An Intelligent Performance Assessment System for Enhancing the Service Quality of Home Care Nursing Staff in the Healthcare Industry

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Abstract--**Due to the aging population in Hong Kong, the need for home care service is growing rapidly and requires nursing staff to frequently visit the homes of the elderly for service. For years, a shortage of qualified nursing staff and the tight service schedule has brought increasing pressure to the existing home care service, sometimes leading to high complaint rates by the elderly and their family members. In order to maintain the home care service quality, it is critical to have an evaluation approach by assessing the workload and characteristics of the home care nursing staff. In this paper, an intelligent performance assessment system (IPAS) is designed to evaluate the performance of home care nursing staff in the healthcare industry. IPAS integrates Online Analytical Processing (OLAP) for the collecting and storing of data on the elderly patient, nursing staff and healthcare agency when providing home care services, and fuzzy logic for evaluating the service quality of the nursing staff. The healthcare agency can then formulate a follow up plan based on the assessment results. By conducting a pilot study in a local healthcare agency, the nursing staff loyalty can be increased while the quality of home care service can be enhanced.**

I. INTRODUCTION

The aging population is a prevalent and profound issue over the world. According to the Census and Statistics Department in Hong Kong [6], 15% of the population aged 65 and over in 2014. It is expected that the proportion of the elderly will rapidly increase in the coming 20 years, reaching 20% in 2024 and 30% in 2034. This phenomenon is mainly caused by the low fertility rate and longer life expectancy [23]. Thus, the needs for long term care service is increasing under the situation of the aging population. However, due to shortage of resources such as beds, qualified nursing staff and doctors in both public and private healthcare organizations, the need for home care service is growing significantly [31]. Home care service refers to providing professional and long term care service, including supportive care, personal care, technical nursing care and domestic aid, to the elderly at their residential homes [10]. In addition, the preferences of the elderly who wish to stay at home rather than live in healthcare organizations also increases the demand for home care service [8].
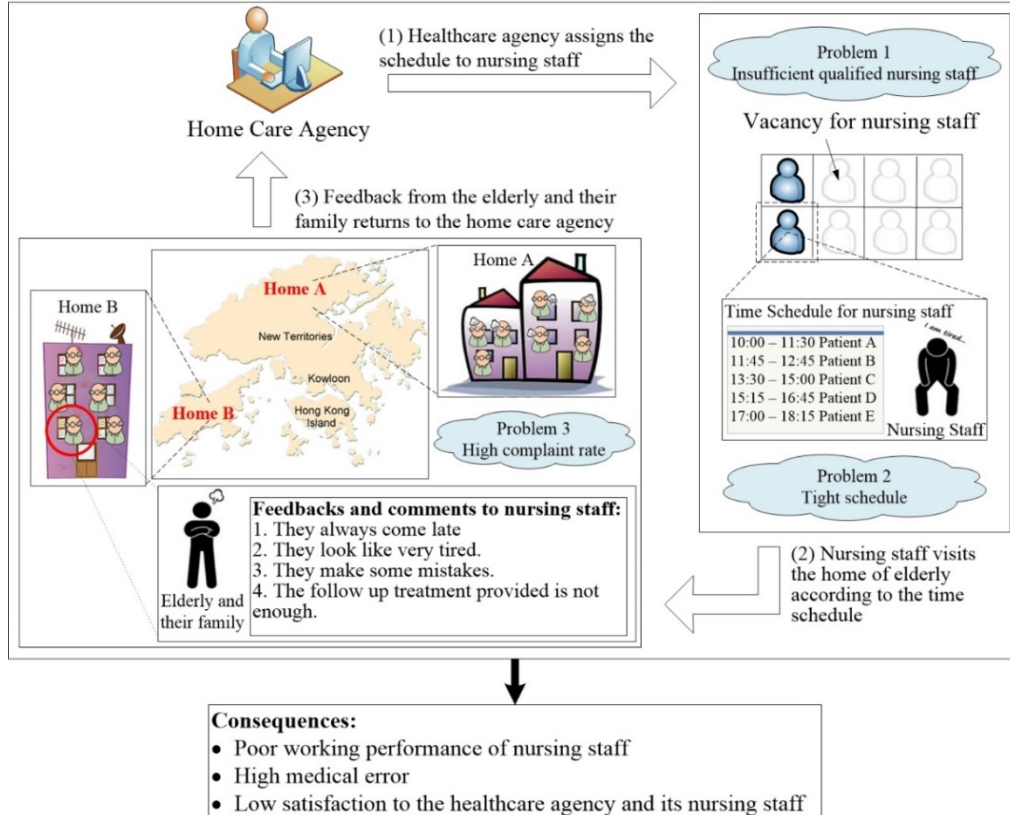

Fig. 1. Existing problems in home care service

Currently, in Hong Kong, there are many healthcare agencies, such as Hong Kong Family Welfare Society, Salvation Army and Tung Wah Group of Hospitals, providing the home care service. However, they are generally facing the challenge of low service satisfaction from the elderly and their families because of the poor service quality providing by the nursing staff. Fig. 1 shows the existing problems in home care service. In general, healthcare agencies assign a number of jobs to nursing staff based on the needs for home care service for the elderly. However, due to the shortage of qualified nursing staff, a tight schedule is usually arranged for the nursing staff which implies that they have to complete several visits per day. This significantly increases the workload and pressure on the nursing staff. On the other hand, long travel distances between the homes of the elderly increases the time for nursing staff to provide home care service and they need to work overtime to finish the assigned jobs. The problems of the tight schedule and long travel distance make the nursing staff feel tired during the service period. As a result, the elderly and their families are dissatisfied with the quality of home care service leading to the high complaint rates to the healthcare agencies. Without the appropriate quality assessment tools to consider the workload of the nursing staff and resource support from the healthcare agencies, it is challenging for healthcare agencies to assess the performance of nursing staff in order to maintain the service quality. Therefore, in this paper, an intelligent performance assessment system (IPAS) is proposed integrating Online Analytical Processing (OLAP) and Fuzzy Logic technique to evaluate the performance of nursing staff.

This paper is divided into six sections. Section 2 reviews the literature including the background of home care service, data warehouse and OLAP and the applications of artificial intelligent (AI) techniques in tackling the quality issues. Section 3 describes the architecture of IPAS while the implementation of the proposed system is presented in section 4. Section 5 presents the results and discussion. Finally, the conclusions are drawn in section 6.

II. LITERATURE REVIEW

In this section, a review of the home care service in the healthcare industry is given to determine the existing practice in managing service quality in the healthcare industry. Data warehouse and OLAP, and, the AI technique are then investigated in order to construct a reliable quality assessment model to assess the service quality.

A. Background of home care service

Because of the aging population trend all over the world, the needs for healthcare service, especially the long term care, are significantly increased which has a great impact on society and the economy [3, 18, 25]. The expenditure by the government in the healthcare sector increases continuously, while the needs for healthcare facilitates and workers are also increased. As a result, the growing expenditure and shortage of resources in the public and private healthcare organizations bring a great pressure to healthcare workers. In such situations, the trend of the healthcare service is shifting from the public and private healthcare organizations to the community, which implies an increasing need for home care services [11, 27]. Home care service refers to care provision to the elderly in order to maintain their independence at home. The adoption of home care service in many countries, such as the Netherlands, Canada and the United States, helps the healthcare organizations to save on costs [13]. However, it is difficult for healthcare organizations to monitor the home care service quality due to the outreaching service of nursing staff and hence results in low patient satisfaction. Service quality is defined as the gap between the expectation of customers and the perception of the service provided [12, 20]. According to Maccellan et al. [17], high service quality, with high reliability, and safe and comforting service to the elderly, offered by the healthcare organizations, is important to maintain patient satisfaction. In order to fill the service quality gap, Aagia and Garg [1] proposed a standard scale involving five dimensions, i.e. admission, medical service, overall service, discharge process and social responsibility, to measure public hospital service quality. Butt and Run [5] applied the service quality assessment model to evaluate the private healthcare service quality in order to enhance the healthcare service with high efficiency. However, research focusing on the assessment of the home care service quality is rare. Therefore, an intelligent system with relevant data on nursing staff, patients and healthcare organizations is important to assess the home care service quality and improve patient satisfaction.

B. Data warehouse and OLAP

A data warehouse is a collection of data, which is integrated, subject oriented, time-varying and non-validated, for decision making processes [24]. Data collected from different data sources are extracted, transformed and loaded to the data warehouse [2]. In order to enhance the understanding of decision makers, a data warehouse is usually inter-connected to Online Analytical Processing (OLAP), which converts the data stored in the data warehouse into valuable information [7]. OLAP is one of popular business intelligence techniques which allows users to observe data from multidimensional structures of a data cube [21]. Through the combinations of five typical operations in OLAP, i.e. roll up, drill down, pivot, slice and dice, users can easily access, analyze and view the mass of data stored in the data cube. Due to the benefits offered by the data warehouse and OLAP, the concept of these techniques have been widely applied in various areas such as water quality assessment, defects extraction, and, security problems [4, 15, 24]. For the healthcare industry, Tremblay et al. [28]

used the OLAP tool to review healthcare planning performance in order to improve the effectiveness in serving the community. Pedersen et al. [22] adopted OLAP to store and collect patient information. Winters-Miner et al. [29] developed a platform with the adoption of the data warehouse and OLAP to integrate, analyze and publish medical knowledge in hospitals. Therefore, it is found that OLAP is a promising tool for storing patient data in the healthcare industry.

C. Artificial intelligence (AI) technique for quality assessment

In the healthcare service, there are many factors that affect customer satisfaction such as the ease of navigation, speediness and efficiency of the healthcare service and quality of staff [14]. Although the application of OLAP allows users to analyze the data in a multidimensional view, it is difficult for users to make decisions in situations in which multi-factors need to be considered. In order to assess the service quality with multi-factors, Artificial Intelligence (AI) is a useful tool to deal with this complicated problem. As one of the AI techniques, fuzzy logic is a good conceptual system of deduction, reasoning and computation in handling real life problems that are unreliable, vague, uncertain and incomplete [30]. Through the introduction of a fuzzy set to variables with unsharp boundaries, users can easily identify the relationship between input and output variables so as to increase the understanding by presenting the solutions in human language [26]. Ezzabadi et al. [9] proposed an European Foundation for Quality Management (EFQM) Excellence model with the integration of fuzzy logic and the analytic hierarchy process to evaluate business performance. Lee et al. [16] applied a fuzzy quality function deployment approach to analyze the technical requirements in hospitals in order to improve customer satisfaction. Nwobi-Okoye et al. [19] used transfer function and fuzzy logic approaches in assessing the performance of the multi input-single output production process in a brewery. From the above literature, it is concluded that fuzzy logic is a feasible technique for assessing the quality problem.

To summarize, previous studies show that providing high quality service is important to maintain the patient satisfaction in the healthcare industry. However, limited attention has been paid in assessing the quality of home care service due to the lack of close monitoring of the outreaching service of nursing staff. Therefore, in order to improve patient satisfaction, it is essential to develop a performance assessment system using OLAP and the fuzzy logic technique for enhancing the service quality of nursing staff.

III. DESIGN OF THE INTELLIGENT PERFORMANCE ASSESSMENT SYSTEM

To evaluate the service quality and formulate a follow up plan for maintaining the patient satisfaction, the IPAS is proposed. The architecture of IPAS is shown in Fig. 2 and consists of two modules: (i) the Online analytical processing-based data storage module, and, (ii) the Fuzzy logic based performance assessment module.

A. Online Analytical Processing-based data storage module

In the Online Analytical Processing-based data storage module, three types of data, i.e. elderly, nursing staff and healthcare organization, are collected for establishing a data warehouse. For example, the elderly have different health problems and make a booking for home care service in different time periods. Healthcare workers arrange the schedule for nursing staff according to the number of bookings. These data may be stored in different files in various formats. It is time consuming for healthcare workers to find these data. In order to store the data in an organized structure, data extract, transform and load (ETL) processes are applied to clean, customize, reform and integrate the data into the data warehouse. In this process, relevant data are first extracted from various sources, and then transformed into a standard format so as to increase the data accuracy. Data cleaning, transformation and integration are performed in this stage. Finally, extracted and transformed data, which are stored in both dimension tables and fact tables, are loaded into the data warehouse. A fact table stores the quantitative information (measures) for analysis. Other than the measure columns, there are a number of foreign keys in the fact table in order to link up the dimension tables, which store the details of an individual object. Through the development of the data warehouse, healthcare workers are able to aggregate and standardize data from various sources and hence improve the data integrity within the healthcare organization.

After building the data warehouse, data are directly transferred to the OLAP which allows users to effective access, view and analyze the data stored in the data warehouse. A multidimensional data cube consists of (i) measures tables, and, (ii) dimensions tables. By defining the hierarchy of dimensions, healthcare workers can effectively view the data at different levels by the rolling up and drilling down of dimensions in the OLAP data cube. In addition, healthcare workers can use other operating functions, i.e. slice, dice and rotate, to access and analyze the data in a desirable manner. Although the multidimensional structure of the OLAP data cube can increase the information and understanding of the healthcare workers, it does not have the ability to make decisions in the situation that multi-factors need to be considered. Therefore, useful data are passed to the fuzzy logic based performance assessment module for evaluating the service quality of home care nursing staff.
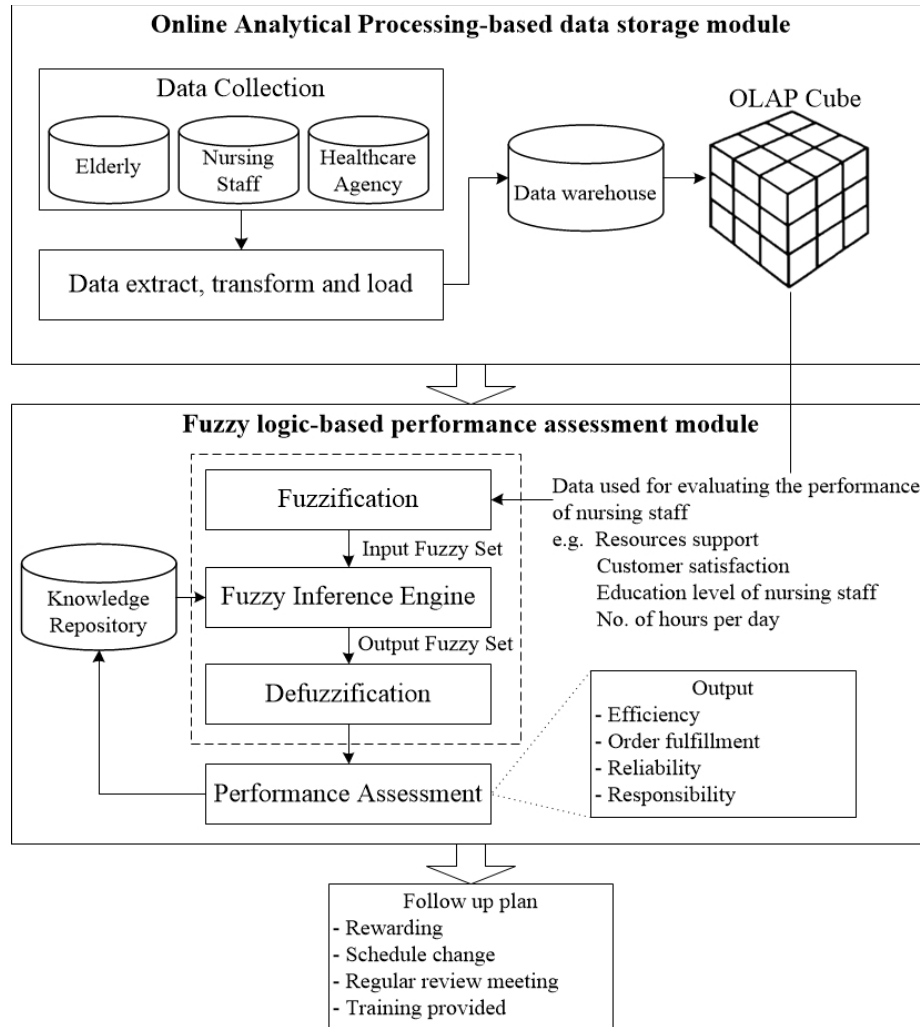
Fig. 2. The architecture of IPAS

B. Fuzzy logic-based performance assessment module

In the fuzzy logic-based performance assessment module, the quantitative value of the input parameters for evaluating the performance of home care nursing staff, such as customer satisfaction level, education level of nursing staff and the number of working hours per day, are first converted into a fuzzy set through the fuzzification. The characteristics of the fuzzy set are determined by the predefined membership function, as shown in the following equation.

$$A = \sum_{i-1}^{n} \frac{\mu_s(x_i)}{x_i}$$

where A is fuzzy set, x is the whole data set and $\mu_s(x_i)$ is the membership function of element x_i.

After that, the fuzzy set input parameters are transferred to the fuzzy inference engine for assessing the performance of the nursing staff using fuzzy logic. Through the matching of predefined decision rules stored in knowledge repository, the fuzzy set outputs are generated. The defuzzification process is required at the final stage in the fuzzy system for obtaining the quantitative values from the output fuzzy sets. Working

efficiency, the order fulfillment and reliability are examples of the output parameters which helps the healthcare workers to understand the performance of home care nursing staff. According to the results generated from fuzzy logic, healthcare workers can formulate an appropriate follow-up plan for the nursing staff. For example, training should be provided for nursing staff with low service performance. In addition, review meetings should be held in order to discuss the problems faced by the nursing staff. As a result, the home care service quality can be enhanced and hence increase customers satisfaction.

IV. CASE STUDY

To validate the feasibility of proposed IPAS, a case study was conducted in ABC Home Care Agency.

A. Company background

ABC Home Care Agency was established in the 2000s, and is located in Hong Kong. It provides long term home care

service, including personal care, medical care and domestic aid, to the elderly or others with Alzheimer's or other chronic diseases in their home. Other than the long term home care service, it provides short term special care service to the customers according to their needs. This home care agency has 40 nursing staff, including doctors, professional nurses, physical therapists, personal care workers and healthcare assistants. In order to make the elderly have a happy, enjoyable and peaceful life, the aim of ABC Home Care Agency is to provide appropriate home care service for them through the professional knowledge of the nursing care personnel.

Normally, after receiving a booking for home care service from the elderly or their families, healthcare workers review the historical records of the patient in the computer to identify which services they required. Based on the historical records, the healthcare workers assign an appropriate nursing staff to serve that particular patient. At the same time, they confirm the date and time of the booking by phone. Finally, the nursing staff follows the time schedule arranged by the healthcare workers to visit the residential home of the elderly patient.

B. Problems in ABC Home Care Agency

Recently, the ABC Home Care Agency received the negative feedbacks and complaints from their customers (the elderly and their families) due to the poor service quality provided by the nursing staff. For example, complaints that the attitude of the nursing staff is poor and they make certain mistakes such as bringing the wrong patient record during the home care service. By conducting the study in ABC Home Care Agency, two major problems that cause the poor satisfaction level of the customers are found as follows:

1) Poor data management

In theABC Home Care Agency, relevant data are stored in different files. It is time consuming for healthcare workers to find the data. On the other hand, due to the infrequent update of related data, some records are missed and hence increase the difficulty for the nursing staff to monitor the health status of the elderly patients.

2) Lack of a systematic approach in assessing the performance of nursing staff

Every year, ABC Home Care Agency reviews the performance of an individual nursing staff by conducting the performance appraisal in order to understand the difficulties in providing the home care service. However, there are many factors affecting the home care service which are not included in the appraisal form, such as the support of home care service to the nursing staff. Without a systematic approach, it is hard for healthcare workers to evaluate the performance of nursing staff comprehensively.

C. Implementation of IPAS

In order to assist the healthcare workers in constructing the appropriate follow up plan for enhancing the home care service quality, ABC Home Care Agency has decided to apply the IPAS for evaluating the service performance of nursing staff.

In IPAS, firstly, three types of data, the Home Care Agency, the elderly patients and the nursing staff, from March 2015 to October 2015, are collected to develop the data warehouse using Microsoft Access. Samples of the collected data are listed in Table 1. In order to standardize the data in different formats, data preprocessing (ETL) is required before transferring the data into the data warehouse. Fig. 2 shows the structure of the data warehouse. A *Service Records* fact table is linked to four dimensional tables, i.e. *Date*, *Elderly, Staff and Resources* using the foreign keys. In addition, there are three measures, namely *Satisfaction Weighting, Communication Weighting* and *Complaints* in the fact table. *Satisfaction weighting* shows the level of satisfaction given by the elderly after receiving the home care service. *Communication Weighting* indicates the degree of communication between the elderly and the nursing staff. For those measures, *Satisfaction Weighting* and *Communication Weighting*, there are 10 levels, 1 to 10, for the elderly to select and hence provide feedback to the Home Care Agency. The number of complaint per service is shown in the *Complaints* measure. On the other hand, in order to avoid data redundancy, additional tables are connected to the dimension table for normalization purposes.

After constructing the data warehouse, the data are imported to the software, Microsoft SQL Server 2008, for establishing the OLAP cube. The multidimensional view of the OLAP data cube allows the healthcare workers to access and analyze the desirable data of home care service effectively. By developing the hierarchical structure of the dimensions in the OLAP, healthcare workers can use the operation functions, such as roll up, drill down, pivot and rotate, in order to view the details of the data systemically. For example, the hierarchical structure of the *Resource* dimension is *Resource Category*→*Resource Sub-category*→*Resource Name*. Healthcare Workers can extract the resources information by drilling down the *Resource* dimension in the OLAP data cube.

TABLE 1. EXAMPLES OF DATA FOR CONSTRUCTING THE DATA WAREHOUSE.

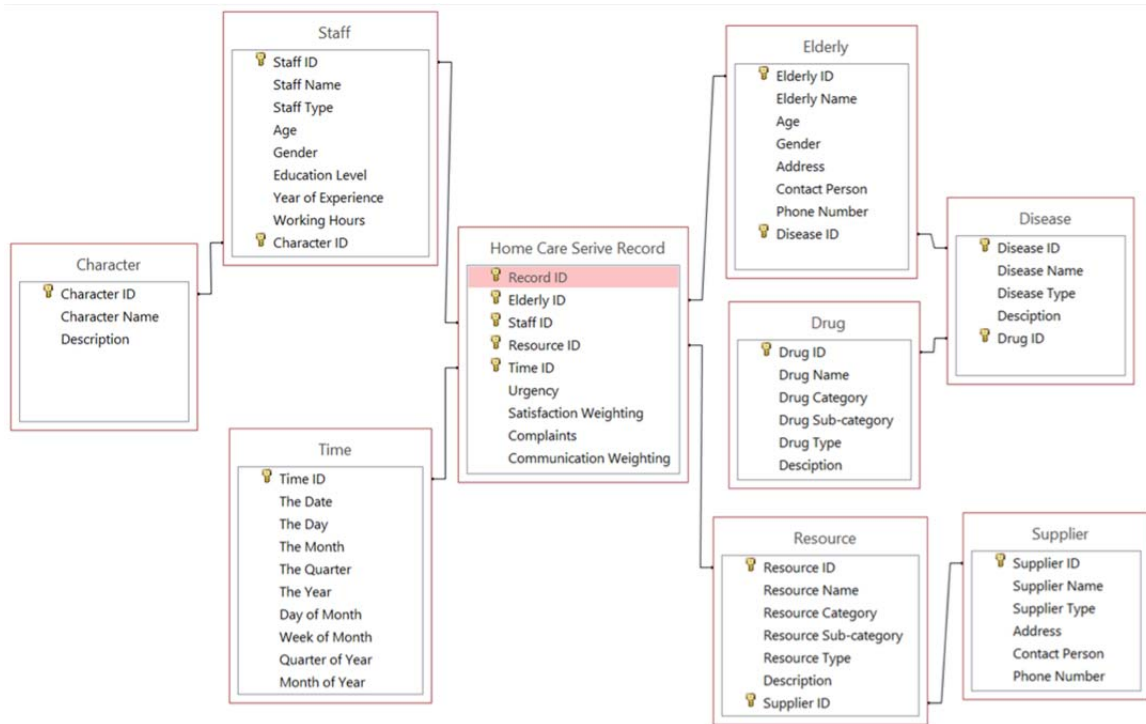| Types of Data	Examples
Home Care Agency	No. of the nursing staff, No. of resources, No. of order received
The elderly	Name, Type of diseases, Service satisfaction level
The nursing staff	Education level, No. of working hours, Years of experience

Fig. 3. The structure of data warehouse.

Finally, useful data are transferred to the next module, *Fuzzy logic-based performance assessment module*, as input parameters for assessing the performance of the nursing staff using MATLAB Fuzzy Logic Toolbox. Table 2 shows the input and output parameters in the fuzzy system. The input parameters can be classified in three groups: the home care agency, the elderly and the nursing staff. In the fuzzy logic process, firstly, the quantitative values of the input parameters are converted to the fuzzy set inputs based on the corresponding membership function stored in the Fuzzy Logic Toolbox. The samples of fuzzy set conversion are shown in Table 3. After that, the fuzzy set inputs pass through the fuzzy inference engine to generate the fuzzy set outputs by fitting the individual decision rules in the knowledge repository. Those decision rules are predefined by domain experts and represented in an "IF-THEN" format. A sample of the decision rules is shown in Table 4. Finally, the numerical value of the output parameters can be determined through the conversion of the fuzzy set outputs. Healthcare workers can input the value of the input parameters into the software and then easily generate the values of output parameters. Fig. 4 shows the values of the input parameters and the result of the fuzzy logic. Using the result from the fuzzy logic, healthcare workers can determine the performance of the nursing staff during the home care service, and thus develop the appropriate follow up plan for the nursing staff in order to enhance the home care service quality.

TABLE 2. THE SYMBOL OF INPUT AND OUTPUT PARAMETERS.

Categories		Parameters
Input	Home Care Agency	Resource support
		No. of order per day
	The elderly	Service satisfaction level
		No. of complaint per week
		Communication level
	Nursing staff	Willing to help the elderly
		Respond to the elderly request
		Personal appearance
		Number of working hours
		Knowledgeable staff
Output		Efficiency (%)
		Order fulfillment (%)
		Reliability (%)
		Responsibility (%)

TABLE 3. SAMPLES OF FUZZY SETS.

where L is low, RL is relative low, M is medium, RH is relative high and H is high;
VP is very poor, P is poor, N is neutral, G is Good and VG is very good.
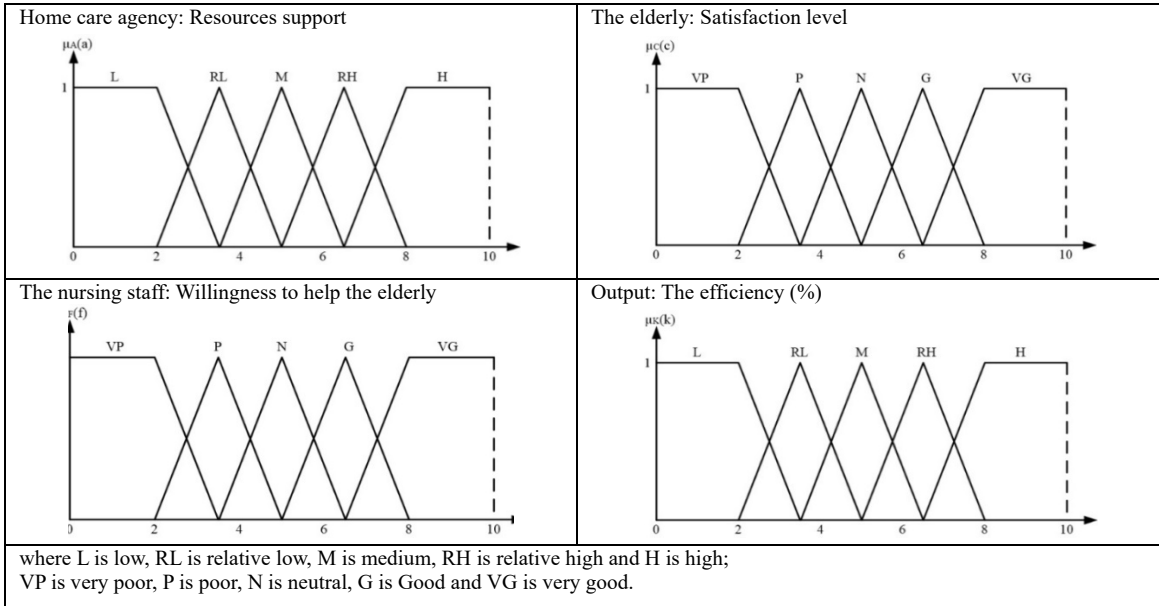
TABLE 4. A SAMPLE OF DECISION RULES.

IF	THEN
Resource support is medium **AND**	Efficiency is relative low **AND**
No. of order per day is high **AND**	Order fulfillment is relative low **AND**
Service satisfaction level is poor **AND**	Reliability is relative low **AND**
No. of complaint per week is poor **AND**	Responsibility is relative low
Communication level is neutral **AND**	
Willing to help the elderly is good **AND**	
Respond to the elderly request is good **AND**	
Personal appearance is neutral **AND**	
Number of working hours is poor **AND**	
Knowledgeable staff is neutral	

Input Value:
Resource: 6   Order: 72   Satisfaction: 4.8
Complaint: 7   Communication: 6   Willingness: 7.5
Response: 7   Appearance:6.2
WorkHrs: 6.5   Knowledgeable: 5.9

Output Result:
Efficiency: 48.1%
Order fulfillment: 55.8%
Reliability: 51.9%
Responsibility: 51.9%

Fig. 4. The result of fuzzy logic in fuzzy logic-based performance assessment module

V. RESULTS AND DISCUSSION

A. Results for constructing the follow up plan

The results generated from IPAS can assist the ABC Home Care Agency in formulating the appropriate follow up plan for individual nursing staff. According to the example shown in Fig. 4, the performance of the nursing staff is acceptable in which the efficiency is 48.1%, the order fulfillment is 55.8%, and the reliability and responsibility are 51.8%. However, the elderly patients and their families expect to receive the home care service with high quality. Thus, the follow up plan should be developed to improve the service quality. The frequency of the review meeting should be increased for the healthcare workers and nursing staff to identify and fix the problems in providing the home care service. For example, the nursing staff may argue that the time schedules arranged by healthcare workers are tight. In addition, the nursing staff may spend a lot of time in travelling due to the long distance between the residential homes of the elderly patients. As a result, the nursing staff may feel tired and hence this will affect the working efficiency. Furthermore, training should be provided regularly for the nursing staff to maintain their professionalism. For the nursing staff with good performance, rewards should be given to motivate the nursing staff and improve their loyalty.

B. Advantages of the proposed IPAS

After implementing IPAS in ABC Home Care Agency for two months, it is found that (i) the efficiency and accuracy in extracting the valuable data and (ii) the quality of home care service are improved.

1) Increasing efficiency and accuracy for extracting the valuable data

After implementing the proposed IPAS, healthcare workers in ABC Home Care Agency can easily access and retrieve the required data from the OLAP data cube by aggregating the relevant data in the data warehouse. In addition, the regular update of data in the OLAP is important to minimize the data errors by adding missing data and checking data accuracy. In this way, healthcare workers and nursing staff can review and monitor the health status of the elderly accurately and hence provide good home care service for them.

2) Improvement in the quality of home care service

By providing the appropriate follow up actions to the nursing staff, the quality of home care service in ABC Home Care agency was improved. The number of complaints per week decreased significantly from 7 to 3. In addition, the healthcare workers conducted a telephone interview by randomly selecting 50 elderly patients who are receiving home care service. The result showed that the satisfaction rate of the home care service was increased from 4.8 to 7.2. It implies that the elderly patients are more satisfied with the home care service provided by the nursing staff. It was commented that the nursing staff visit the elderly patient's home on time and they are more willing and patient to listen to the elderly patients.

VI. CONCLUSION

Patients nowadays are not only concerned about the healthcare service received, but they also pay attention to the service, requiring high reliability, comfort and safety. Therefore, service quality improvement is an essential process in the healthcare industry in order to satisfy the needs of patients. The advantages of the quality improvement include enhancing the service efficiency, increasing the customer satisfaction level, and reducing complaint rate. In this paper, an intelligent decision support system is developed for assessing the performance of nursing staff using the OLAP and fuzzy logic technique. The OLAP is introduced as the data warehouse to store the relevant data for the home care agency, the elderly and the nursing staff in an effective manner. It allows the healthcare workers and the nursing staff to easily review and monitor the health condition of the elderly. After that, fuzzy logic is applied to evaluate the performance of the nursing staff. The results generated are used to develop the appropriate follow up plan for the nursing staff to enhance the home care service quality. After a pilot study in the ABC Home Care Agency, the quality of the home care service was improved and the customers are more satisfied with the performance of the nursing staff. It is proven that the IPAS is a feasible way to improve the service quality in the home care agency. In order to further validate the feasible of IPAS, future research will be conducted in various healthcare organizations, such as nursing homes and elderly homes, for enhancing healthcare services.

ACKNOWLEDGEMENTS

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