Chapter

An Intelligent Clinical Decision Support System for Assessing the Needs of a Long-Term Care Plan

Paul Kai Yuet Siu, Valerie Tang, King Lun Choy, Hoi Yan Lam and George To Sum Ho

Abstract

With the global aging population, providing effective long-term care has been promoted and emphasized for reducing the hospitalizations of the elderly and the care burden to hospitals and governments. Under the scheme of Long-term Care Project 2.0 (LTCP 2.0), initiated in Taiwan, two types of long-term care services, i.e., institutional care and home care, are provided for the elderly with chronic diseases and disabilities, according to their personality, living environment and health situation. Due to the increasing emphasis on the quality of life in recent years, the elderly expect long-term care service providers (LCSP) to provide the best quality of care (QoC). Such healthcare must be safe, effective, timely, efficiently, diversified and up-to-date. Instead of supporting basic activities in daily living, LCSPs have changed their goals to formulate elderly-centered care plans in an accurate, time-efficient and cost-effective manner. In order to ensure the quality of the care services, an intelligent clinical decision support system (ICDSS) is proposed for care managers to improve their efficiency and effectiveness in assessing the long-term care needs of the elderly. In the ICDSS, artificial intelligence (AI) techniques are adopted to distinguish and formulate personalized long-term care plans by retrieving relevant knowledge from past similar records.

Keywords: long-term care, personalized care services, clinical decision support system, artificial intelligence techniques, care plan

1. Introduction

Facing the unavoidable aging population, the demands for long-term care services are increasing and need to be addressed in modern society [1, 2]. In order to effectively provide long-term care to the elderly in the community, the Taiwan government proposed a 10-year long-term care project, namely Long-term Care Project 1.0 (LTCP 1.0), in 2007. The goal of the project was to establish a comprehensive community-based care system for (i) providing appropriate services to the elderly, (ii) improving the independence of the elderly, (iii) enhancing the quality of life, and (iv) maintaining autonomy and dignity [3]. Difference in gender, level of urbanization, culture, economy and health are also considered in this system. Eight services items are covered in LTCP 1.0: daily care services, transportation services, meal services, home and community-based rehabilitation services, respite care services, home nursing, rental of equipment and long-term care institution services [4]. Subsequently, the government launched a more extensive public framework, i.e., LTCP 2.0, in 2017 to increase the services coverage in the community [5]. **Table 1** shows the differences between LTCP 1.0 and LTCP 2.0, in which LTCP 2.0 expands the scope of services to optimize the front-end preventive care and to provide back-end connections to multi-target support services and home hospice services.

In order to provide high quality and affordable services, the ABC community care model with 3 tiers was established to clearly define the roles and responsibilities of healthcare parties involved in LTCP 2.0, as shown in **Figure 1** [6]. Tier A refers to a community integrated care service center for coordinating and allocating the resources of care services based on the care plan formulated by care managers. Moreover, Tier A also provides a localized delivery system that connects to Tier B and Tier C. Based on the assessment results from Tier A, Tier B, i.e. a multiple service center, provides corresponding diverse healthcare services for the public. Information from Tier A and Tier B is then sent to the long-term care station in Tier C for providing various care functions to the elderly. Therefore, the care managers in Tier A play an important role in LTCP 2.0 in evaluating the needs and formulating care plans [7]. However, it is complicated for care managers to perform the tasks of health assessment, reviewing historical health records and resources planning in a short time. In addition, it requires care managers with adequate knowledge and experience to handle these tasks. Due to the fact that in healthcare resources are as shortages in terms of staff and equipment, the implementation of care planning in

	LTCP 1.0	LTCP 2.0
Services targets	4	8
Services scopes	8	17
Financial resources	• Government funding • Medical development funding	• Government funding • Social welfare funding • Long-term service development funding
Innovative service	N/A	ABC community care model

Table 1.
Differences between LTCP 1.0 and LTCP 2.0.

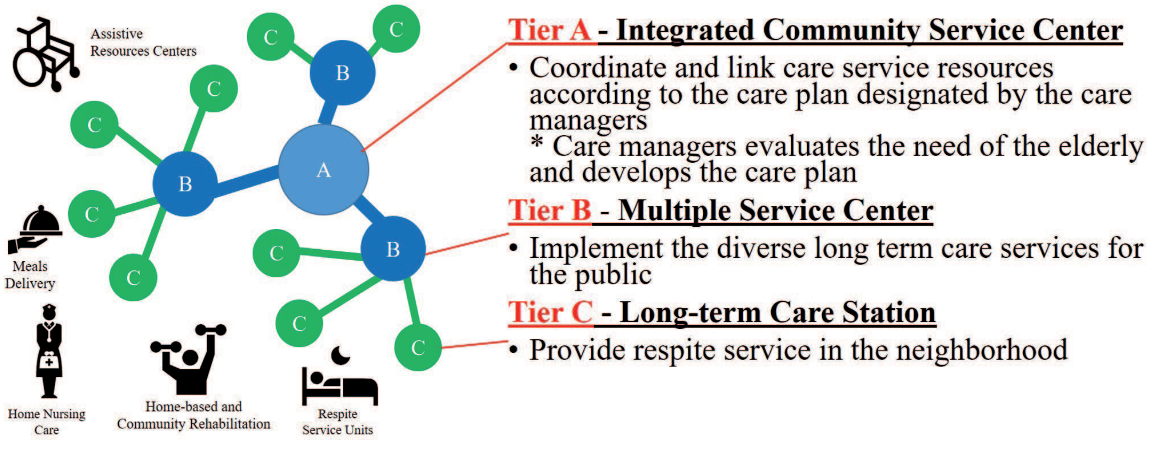

Figure 1.
ABC community care model.

LTCP 2.0 becomes challenging to achieve the goals of providing accurate and fast-responsive healthcare services.

To address the above problems, the objective of this article is to present an intelligent clinical decision support system (ICDSS) for care planning. The case-based reasoning (CBR) technique is adopted to provide the knowledge support for decision-making in care planning. By extracting the relevant knowledge from similar past cases, the care plans can be formulated in a cost-effective and time-efficient manner so as to maintain the high quality of services. The rest of article is structured as follows. Related studies and background are discussed in Section 2. Section 3 describes the architecture of the proposed system while Section 4 discusses the case study and findings. Section 5 shows the future research directions. Conclusions are drawn in Section 6.

2. Related work

Due to the development of medical technology and increased life expectancy, the number of elderly people in Taiwan is expected to increase continuously annually. According to the statistics [8], the percentage of the elderly population aged 65 or above is 13.2% in 2016. It is estimated that this population in 2026 will reach to 20.6%. Associated with the fast growth of the aging population, the reporting of chronic diseases has also increased significantly. As a consequence, the needs for long-term care services have become more demanding and urgent. In response to the increased demands for long-term care services, the government of Taiwan has considered long-term care services in healthcare industry as one of eight key industries to minimize the threats of chronic diseases [9]. Therefore, the Long-term Care Project 1.0 (LTCP 1.0) was launched in 2007 and was an initiative to integrate the home and residential-based services in Taiwan. Up to the end of 2015, over 160,000 people had received the services offered by LTCP and there are nearly 2800 institutions providing care services following the principles of LTCP. In view of the benefits offered by LTCP 1.0, a revised version of the original LTCP, i.e. LTCP 2.0, was created to further facilitate the integration of preventative care, social care and medical care in the community. In order to facilitate the implementation of LTCP 2.0 and coordinate the operation of long-term services and resources, researchers have been focusing on improving the performance of LTCP. Liu and Yao [10] adopted latent class analysis to examine the interrelationship among health indicators so as to determine the level of needs of the elderly care recipients. Lin et al. [11] studied the performance of LTCP according to the dimensions of the workforce, sources of funding, application of technology, service nature and norms. The aims of their study is to identify problems in LTCP and develop a continuous improvement strategies so as to improve the long-term care services. However, attention is rarely paid to the field of LTCP as well as providing knowledge support for decision-making. In fact, due to the shortage of knowledge manpower, it is time-consuming and tedious for care managers to effectively provide an integrated “one-stop” consultation for applications, health evaluations, care plans formulation and the coordination and delivery of long-term care services. Therefore, it is essential to provide knowledge support for decision-making processes in the care planning of LTCP.

In recent years, decision support systems have become increasingly popular for providing decision support in various industries [12, 13], and are designed to facilitate precise decision-making through the use of accurate and timely data, information and knowledge management. In the healthcare industry, the clinical decision support system is a specific term for the health customized version of decision support system [14]. The emerging clinical decision support system allows healthcare professionals to manage and manipulate the massive amount of data in an effective and efficient manner. In this situation, automatic decision-making can be provided for evaluating the health status of patients and providing corresponding treatment. Case-based reasoning (CBR) is one of the well-known artificial intelligent techniques commonly embedded in the clinical decision support system and adopts previous experience and knowledge for solving new problems [15]. The general CBR model has been formalized for computer reasoning as a four-step process: (i) retrieve the most similar case, (ii) reuse the retrieved case for solving the new problem, (iii) revise the content in the solutions if necessary, and (iv) retain the solutions as the new case stored in the case library [16]. The predictive process in the CBR allows users to takes less effort and time to generate solutions. CBR has been widely adopted in the healthcare industry in disease diagnosis, planning and resources allocations [17, 18]. Chang et al. [19] adopted CBR to develop a continuous care information system for facilitating discharge planning. By the adoption of computer-reasoning in the evaluation process of care planning, accurate continuing care solutions can be formulated in a timely manner. Wang et al. [20] developed a hybrid CBR approach to shorten the time for providing the treatment planning for the people with mental problems. Petrovic et al. [21] applied CBR in radiotherapy treatment planning to reduce the errors in planning and in recommending radiotherapy solutions. The above studies show that CBR is a promising approach in providing knowledge support for generating the solutions in the healthcare industry.

In summary, from the above literature, it is found that care managers play an essential role in the LTCP for generating appropriate and personalized long-term care solutions and in coordinating care services resources. Due to the needs for accurate and fast-responsive healthcare services, the adoption of a clinical decision support system using CBR is a feasible solution to shorten the evaluation time and improve the service quality in LTCP.

3. Methodology

In order to facilitate the decision-making of care managers, an intelligent clinical decision support system (ICDSS) is developed. The ICDSS architecture is shown in **Figure 2** and consists of three modules: (i) data collection module, (ii) case-based reasoning module, and (iii) care plan formulation module. With a systematic method to provide knowledge support for care managers, the effectiveness and efficiency in the processes of assessing the health information and formulating care plans can be improved. Consequently, accurate and fast-responsive healthcare services can be delivered to the elderly so as to maintain a high quality of care.

3.1 Data collection module

In the data collection module, the elderly with chronic diseases or disabilities can apply for the community care service through the online platform. Three types of data, historical data, medical records and personal information, are collected and uploaded to the cloud databases in electronic format. Historical data refers to past health data such as vaccination records, surgery records, and the historical data from the past public system. The medical record is the biometric data for reflecting the psychological and physiological aspects of the elderly. Heart rate, blood sugar index, vision and muscle strength are examples of the medical record. Personal information of the elderly including name, age, gender, family relationships,

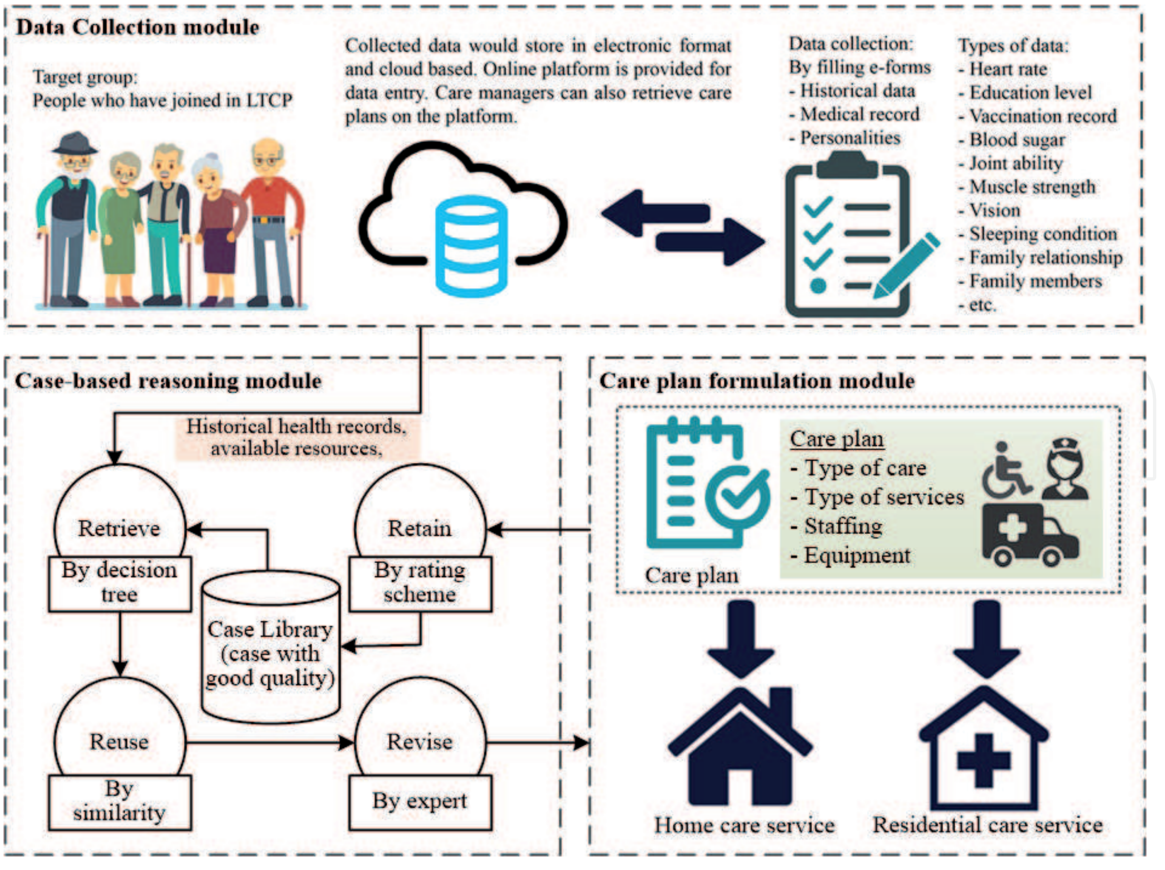

Figure 2.
An architecture of ICDSS.

personality, joint condition, sleeping ability and living environment are also collected. Apart from uploading the three types of data, an interview is conducted to understand the problems of the elderly in daily living. By doing so, care managers can collected both subjective and objective data for further data analysis in the case-based reasoning.

3.2 Case-based reasoning module

Traditionally, care managers have to review the massive amount of health data one by one for evaluating the needs of the elderly. The use of ICDSS allows care managers to effectively formulate appropriate care plans according to the needs. In this module, CBR is adopted to retrieve the most similar care records for generating the care solutions. To begin with the first stage in the CBR, i.e. case retrieval, past care records are firstly stored in the case library. An indexing tree is constructed to cluster past care records according to the key attributes that may affect the types of service provided. Along the searching path of the indexing tree, a small group of past case records are retrieved. In the reuse stage, retrieved case records are ranked descending order according to their similarity value. Eq. (1) is the expression for calculating the total similarity value.

$$\text{Total similarity value} = \frac{\sum_{i=1}^{n} w_i sim\left(f_i^I, f_i^R\right)}{\sum_{i=1}^{n} w_i} \tag{1}$$

where w_i is the weighting of the attribute i, sim is the function for calculating the similarity value of attributes, and, f_i^I and f_i^R are the values of attributes f_i in the new and past cases. The care record with the highest similarity value is selected and considered as the most significant reference to generate care solutions for solving the new problem. After that, care managers can make modifications to the retrieved

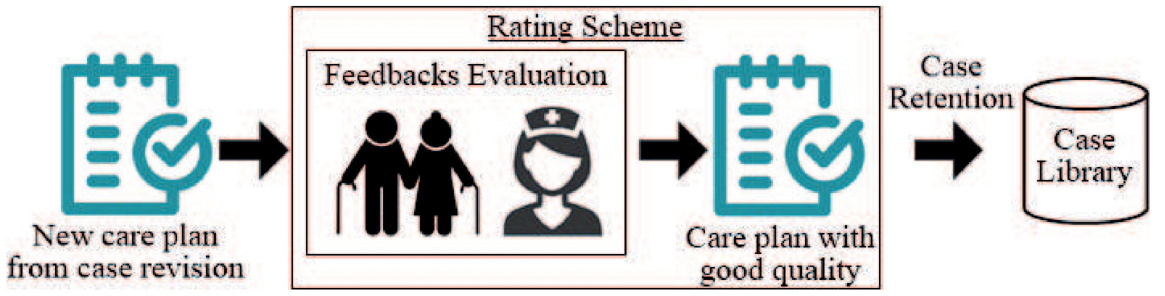

Figure 3.
Rating scheme in the case retention of CBR.

care records so as to meet the real-life situations of the elderly. Therefore, a new care plan is formulated for serving the elderly.

Differing to the traditional CBR process, a rating scheme is deployed in the case retention process to assess and monitor the effectiveness of the care plan. **Figure 3** shows the rating scheme in the case retention of CBR. As it is a long-term care service, regular meetings between care managers and the elderly or their families is required so as to collect their feedback. In addition, feedback from direct service providers, i.e. social workers and nursing staff, are also collected for the performance evaluation. Only care plans with good quality are retained in the case library for continuously improving the quality of the care records.

3.3 Care plan formulation module

After the case revision process of CBR, a new care plan with specific goals is generated. The care plan consists of several elements: (i) type of care, (ii) meals & nutrition, (iii) transportation and (iv) community center/activity recommend. According to the different nature of healthcare services, i.e. home care services or residential care services, different levels of healthcare services are provided for the elderly. In addition, details of the care plan are shared and transferred to the healthcare parties in Tier B and Tier C in the ABC community care model. Based on the care plan, operational guidelines can be provided to caregivers so as to deliver the corresponding healthcare services. Considering the health deterioration occurred in the elderly, the needs of healthcare services will move from less intensive care towards more intensive care via ABC model. Therefore, the re-evaluation of care plan is required every month to ensure its appropriateness.

4. Case example

In this section, a case example is illustrated to demonstrate the application of the ICDSS for providing knowledge support for decision-making in care planning. The case company is one of integrated community service centers located in Taichung, Taiwan. The main objective of the case company is to bring "Health and Happiness" for the elderly so as to maintain their quality of life, and physical and mental health in the community. The main staff members in the case company are care managers and supervisors such as social workers, nurses, occupational therapists and pharmacists for formulating care plan and coordinating care service resources. **Figure 4** shows the existing operation flow in the case company. The current practice of information flow, elderly health evaluation, healthcare service suggestions and follow up services are done manually. Care managers base on their experience to provide suggestions for the elderly. However, it is time-consuming and ineffective for care managers to implement these complicated steps in care planning. In

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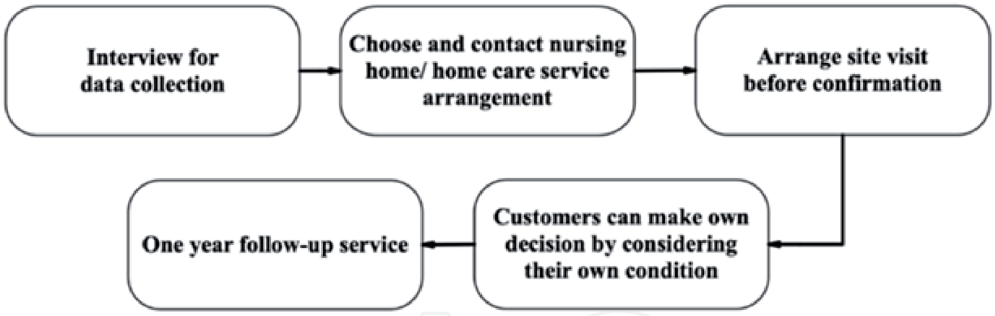

Figure 4.
Existing operation flow in the case company.

addition, human errors easily occurs in these evaluation processes, resulting in high complaint rates and poor service satisfaction in the case company.

4.1 Implementation of ICDSS

In order to tackle the above mentioned problems, the case company decided to implement the proposed system in providing knowledge support in care planning. Instead of the traditional in-person application method, the online platform is developed to collect the information. As mentioned in Section 3.1, data such as historical data, medical record and personal information are inputted by the elderly and then stored in the cloud database of the Data Collection Module. After submitting the application, care managers can note the new application in the ICDSS. An interview can be arranged to understand their current health situation and problems faced in daily living. The interview results are also stored in the database. In order to reduce the errors in the care management processes, care managers have to verify the accuracy of the data provided by the elderly.

Relevant information is then extracted and transfer to the Case-based Reasoning Module for further data analysis. In the case-based reasoning module, care managers have to identify the key attributes for constructing the indexing tree and retrieving the past care records. In this situation, five attributes: (i) kind of mobility, (ii) self-care ability, (iii) type of neuropsychiatric condition, (iv) communication method and (v) age are defined as key attributes that may significantly influence the type of services provided in care planning. **Figure 5** shows the user interface

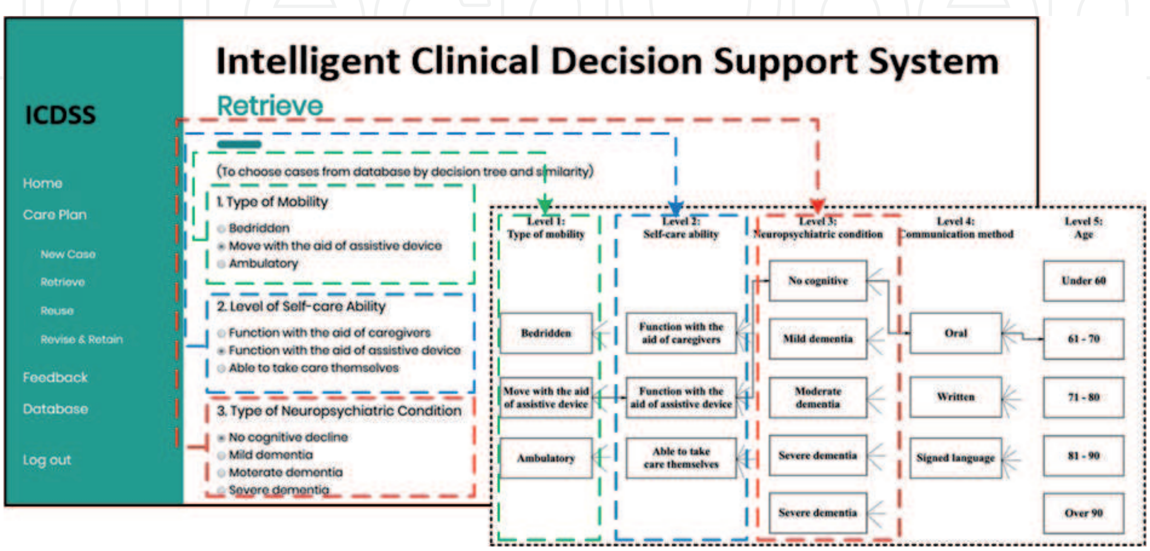

Figure 5.
The user interface for case retrieval.

for case retrieval. According to the structure of the indexing tree, the small group of past case records which match the specifications are retrieved. After that, the retrieved past case records are ranked using Eq. (1) so as to distinguish the most suitable case record. A total of 17 attributes are used to calculate the total similarity value of care records, as shown in **Table 2**. Based on the results from the case reuse, the care record with highest similarity value is extracted. An applicant is selected to illustrate the mechanism of CBR in ICDSS and details of the applicant are shown in **Table 3**. It is found that the elderly needs assistive devices for performing the movement and self-care activities. She does not have any problem of cognitive decline. A comprehensive review is implemented for deciding on the type of services. After the processes of case retrieval and reuse, the past care record (ID: 0082) has the highest similarity value (91.21%) to the new applicant. Therefore, care managers can select the past care record (ID: 0082) as the most significant reference for generating the new long-term care solutions.

To formulate a tailor-made care plan according to the needs of the elderly, modifications are made by care managers to add additional healthcare information and revise the content of the past care record. Therefore, a new care plan with services details can be generated, as shown in **Figure 6**. In the new care plan, home care services are provided to the new applicant three times per week. Therefore, this information is sent to the caregivers in Tier B and Tier C for allocating the

No.	Attributes	Weighting	No.	Attributes	Weighting
1	Living condition	1	9	Percentage of falling	2
2	Height	1	10	Drinking	2
3	Weight	1	11	Smoking	2
4	Glucose	1	12	Arthritis	2
5	Heart rate	1	13	Cancer	2
6	Upper blood pressure	1	14	Dysphagia	2
7	Lower blood pressure	1	15	Liver disease	2
8	Body temperature	1	16	Mental disease	2
			17	Urinary	2

Table 2.
Attributes for calculating the similarity value of care records.

Items	Detail	Items	Detail
Name	JL	Gender	Female
Age	69	Weight (kg)	57
Communication method	Oral	Height (cm)	160
Mobility	Move with the aid of assistive devices	Blood pressure (mmHg)	108/46
Self-care ability	Function with the aid of assistive devices	Heart rate (bpm)	80
Neuro-psychiatric	No cognitive decline	Body temperature (°C)	36.4
Living condition	Living with family	Fall (%)	18

Table 3.
Details of the applicant.

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corresponding healthcare resources. In each visit, caregivers are required to measure the biometric data including blood pressure, heart rate, blood glucose level and body temperature. They have to assist the elderly in bathing and filling the drug organizer. In addition, transportation service is provided for pick from their home to the hospital for regular checking. By doing so, community-based long-term care services can be delivered.

In order to ensure the quality of care provided, a feedback survey is conducted to measure the performance of the care plan, as shown in **Figure 7**. In addition, a regular meeting is held for nursing staff participating in serving this elderly so as to discuss and understand the problems faced in delivering the healthcare services. The care plan with good quality is then retained in case library for continuously quality improvement purposes.

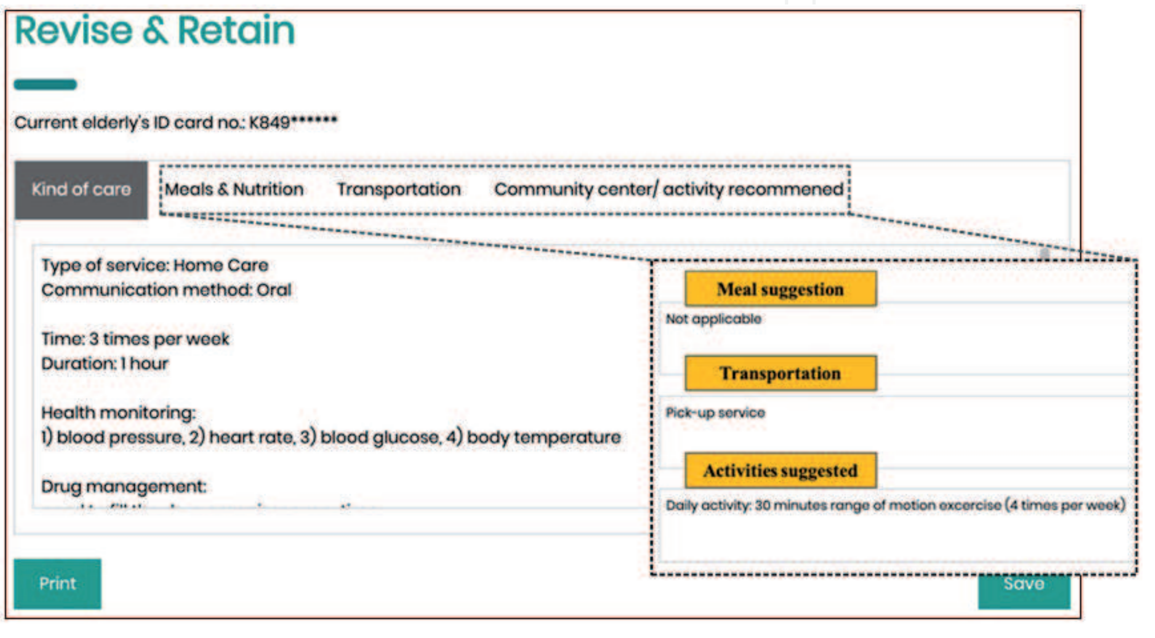

Figure 6.
The details of the retrieved past care record.

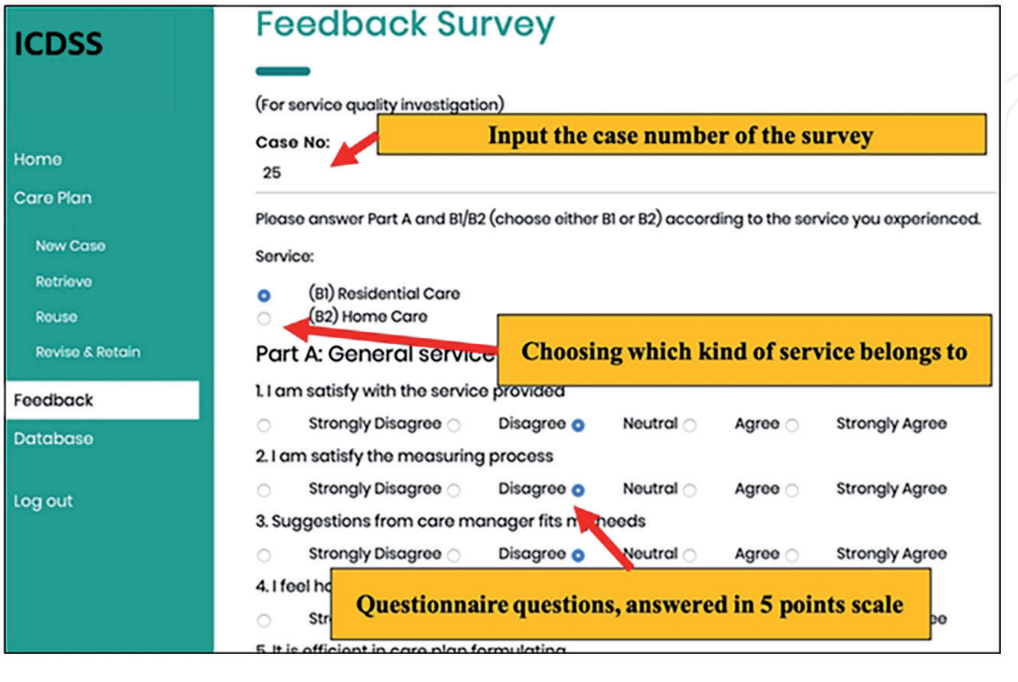

Figure 7.
Feedback survey for the elderly.

4.2 Findings

Through the pilot study in the case company, the ICDSS contributes to (i) improve the efficiency in care planning, and (ii) enhance the quality of long-term care services.

With the implementation of the ICDSS, it found that ICDSS offers several benefits to the case company. Firstly, it improves the efficiency in care planning. Instead of the traditional manual approach in care planning processes, ICDSS allows the care managers to formulate personalized long-term care solutions based on past explicit knowledge. **Table 4** shows the performance improvements after the use of ICDSS. With the use of ICDSS, care managers can review the health records provided by the elderly in the online platform rather than finding such information from separate data files. Therefore, the time for reviewing health records is significant reduced by 80.77% Moreover, the time for formulating the details of the care plan is also reduced from 156 to 22 min. Since the knowledge in past care records is extracted for solving new cases with similar problems, care managers can effectively generate solutions for providing the appropriate healthcare services and promoting the preventive health.

Furthermore, ICDSS prevents knowledge loss for formulating care plans. Since care managers with different levels of experience are employed in the case company, there may be some variations in the context of care plans. The adoption of ICDSS allows the valuable knowledge to be stored and shared in the form of past care records. Care managers, especially junior care managers, can make use of this knowledge to facilitate their decision-making. Thus, consistent long-term care solutions can be generated by different care managers. In addition, the number of complaints per week is reduced from 8 to 2. With the decrease in the number of complaints, the service satisfaction is significantly improved. Not only can the integrated community service center in Tier A enhance the service satisfaction, but also the healthcare parties in Tier B and Tier C.

Performance indicator	Without ICDSS (min)	With ICDSS (min)	Improvement (%)
Time for reviewing health records	52	10	80.77
Time for formulating the details of care plan	156	22	85.90

Table 4.
Performance improvement after the use of ICDSS.

5. Future research directions

5.1 Explore the adoption of the Internet of Things (IoT) in residential care services

According to Zhao et al. [22], there is growing evidence that chronic diseases are the major issue associated with aging population. In the last decade, the Internet of Things (IoT) is a newly emerging technology for the healthcare industry [23]. Under the IoT platform, information can be gathered, processed and analyzed to serve individual and healthcare organizations. IoT has been widely adopted in hospitals and home care services for remote monitoring and disease diagnosis. It is not only to help increase the data accuracy of the clinical decision support system, but also to provide early detection of any abnormalities occurring. In fact, its application can be further explored in residential care services. Current adoption of the IoT in nursing homes are lagging behind the hospitals and home care services providers. As one of the important long-term care service providers in LTCP 2.0, future research effort can be paid in extending the adoption of IoT in nursing homes so as to speed up its daily routine processes. Considering that numerous healthcare parties are involved in the LTCP 2.0, the IoT allows the caregivers to real-time collect and monitor the biometric data of the elderly through the equipment of the sensors. It also facilitates the information exchange among various parties. Once the abnormalities occurred, instant actions can be generated by corresponding healthcare parties to prevent the further health deterioration.

5.2 Explore a big data analytics platform for data management and manipulation

On the other hand, due to the application of smart devices and social media in healthcare services, there is an exponentially increase of health-related big data [24]. It is necessary to develop big data analytics platforms with text mining and machine learning abilities for facilitating data management and manipulation. For example, with the use of IoT, massive health data can be collected and stored in the cloud platform. The data analytic techniques such as artificial intelligence help discover the hidden pattern of available data and generate invaluable knowledge for supporting the proactive healthcare services in the LTCP 2.0. Criteria, including the ability to manipulate, continuity, ease of use, availability, quality assurance, privacy and security, should be considered in designing of this platform [25]. In addition, any data lag between data collection and processing should be avoided in this platform for achieving real-time big data analytics. Therefore, how to integrate the mentioned elements in the big data analytics platforms should be considered in future research so as to improve the effectiveness of LTCP.

6. Conclusions

To cope with the aging population, the needs for healthcare services as well as community care services are demanding. With the purpose of reducing the burden on caregivers, healthcare parties are seeking ways to better utilize the limited resources to improve the service quality. In Taiwan, LTCP 2.0 has been launched to create a comprehensive community-based care and health support system for the elderly. Care managers in Tier A play crucial roles in LTCP 2.0 for deciding on the types of service provided and in coordinating with care service resources. However, the traditional manual approach relying on care manager experience to perform the evaluation tasks and care plan formulation is ineffective. Without a knowledge-based decision support system, it is difficult for care managers, in a timely manner, to generate personalized long-term care solutions as well as coordinating care resources in Tier B and Tier C. Therefore, in this chapter, the ICDSS is designed to provide the knowledge support for decision-making in care planning of LTCP 2.0. The adoption of CBR in ICDSS approach allows care managers to disseminate the experience gained from the past similar care records. By doing so, it enables the successful execution of care planning so that fast-responsive and accurate healthcare services can be delivered. Furthermore, it enables data sharing and communication among healthcare parties in the LTCP 2.0, so that correct caring guidelines and knowledge can be transferred in a timely way to caregivers who provide direct care to the elderly timely. By so doing, the service quality can be greatly enhanced.

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