-speed communication and ICT infrastructure would support real-time or quasi-real-time remote monitoring of elderly health and wellbeing conditions. Therefore, smart homes could enable healthcare-sensitive seniors to stay at home rather than at costly medical facilities. This research focuses on the development of a web-based interactive decision support system for designing personalized healthcare-sensitive systems and services.

Life-long healthcare trend has led to the development of systems and applications that support Ambient Assisted Living (AAL). AAL primarily targets technology-supported independent living at home, especially for those who need special care. Stodczyk et al. (2020) found that the common AAL applications are related to smart homes, transducers,

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and robots, while the major user group of these applications is seniors who showed a positive opinion over AAL but criticized their cost and inability to participate in the development process. AAL is conceptually related to another ideation, namely 'Aging in Place'. It was pointed out that aging in place is influenced by dynamically changing life-course conditions as well as the neighborhood environments over time, so delicate attention would need to be paid to the changing dynamics of the physical environment where people age (Lewis and Buffel, 2020). Ahn et al. (2017) claimed that overall well-being would be the sum of those distinctive domains such as psychological, financial, and environmental well-being. Especially, environmental gerontology emphasizes that certain environmental features, namely universal design and related services, have been recognized as critical.

Different social groups pose diversified health and safety-related needs and requirements in general. For instance, the demographic trend of a rapidly aging population, which requires more coordinated care based on potential consumer preferences, was addressed in the "Future of Home Health project." This project aimed to support the transformation of home-based healthcare to consider the patients' demands, targeting the U.S. healthcare system (Landers et al., 2016).

Ambient Assisted Living (AAL) aims not only to improve the convenience of elderly people's daily living environments but also to promote their health and active lifestyles. To achieve these goals, AAL requires spatial and instrumental enablers that are intelligently customized to specific user profiles. This paper presents an online healthcare-sensitive smart home design recommendation system that provides personalized spatial and instrumental patterns for a specific group of users.

This study was conducted using surveys in South Korea and expert interviews to identify 100 critical AAL-related smart home design patterns, which are presented to the users through an online interface. Users are asked to provide personal information such as gender, age, education, economic level, and location/housing type for living. This information is then used to identify the users' preferences and requirements for AAL patterns through a deep learning process. The development of an online AAL Pattern Support System (AALPSS) aims to disseminate AAL-promoting patterns and collect user responses and preferences to provide customized AAL-oriented smart home design solutions.

## 2. Methodology

### 2.1. Survey on Personalized Healthcare Demands

There have been diversified studies emphasizing the analysis of social needs for better healthcare practices. Kreuter et al. (2021) investigated the relationships between social needs and their impact on health improvement, utilization levels, as well as the costs of healthcare services and systems. They also stressed the criticality of reshaping resource allocation to address varied social determinants of health. Understanding the needs and preferences of different social groups regarding healthcare-related systems and services is a critical matter in providing socially sustainable healthcare practices.

In this context, our study began with the elicitation of AAL-supported smart home design requirements based on literature review, expert opinion collection, and surveys. A questionnaire survey was conducted in November 2019 with 852(448 men and 404 women) people aged from 30s, 40s, 50s and 60s or over, asking for their personal profiles, including gender, age, education, economic status, housing type, living location, co-residents and chronic illness to identify their preferred AAL service types. The subjects were given 100 candidate systems/services potentially inclusive to AAL sensitive smart home designs to rate based on a 5-point scale (1 as no preference and 5 as the strongest preference). The rated weights were then averaged and further processed to yield an overall preference score for each AAL promoting smart home service through a cross-tabulation process. The pre-pandemic era survey outcomes may not fully represent the most recent trends in healthcare sensitive smart home design, and yet identified personal profile dependent preferences found in the study could claim their validity since the focus was placed onto indoor healthcare systems and services which have been effective even throughout the pandemic period.

Among the defined AAL core services, it could be seen that the most preferred pattern was the inter-floor noise blocking with the highest score. In addition, fire/gas leak detection and eco-friendly finishing materials were selected as the second and third priorities, respectively. Identified top 10 priority core AAL services were inter-floor noise blocking, automatic electricity cut-off, and final inspection support when going out, automatic gas shut-off, overcurrent detection, fire/gas leak detection, eco-friendly finishing materials, indoor air cleaning, intrusion prevention and emergency response.

Across all ages and genders, it could be seen that most users have a high interest in safety and indoor environmental conditions especially for the residents living in apartment houses. Both men and women tend to place importance on the environmental requirements for safety and indoor air quality. In particular, women tend to emphasize intrusion prevention, emergency response, and kitchen ventilation. For the people in their 30s, preventing inter-floor noise is the most important demand. They show a preference for high-tech products such as self-cleaning robots or automatic cleaning system. Seniors aged 60 and over value eco-friendly finishing materials the most. While the demand for inter-floor noise prevention is relatively weak, emergency response, indoor air cleaning and smart ventilation are also kept noted.

The group with higher economic status preferred preventing inter-floor noise, eco-friendly materials and showed interest in safety requirements such as shutting off electricity/gas, preventing fire and personal health management services such as heart rate monitoring and personal abnormalities prediction. In the meantime, lower economic status group expressed priorities for the safety requirements such as electricity/gas shut-off, fire/intrusion prevention while showing a relatively weak demand for inter-floor noise prevention, eco-friendly finishing materials.

Residential groups in multi-unit dwellings such as apartments, prioritized preventing inter-floor noise blocking, indoor air cleaning, eco-friendly finishing materials, and indoor/outdoor air quality detection. As for the group living in detached houses, it turned out that inter-floor noise blocking was unnecessary due to their house structure. Instead, they showed high interest in indoor environment and energy management such as indoor air purification, waste heat recovery ventilation, smart ventilation, smart air conditioner, and smart air conditioning.

In the case of the people living alone, they expressed interest in requirements coupled with their situation of living alone, namely stress level measurement, living guide against chronic disease, and barrier-free space. On the other hand, the group living with a spouse generally showed similar preference profiles to those of living alone, but they expressed interest in heart rate monitoring, prediction of individual abnormal symptoms as well as inducement of comfortable sleep. This group showed a relatively low preference over the most of various home health care systems and services, which implies that they do not have economic afford, therefore are not interested in the systems or services that are not essential to life.

In the meantime, Reynolds et al. (2018) claimed that self-management support is the most common chronic care model element that is linked to statistically meaningful improvements, especially for diabetes and hypertension. In response to unavoidable leaking points of modern medical practices for chronically ill patients, Wagner et al. (1996) also suggested effective interventions including improved patient self-management and increased accessibility to expertise as well as clinical information in addition to evidence-oriented, carefully planned care and restructuring of chronic illness care systems. Both of these two precedent studies emphasized the importance of self-management for the populations having chronic illnesses.

In our investigation, among those with chronic diseases, Asthmatic group showed a preference for maintaining indoor air quality and managing chronic diseases such as eco-friendly finishing materials, smart air conditioning, lifestyle guides against chronic disease and smart ventilation systems. On the other hand, the Parkinson patient group expressed preference for the systems that compensate physical activity limitations such as height-adjustable sinks, countertops and sinks. In the case of hypertension and diabetes, which are also representative chronic diseases, diabetic patients showed a higher interest in nutritional status checks or diet management than hypertensive patients and were more interested in overall health care support type smart home systems or services. Patients with cerebrovascular disease showed high interest in emergency notification and chronic disease management.

**Table 1:** Male AAL service preference (left) and female AAL service preference (right)

| Order | Sector | Demanded AAL Service | Score (1-5) | Order | Sector | Demanded AAL Service | Score (1-5) |
|---|---|---|---|---|---|---|---|
| 1 | E6 | Inter-floor noise blocking | 4.43 | 1 | E6 | Inter-floor noise blocking | 4.39 |
| 2 | A18 | Auto-electrical shut-off | 4.25 | 2 | A18 | Auto-electrical shut-off | 4.34 |
| 3 | A25 | Outing final inspection | 4.25 | 3 | A25 | Outing final inspection | 4.34 |
| 4 | A28 | Automatic gas shut-off | 4.25 | 4 | A28 | Automatic gas shut-off | 4.34 |
| 5 | E15 | Overcurrent detection | 4.25 | 5 | E15 | Overcurrent detection | 4.34 |
| 6 | E16 | Fire/gas leak detection | 4.25 | 6 | E16 | Fire/gas leak detection | 4.34 |
| 7 | E8 | Eco-finishing materials | 4.21 | 7 | E22 | Indoor air cleaning | 4.33 |
| 8 | E12 | Smart air conditioning | 4.17 | 8 | E8 | Eco-finishing materials | 4.29 |
| 9 | E5 | Smart heating/cooling | 4.17 | 9 | E20 | Intrusion prevention | 4.29 |
| 10 | H6 | Emergency response | 4.16 | 10 | E1 | Smart ventilation | 4.26 |
| 11 | E22 | Indoor air cleaning | 4.15 | 11 | E14 | Heat recovery ventilation | 4.26 |
| 12 | E20 | Intrusion prevention | 4.15 | 12 | E2 | Air quality monitoring | 4.22 |
| 13 | E1 | Smart ventilation | 4.10 | 13 | H6 | Emergency response | 4.21 |
| 14 | E14 | Heat recovery ventilation | 4.10 | 14 | E23 | Smart home anti-hacking | 4.21 |
| 15 | E2 | Air quality monitoring | 4.10 | 15 | E26 | Smart kitchen ventilation | 4.21 |
| 16 | E23 | Smart home anti-hacking | 4.10 | 16 | E27 | Smart bathroom ventilation | 4.21 |
| 17 | E13 | Self-cleaning robot | 4.05 | 17 | E13 | Self-cleaning robot | 4.20 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 18 | E3 | Automatic cleaning | 4.05 | 18 | E3 | Automatic cleaning | 4.20 |
| 19 | E17 | Smart humidity control | 4.04 | 19 | E18 | EMF Blocking | 4.20 |
| 20 | H11 | Heart rate monitoring | 4.04 | 20 | E12 | Smart air conditioning | 4.19 |

**Table 2:** AAL service preference in the 30s (left) and AAL service preference in the 60s or older (right)

| Order | Sector | Demanded AAL Service | Score (1-5) | Order | Sector | Demanded AAL Service | Score (1-5) |
|---|---|---|---|---|---|---|---|
| 1 | E6 | Inter-floor noise blocking | 4.47 | 1 | E8 | Eco-finishing materials | 4.24 |
| 2 | A18 | Auto-electrical shut-off | 4.32 | 2 | A18 | Auto-electrical shut-off | 4.22 |
| 3 | A25 | Outing final inspection | 4.32 | 3 | A25 | Outing final inspection | 4.22 |
| 4 | A28 | Automatic gas shut-off | 4.32 | 4 | A28 | Automatic gas shut-off | 4.22 |
| 5 | E15 | Overcurrent detection | 4.32 | 5 | E15 | Overcurrent detection | 4.22 |
| 6 | E16 | Fire/gas leak detection | 4.32 | 6 | E16 | Fire/gas leak detection | 4.22 |
| 7 | E20 | Intrusion prevention | 4.32 | 7 | E6 | Inter-floor noise blocking | 4.21 |
| 8 | E23 | Smart home anti-hacking | 4.32 | 8 | E22 | Indoor air cleaning | 4.13 |
| 9 | E13 | Self-cleaning robot | 4.32 | 9 | H6 | Emergency response | 4.13 |
| 10 | E3 | Automatic cleaning | 4.32 | 10 | E1 | Smart ventilation | 4.11 |
| 11 | E22 | Indoor air cleaning | 4.30 | 11 | E14 | Heat recovery ventilation | 4.11 |
| 12 | E8 | Eco-finishing materials | 4.26 | 12 | E26 | Smart kitchen ventilation | 4.09 |
| 13 | E12 | Smart air conditioning | 4.26 | 13 | E27 | Smart bath ventilation | 4.09 |
| 14 | E5 | Smart heating/cooling | 4.26 | 14 | E20 | Intrusion prevention | 4.05 |
| 15 | E1 | Smart ventilation | 4.23 | 15 | E12 | Smart air conditioning | 4.01 |
| 16 | E14 | Heat recovery ventilation | 4.23 | 16 | E5 | Smart heating/cooling | 4.01 |
| 17 | E2 | Air quality monitoring | 4.21 | 17 | E23 | Smart home anti-hacking | 4.00 |
| 18 | E26 | Smart kitchen ventilation | 4.20 | 18 | E2 | Air quality monitoring | 4.00 |
| 19 | E27 | Smart bath ventilation | 4.20 | 19 | H11 | Heart rate monitoring | 3.97 |
| 20 | E17 | Smart humidity control | 4.19 | 20 | H20 | Personal anomaly prediction | 3.97 |

**Table 3:** AAL service preference (Asthma) (left) and AAL service preference (Parkinson) (right)

| Order | Sector | Demanded AAL Service | Score (1-5) | Order | Sector | Demanded AAL Service | Score (1-5) |
|---|---|---|---|---|---|---|---|
| 1 | E6 | Inter-floor noise blocking | 4.53 | 1 | E6 | Inter-floor noise blocking | 4.33 |
| 2 | E8 | Eco-finishing materials | 4.47 | 2 | A11 | Height adjustable washbasin | 4.33 |
| 3 | E12 | Smart air conditioning | 4.41 | 3 | A10 | Height adjustable countertop | 4.33 |
| 4 | E5 | Smart heating/cooling | 4.41 | 4 | A22 | Height adjustable sink | 4.33 |
| 5 | E20 | Intrusion prevention | 4.34 | 5 | E22 | Indoor air cleaning | 4.00 |
| 6 | A18 | Auto-electrical shut-off | 4.31 | 6 | E20 | Intrusion prevention | 4.00 |
| 7 | A25 | Outing final inspection | 4.31 | 7 | E8 | Eco-finishing materials | 4.00 |
| 8 | A28 | Automatic gas shut-off | 4.31 | 8 | E1 | Smart ventilation | 4.00 |
| 9 | E15 | Overcurrent detection | 4.31 | 9 | E14 | Heat recovery ventilation | 4.00 |
| 10 | E16 | Fire/gas leak detection | 4.31 | 10 | E18 | EMF blocking | 4.00 |
| 11 | H14 | Heat recovery ventilation | 4.25 | 11 | H11 | Heart rate monitoring | 4.00 |
| 12 | H8 | Guide for chronic disease | 4.25 | 12 | H20 | Personal anomaly prediction | 4.00 |
| 13 | E1 | Smart ventilation | 4.22 | 13 | A1 | Smart bed | 4.00 |
| 14 | E14 | Heat recovery ventilation | 4.22 | 14 | A12 | Biometric door | 4.00 |
| 15 | H12 | Self-health check toolbox | 4.22 | 15 | A27 | Smart door | 4.00 |
| 16 | H3 | Health monitoring | 4.22 | 16 | A15 | Smart TV | 4.00 |
| 17 | H18 | Comfortable sleep induction | 4.22 | 17 | H14 | Stress level measurement | 4.00 |
| 18 | E23 | Smart home anti-hacking | 4.19 | 18 | H8 | Guide for chronic disease | 4.00 |
| 19 | E17 | Smart humidity control | 4.19 | 19 | H12 | Self-health check toolbox | 4.00 |
| 20 | H19 | Customized healthcare guide | 4.19 | 20 | H3 | Health monitoring | 4.00 |

## 2.2. Establishment of Healthcare Sensitive Smart Home Patterns

According to Alexander et al. (1977), a pattern is supported by drawings, images, and other graphic elements and it describes adequate ways for identifying feasible, safe, and preferable designs at every scale, from entire regions all the way down to the level of doorknobs. Each pattern denotes best potential solution as to how the physical environment could be configured to solve the given problem. Grouping these patterns constitutes a sort of language, called pattern language.

Bennett et al. (2017) emphasized the role of the smart home for monitoring residents' health conditions and providing necessary interventions. They argued that smart home technologies could enhance conventional healthcare delivery system or completely replace it, resulting cost reduction and increased medical adherence. In the meantime, Kelly et al. (2020) pointed out IoT's potential benefits of facilitating and improving health care delivery services towards a preventive mode covering remote diagnose, treatment, and monitoring of patients regardless of their locations. They argued that IoT-based health care supports preventative public health services while improving health system efficiency and promoting population health.

Based on the surveyed preferred healthcare sensitive smart home services characterized by different social groups representing their prioritized personal demands, we constructed total 100 AAL supporting smart home design patterns classified into 4 categories, namely Health, Environment, Activity and Information, strictly described by Christopher Alexander's 'Pattern' framework. Examples of such patterns are as follows:

| Category | AAL Support Patterns |
|---|---|
| **Health (H5)**<br>**Pattern Name**: Activity Monitoring System<br><br> | **Background**: Efficient disease treatment is possible and additional complications are prevented by improvement<br>**Problem**: The high likelihood of forgetting the date, time, and number of medications to be taken makes prompt disease treatment impossible.<br>**Solution**: The smart medicine box provides information about the date and time for medicine intake through LEDs or sounds. The remaining amount of medicine is measured using a precise weight sensor. The issue of overdose is resolved by displaying real-time dosage information.<br>**Related patterns**: Remote Health Consultation System, Realistic Indoor Exercise Equipment, Living Guide System for Chronic Illness |
| **Health (H6)**<br>**Pattern Name**: Emergency Response System<br> | **Background**: The need for social awareness and supporting measures for the safety and life-saving of the elderly living alone is becoming critical.<br>**Problem**: In the case of the elderly living alone in their own residences, they often lose their lives due to a lack of timely detection, resulting in a failure to provide necessary measures when emergencies such as a sudden worsening of depression, falls, or cardiac arrests occur.<br>**Solution**: By implementing delicate activity detection systems, including fire detection, activity detection, fall detection, and gas detection, the healthy daily lives of the elderly living alone can be effectively monitored. In the case of an emergency, an intelligent emergency response system would promptly identify the situation and initiate the necessary measures.<br>**Related patterns**: Activity Monitoring System, Fall Detection Floor, Indoor/Outdoor Location Detection System, Home Device Control Interface |

*Figure 1: Examples of AAL support patterns*

Built upon the performed survey on the diverse social group-specific preferences over 100 AAL promoting spatial and instrument patterns, an extensively informative and interactive Web-based system is designed. The designed system aims at recommending customized AAL sensitive smart home design solutions for different population groups.
Table 4 shows the most preferred basic and critical patterns.

**Table 4:** AAL support patterns

| Category | Pattern Names | |
|---|---|---|
| Health<br>(H Sector) | Living Guide System for Chronic Illness<br>Emergency Response System<br>Smart Toilet Bowl<br>Fall Detection Floor<br>Medication Management System<br>Drinking Water Quality Management System | Remote Health Counseling System<br>Health Monitoring System<br>Activity Monitoring System<br>Nutritional Status Monitoring<br>Diet Management System<br>Realistic Indoor Fitness Equipment<br>Smart outdoor fitness equipment |
| Environment<br>(E Sector) | Barrier Free Space System<br>Interlayer Noise Suppression System<br>Auto Cleaning System<br>Smart Air Conditioning System<br>Smart Ventilation System | Indoor/Outdoor Air Quality Detection System<br>Flexible Space System<br>Eco-Friendly Finish Materials<br>Smart Lighting |
| Activity<br>(A Sector) | Telecommuting System<br>Smart Veranda Garden<br>Realistic Remote Conversation System<br>Height Adjustable Sink<br>Smart Mirror<br>Water Temperature Display System<br>Biometric Front Porch<br>Height Adjustable Countertops | Pet Care System<br>Companion Robot<br>Smart Chair<br>Walking Aids<br>Smart Bed<br>Smart TV<br>Smart Bathtub |
| Information<br>(I Sector) | Table Embedded Multimedia Interface<br>Indoor/Outdoor Position Detection System | Home Appliance Control Interface |

### 2.3. Design and Implementation of an AAL Supportive Smart Home System

To develop the internal algorithms of an online AAL Pattern Support System (AALPSS), registered users are asked to rate established 100 AAL promoting patterns on a scale of 1 to 5, similar to the offline questionnaire in order to collect datasets for learning. A preprocessing step is applied to make the collected dataset more easily analyzable. Specifically, the collected dataset on the user profiles is arranged in categorical form. However, this type of dataset is not suitable as inputs for neural network model. Therefore, the system uses one-hot encoding method to transform categorical data (such as gender and job) into binary form (0 and 1), which can be used as a feature to train a neural network model. After this transformation process, all input variables are applied to the established Deep Neural Networks (DNNs).
The general neural network model consists of an input layer, hidden layer(s), and an output layer in a hierarchical arrangement. In our proposed system, a Deep Neural Network (DNN) is used to recommend personalized spatial/instrumental patterns to users. As shown in Figure 2, the input layer of the network consists of various user specific information such as gender, age, educational background, and housing location/type as

well as preferred AAL support pattern information including pattern types and IDs. Three hidden layers are used to prevent overfitting in the neural network.

The optimum weight is calculated in each hidden layer using activation functions such as ReLUs and softmax for multi-classification. Deep convolutional neural networks that employ ReLUs as activation functions, which are a type of neuron nonlinearity known as Rectified Linear Units, train much faster compared to networks that use tanh units, which are a standard way to model a neuron's output (Krizhevsky et al. 2012). Additionally, a softmax classifier is a valuable method for discerning a user's history and context within the task of a deep neural network (Covington et al. 2016). With the optimal weight values, the designed DNN is ready for the next recommendation step. The output of the system is the preference scores of the patterns, which are used to derive the recommendable set of AAL patterns.

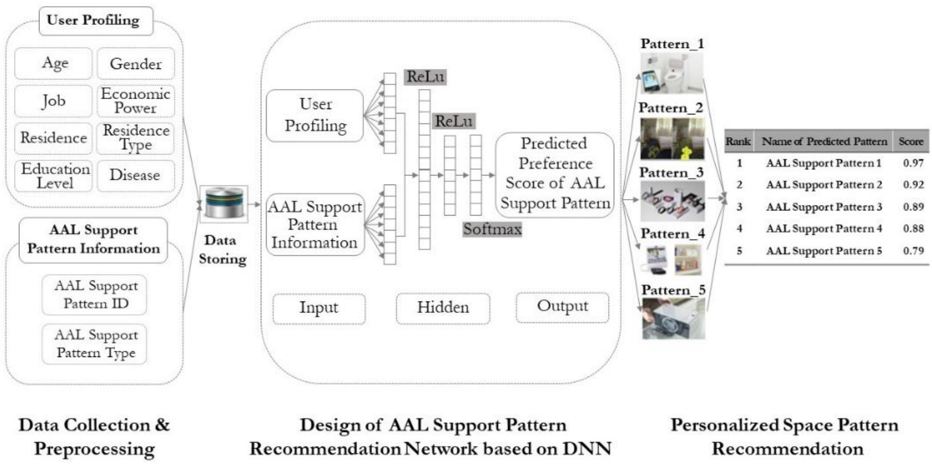


*Figure 2: Overall Architecture of the Proposed System Model for Recommending Customized Ambient Assisted Living (AAL) Support Patterns.*

**2.4. Personalized Healthcare Pattern Recommendation/Feedback Mechanism**

Computerized Clinical Decision Support Systems (CDSS) are considered to be leveraged for empowering complex clinical decision-making processes, which has been mainly facilitated by rapidly spreading electronic medical records possessing ever-increasing capabilities (Sutton et al. 2020). Feedback is a valuable tool for clinical experts to collect information, confirm treatment strengths and weaknesses, and support effective behaviors, despite its inherent challenges (Hardavella et al. 2017). Our proposed system aims to utilize computational resources by remotely interacting with diverse users in cyberspace. It provides machine learning-induced recommendations and collects their feedback to continuously improve the alignment between different social groups and their preferred home-based healthcare requirements.

After sufficient training, our online system provides personalized recommendations for AAL support patterns to online users. The system generates and adjusts a set of weights based on the user's input data through the network model, which is then applied to the spatial/instrumental pattern recommendation. The output of the network produces predicted potential preference scores for each pattern, which range from 0 to 1. These scores are sorted in descending order, and the system selects the top 10 patterns with the highest predicted preference values to provide personalized AAL support recommendations to the user.

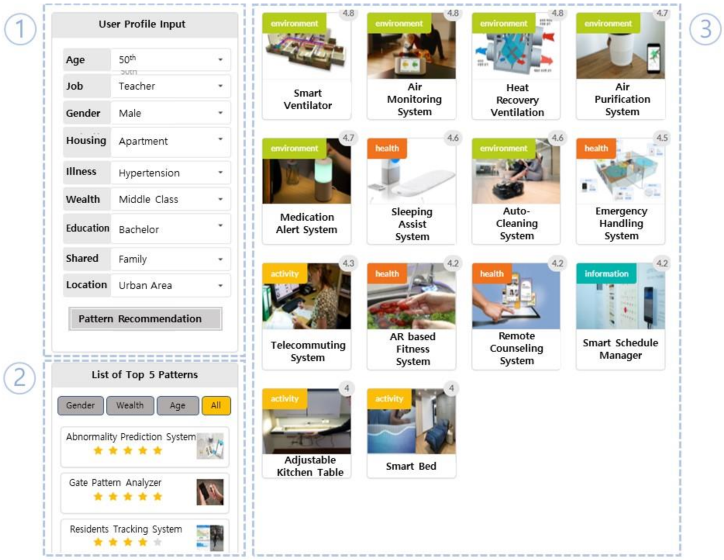


*Figure 3: AALPSS System Operation Snap Shot: (1) User Profile Input, (2) Display of Representative Patterns, (3) Personalized AAL Pattern Recommendations*

## 3. Conclusion

The pattern-based online AAL sensitive smart home design support system proposed in this study has the potential to serve as an effective and easily accessible interface for promoting AAL practices leveraging sophisticated combinations of spatial and instrumental healthcare related patterns considering different social groups' diversified requirements and demands. Even though the system used surveyed datasets as the basis for learning and predicting user-specific preference profiles for the selection of demanding AAL oriented smart home design patterns in the first place, by continuously collecting and analyzing user responses and preferences through its online interface, it could evolve into a high-precision decision support system for recommending best combinations of in-house healthcare systems and services based on each individual's personal profile. It would, therefore contribute to the practices aiming at supporting social sustainability by making people safe, healthy and comfortable in their living environments regardless of their gender, age, job, educational/economic status, housing location/type, co-residents and even chronic illnesses. There are couple reasons why our research deserves attention from AAL flowers across the chronological transition from pre-pandemic to post-pandemic era. Firstly, those identified and developed 100 healthcare related systems and services are mostly applicable to home environment for supporting AAL, which pertains crucial meaning especially in pandemic period when indoor dominant living is inevitable. Secondly, our study was motivated to explore future possibilities for healthcare sensitive smart home design based on the evolving knowledgebase upgradable by the online participants, therefore our online system could cast insights onto the future route of emerging digitalization-associated AAL practices.

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