Corporate Management Review
Vol. 38 No. 1, 2018
pp. 63-98

Identifying key factors of adopting an RFID system in nursing care using DEMATEL-based ANP
使用 DEMATEL-based ANP 探討護理照顧服務導入無線射頻系統之關鍵因素

Chao Chan Wu
Department of Cooperative Economics and Social Entrepreneurship, Feng Chia University
Dong Shang Chang
Department of Business Administration, National Central University
Rouwen Wang[1]
Department of Business Administration, National Central University

Abstract: Technology in an aging society can reduce the impact of the shortage of health care workers, with radio frequency identification (RFID) technology quite suitable for solving the issue of a labor shortage in the nursing care industry. This study constructs an evaluation model for adopting RFID in nursing care, using a hybrid modified multiple criteria decision-making (MCDM) and dividing it into three stages: (1) selecting important factors by the modified Delphi method; (2) constructing the causal diagram through Decision Making Trial and Evaluation Laboratory (DEMATEL); and (3) exploring the weights of the factors utilizing DEMATEL-based ANP (DANP). The results show that one should consider five dimensions, which contain twenty-four criteria, when adopting an RFID system in nursing care. Moreover, the most influential dimension is technology. The dimension that is most related to the other dimensions is cost, whereas organization is considered the most important dimension. The contribution of this study is to define the key dimensions and criteria for adopting an RFID system by the nursing care industry. This study also constructs an evaluation model that can be used as a guidance for decision making in a nursing care facility that adopts an RFID system.

[1] Corresponding author: Rouwen Wang, Department of Business Administration, National Central University, 300, Zhongda Rd., Zhongli District, Taoyuan City 32001, Taiwan, E-mail: h80005@gmail.com .

Keywords: Radio frequency identification (RFID) system, modified Delphi method, decision making trial and evaluation laboratory (DEMATEL), DEMATEL-based ANP (DANP), nursing care.

摘要：在高齡化社會下，科技技術可以減少醫護人員短缺帶來的衝擊。無線射頻辨識 (radio frequency identification, RFID) 系統正好用來協助解決護理產業勞動力短缺的問題。本研究透過混合式多準則決策 (multiple criteria decision-making, MCDM) 方法構建一個以RFID導入護理產業的評估模型。研究可分為三個階段，分別為 (1) 採用修正式德爾菲法 (modified Delphi method) 萃取重要因素；(2) 透過決策實驗室法 (Decision Making Trial and Evaluation Laboratory, DEMATEL) 構建因果關係圖；(3) 利用DEMATEL-based ANP (DANP) 獲得因素的權重。結果顯示在採用RFID系統進行護理時，需要考慮五個構面、二十四個準則。其中，最有影響力的構面是技術構面；與其他構面最相關的構面是成本構面；組織構面則被認為是最重要的構面。研究貢獻將確定護理產業採用RFID系統的關鍵構面和準則。而本研究構建的評估模型可以作為採用RFID系統的醫療機構的決策指引。

關鍵詞：無線射頻識別系統, 修正式德爾菲法, 決策實驗室法, DEMATEL-based ANP, 護理照顧服務.

1. Introduction

Recent epidemiological studies have confirmed that extending life expectancy prolongs the number of years of a person's physical health (Tesch-Romer and Wahl, 2017), and additional physicians are needed to accommodate population growth and aging. In order to support a large number of elderly care needs, nursing care services are exhibiting a labor shortage phenomenon. Thus, long-term care for achieving a high quality of life is a long-standing issue in aging research (Flores and Cabigao, 2014). To satisfy the potential needs of various types of patients, research has focused not only on the more advanced medical facilities, but also on the implementation of medical service quality (Ortíz *et al*., 2016). From the physicians' point of view, their stress comes from heavy patient loads, administrative tasks, and physical and emotional challenges (Hayes *et al.*, 2010). Long-term care (LTC) as a burden on society refers to the burden of informal and formal caregivers (George and Ferraro, 2015), and it is becoming more and more important, because elderly health care is now a global problem (Chang *et al.*, 2017). This phenomenon shows that care providers face a great challenge in the supply of nursing services.

The medical sector is naturally an important industry for providing high quality services and health care (Ismail *et al.*, 2015; Ortíz *et al.*, 2015). Many countries have developed strategic policies for large-scale health systems in order to provide their citizens with the benefits of proper care (Omachonu and Einspruch, 2007). The concept of care refers to providing someone with the necessary support, including protection, health, and welfare (Tesch-Romer and Wahl, 2017). National health insurance provides convenient and comprehensive care for the masses, but the capital needed for quality health care is inadequate (Bauer and Bodenheimer, 2017). On the other hand, the scope of services being large makes it more difficult for the inadequate supply of practitioners to spend enough time on patients. Therefore, nursing homes are finding it necessary to adopt technology to enhance the quality of their care services.

Technology can make management more automated or intelligent, in order to improve the increasing amount of medical industry problems. Radio Frequency Identification (RFID) is suitable for use as a management tool that provides assistance to caregivers, because managers can record and track caregivers through RFID technology and act upon predictions that are based on past records so as to reduce accidents. Caregivers can better protect their patients by using an RFID system that recognizes both location and tracking. In the past few years, RFID technology has experienced a period of rapid growth, has become a stable technology, and is widely used in various fields. For the medical industry, reliable technology is naturally now the preferred choice of care organizations.

Successful elderly services may come from the joint efforts of care recipients and care providers who can maintain self-determination and quality of life for elderly people with care needs (Tesch-Romer and Wahl, 2017). Hence, it is necessary to focus on new developments in technology and new creative housing solutions that are critical to facilities with long-term care needs (Wahl *et al.*, 2012). When an agency decides to adopt new technologies, many variables need to be considered, and so it is not easy to select and evaluate industrial planning. When a decision problem arises, the usual alternatives are limited, and the best solution is to consider a large number of criteria.

Maintaining the individual autonomy of patients is essential in health care (Gott and Ingleton, 2011), and an RFID system provides the caregiver with an activity space that is safe and not disturbed. Although this study focuses on planning the improvement of a care service, the nursing care industry has presently adopted RFID systems without any comprehensive guidelines. In the past, many important strategic decisions were done on the basis of self-evidence, intuition, as well as a lack of sufficient understanding and relationships among factors (Herazo-Padilla *et al.*, 2013). Previous research used Multiple Criteria Decision Making (MCDM) when faced with making a decision from many criteria (Ortíz *et al.*, 2016). MCDM can help solve the problem of decision making and planning of multiple conflicting criteria, and assessing important criteria can improve the success rate of a project (Yang and Hsieh, 2009; Yang and Tzeng, 2011). The most common decision-making methods are Analytic Hierarchy Process (AHP) (Saaty, 1980), Analytic Network Process (ANP) (Saaty, 1996), Goal Programming (Charnes, Cooper, and Ferguson, 1955), Delphi (Dalkey and Helmer, 1963), Decision Making Trial and Evaluation Laboratory (DEMATEL), and fuzzy logic (Zadeh, 1965). However, some methods assume that the criteria are all independent, as they select the most critical criteria and then improve the adopted planning. This study thus aids in planning the adoption of new technologies in nursing care by the modified Delphi method, DEMATEL, and DANP. This study adopts RFID as a new technology, in order to address the shortage of nursing care workers and to enhance management efficiency. We divide the research steps herein into three stages. First, the modified Delphi method determines the important indicators in nursing care when adopting an RFID system. Second, DEMATEL explores the causal relationships among factors. Finally, DANP measures the weight of each factor.

This study is divided into five parts as follows. The second part reviews the dimensions and criteria for adopting an RFID system in nursing homes. The third part describes the methods herein, including modified Delphi method, DEMATEL, and DANP. The fourth part discusses the empirical analysis results. The last part presents the conclusion of this study.

2. Theoretical background

Access to high-quality care is unequally distributed due to income, education, race, and ethnicity. The reality of long-term care has to be improved to the extent that high-quality care should be delivered to everybody in need and across different settings (Tesch-Romer and Wahl, 2017). The previous literature has discussed very little about the dimensions and criteria used by RFID systems in the healthcare industry. After reviewing the previous studies, this present research aggregates the relevant criteria to present the following assessment architecture.

2.1 Related literature about adopting RFID systems in nursing care

According to the World Health Organization (WHO), the proportion of the total population over the age of 60 will increase from 12% to 22% between 2015 and 2050 (World Health Organization, 2016), putting elderly nursing care under even greater pressure to take care of demand. The WHO has also proposed a global aging and health strategy and action plan. One of the goals is to create public places in metropolitan and residential areas that are inclusive, safe, and flexible and exhibit sustainable development, especially for the elderly population. The health of the elderly can be promoted by regular activities (Bean *et al.*, 2004; Singh, 2002), such as those that help strengthen muscles, aerobic capacity, balance, and flexibility, reduce incidences of chronic diseases, and improve sleep quality inside or outside of care wards (Sugiyama and Thompson, 2007). Because the health and safety of the elderly population are easily affected by their own functional state, there is a need for a quarantine social environment (Clarke and Nieuwenhuijsen, 2009; Shumway-Cook *et al.*, 2003; Wahl and Lang, 2003). As the demographic structure changes, the needs and expectations of society for nursing care have also changed. Therefore, under limited resources, effective arrangements and planning are essential by using technology to improve nursing care quality and management efficiency for all countries.

RFID has proven to be an effective tool for improving operational efficiency and gaining a competitive advantage in the healthcare industry (Iranmanesh *et al.*, 2017). When the needs of nursing care have their own particularity, RFID technology can quickly give the corresponding technical assistance. RFID systems consist of three components: an antenna, a reader, and a tag (Chen and Zhang, 2008). At present, RFID has broken bar code restrictions, such as manual scanning and reading one at a time, and its biggest features are high-speed reading, large reception, instant tracking, repeat reading and writing, and the ability to be used in harsh environments. RFID has been used in various fields, such as library management, drug safety, commodity security, and e-passports (Fan *et al*., 2005; Juels *et al*., 2005). Overall, RFID is able to get and deliver real-time, correct, and complete quantitative information (Huang *et al*., 2017).

Data mining technology and parallel computing technology allow for the analysis of large amounts of data. The information after analysis can then be used by care providers during nursing care or for improving management efficiency. It is easy to find a regular pattern of medical service error through RFID, which reduces medical risks. Moreover, direct access to data through an RFID system significantly decreases the likelihood of a loss of human input. Therefore, RFID improves the performance of an organization's health and competitiveness in the healthcare field (Lim and Koh, 2009). In addition to its implementation by businesses, RFID can also ensure the safety of patients (Wickboldt and Piramuthu, 2012).

2.2 Exploring the key indicators of adopting RFID system technology

Aging with a disability and the need for care challenge any individual, environment, and social context. There are effective strategies and resources for aging with care needs that support autonomy and quality of life in people's old age and hence foster successful aging (Tesch-Romer and Wahl, 2017). Coping resources and strategies might be differentially available to individuals, but overall they are efficient means to confront care needs (Gignac, Cott, and Badley, 2000). Successful aging with care needs depends, to a large extent, on environmental factors such as housing, technological equipment, provision of services, and neighborhood infrastructure (Tesch-Romer and Wahl, 2017). After a literature review, this study proposes a research architecture that contains five important dimensions as follows. Appendix I lists the definitions of all criteria.

2.2.1 Environment

Previous research has demonstrated that companies spend a long time to make a decision about adopting an RFID system since the basic strategic assessment of the market environment and its relationships with stakeholders is needed (Jones *et al*., 2005; Lee and Shim, 2007). In this study, "environment" refers to the relationship between stakeholders, including four criteria: vendors' technology (Dey *et al*., 2016; Lee and Shim, 2007; Mathew *et al*., 2013), integrated information systems (Mathew *et al*., 2013; Thong *et al*., 1996), government encouragement (Lin and Ho, 2009; Ramanathan *et al*., 2014), and electronic product code (Mathew *et al*., 2013; Smith, 2005).

2.2.2 Organization

Mathew *et al*. (2013) consider barriers to adopting RFID, including a lack of organizational support. The top management and employees in an organization take on key roles influencing innovation and change (Damanpour and Schneider, 2006; Meyer and Goes, 1988). In this study, "organization" refers to the wellness of an organization's internal staff, including four criteria: top management support (Lee and Shim, 2007; Mathew *et al*., 2013; Thong *et al*., 1996), cost-benefit evaluation (Lai and Guynes, 1997; Lee and Shim, 2007), demand planning (Lai and Guynes, 1997; Lee and Shim, 2007), and collaboration of inter-organization (Chwelos *et al*., 2001; Lee and Shim, 2007; Mathew *et al*., 2013).

2.2.3 Technology

When adopting an RFID system, one should consider the technology issue (Lee and Shim, 2007). Researchers argue that the choice of technology and the management of RFID are aspects that deserve attention (Najera *et al*., 2011; Wamba *et al*., 2013). This study refers to "technology" as technical specifications required for the organization's assessment, including six criteria: identification rate (Mathew *et al*., 2013; Wamba *et al*., 2013; Wyld, 2006), read range (Mathew *et al*., 2013), antenna attachment options (Mathew *et al*., 2013), technology reliability (Mathew *et al*., 2013; Wamba *et al*., 2013; Wyld, 2006), optional characters (Mathew *et al*., 2013), and system integration technology

(Mathew *et al*., 2013).

2.2.4 Cost

With respect to adopting the RFID system, costs must be considered, including initial software and hardware infrastructure costs, training, and RFID maintenance and upgrade costs (Mathew *et al*., 2013; Wamba *et al*., 2013). In this study, “cost” refers to the cost of the system, including five criteria: set-up cost (Lee and Shim, 2007; Luca, Riccardo, Giovanni, Alessandro, and Angela, 2015; Mathew *et al*., 2013), maintenance cost (Mathew *et al*., 2013), system integration costs (Luca *et al*., 2015; Mathew *et al*., 2013; Ranasinghe *et al*., 2005), customized cost (Mathew *et al*., 2013), and operating costs (Luca *et al*., 2015; Mathew *et al*., 2013).

2.2.5 Society

An RFID system may benefit the medical environment (Mathew *et al*., 2013; Rosenbaum, 2014; Wu *et al*., 2013), because managers also need to consider patient needs and data security. In this study, “society” refers to the use of RFID technology, as well as the need to consider the public and the feelings of caregivers, including five criteria: customer satisfaction (Lee and Shim, 2007; Luca *et al*., 2015; Phillips, 1966), privacy (Mathew *et al*., 2013; Ranasinghe *et al*., 2005; Rosenbaum, 2014), law and regulation/policy (Mathew *et al*., 2013; Rosenbaum, 2014), certification (Mathew *et al*., 2013; Rosenbaum, 2014; Wu *et al*., 2013), and public perception (Katz and Rice, 2009; Strickland and Hunt, 2005; Thiesse, 2007).

3. Methods

This study uses the MCDM model as an analytical method, because it takes into account the relationship among multiple dimensions or criteria. This will help the care agency to make the optimal decision. The MCDM model of this study is divided into three stages according to the analysis tools: modified Delphi method, DEMATEL, and DANP. The first stage employs the modified Delphi method to define the key factors from the experts. The second stage uses

DEMATEL to explore the causal relationship between factors and shows visual results. The third stage uses DANP to obtain the weights of dimensions and factors.

3.1 Stage 1: Modified Delphi method

Murry and Hammons (1995) present the modified Delphi method, in which its core concept is to obtain the best information about a topic from expert groups as defined by the researchers. The evaluation process of the Delphi method collects the data information by an anonymous questionnaire. After repeated confirmation and feedback, the researchers obtain consensus from the experts. The advantage of gathering and aggregating the opinions of a panel of experts by the Delphi method is its anonymity and iterative process (Hsu and Sandford, 2007). In order to prevent the opinion from being distorted, the experts work anonymously during the process (Löfmark and Mårtensson, 2017).

The pros of the Delphi method are that it is not only reliable and practical, but through anonymity, which helps reduce inaccurate results. The repeated and feedback mechanism also reduces personal bias. It not only takes into account the recommendations of the crowd, but also quickly converges the views of the subjects. It is said that the Delphi method is an objective decision-making method with group opinion and is an effective tool that is often used to analyze complex issues, assess the current situation, and improve policy quality and corporate transformation. The first round of the modified Delphi method constructs the questionnaire by the researcher and is based on the literature review, or through expert interviews, rather than from a traditional open questionnaire. After the Delphi method is modified, the expert or the subject can focus on the research topic. Moreover, the savings on time can decrease speculation on the open questionnaire, so as to improve its recovery rate. The modified Delphi method can be divided into five steps as follows.

Step 1: Build a topic structure

The establishment of the agenda comes from the way in which the documents are collated and through expert interviews, and the topic structure is proposed on the basis of the information collected.

Step 2: Selected expert group

As the Delphi method depends on the experience or intuition of the subject for judgment, contact is made with experts familiar with the subject. Researchers explain the topics so that the subjects can quickly understand the core idea and help facilitate the process. According to the size of the agenda and the scope of the number of experts, there are generally not more than 20 people.

Step 3: Establish and conduct questionnaires

The opinions of the experts are quantified by passing the subject structure through the scale, dichotomy, and hierarchical approaches.

Step 4: Give feedback of the questionnaire results to the experts and conduct the questionnaire again

Comments are consolidated and results are fed back to experts. The questionnaire is repeatedly issued until the same opinion arises.

Step 5: Integrate expert opinions on consistency

Obtain a reliable and objective research architecture about the important criteria.

3.2 Stage2: Decision making trial and evaluation laboratory

The Decision Making Trial and Evaluation Laboratory (DEMATEL) was developed between 1972 and 1976. Its core concept effectively combines expert knowledge and clarifies the causal association of variables. It is also possible to use factors that have different dependencies by converting the causal relationship of criteria into a clear structural model (Hori and Shimizu, 1999). Because DEMATEL is based on the graphical theory, the benefit of DEMATEL is that decision makers can better understand the complexity and imperceptible causality (Ortíz *et al*., 2016). Tamura and Akazawa (2005) note that DEMATEL is mainly for interdependence among multiple criteria and the degree of dependence. The evaluating process of DEMATEL analysis has five steps (Wu, 2008).

Step 1: Calculate the direct-relation matrix A

Evaluate the influence of m experts on the degree of influence between criteria. The m experts will point out the impact of criteria i on criteria j. The degree of influence scale is 0, 1, 2, 3, 4: 0 (no effect), 1 (low impact), 2 (medium impact), 3 (high impact), and 4 (very high influence) (Hung, 2011). After pairwise comparison, the degree of influence of an expert can be used to construct a matrix A, shown as Equation (1).

$$A = [a_{ij}]_{n\times n},\ a_{ij} = \frac{1}{m}\sum_{k=1}^{m} x_i^k \tag{1}$$

Step 2: Calculate the normalized direct-relation matrix *D*

Matrix *D* can be obtained by normalizing matrix *A* and can be obtained by using Equations (2) and (3). The diagonal of the matrix is 0, and the sum of the rows and columns is 1.

$$D = A/S \tag{2}$$

Let

$$\text{s} = \max\left(max_{1\le i\le n}\sum_{j=1}^{n} a_{ij}\,, max_{1\le j\le n}\sum_{i=1}^{n} a_{ij}\right)\ \ i,j = 1,2,\dots,n \tag{3}$$

Step 3: Calculate the total relation matrix *T*

The influence of a continuous decrease comes from the indirect effects among the criteria based on the powers of the matrix *D*, e.g., $D^2, D^3, \dots, D^{\infty}$, therefore guaranteeing convergent solutions to a matrix inversion similar to a Markov chain matrix. Note that $lim_{m->\infty} D^m = [0]_{n\times n}$ and $lim_{m->\infty}(D + D^2 + \cdots + D^m) = D(I-D)^{-1}$, where 0 is the null $n\times n$ matrix and I is the $n\times n$ identity matrix. The total relation matrix *T* is a $n\times n$ matrix and defined through Equation (4) as follows:

$$T = \lim_{m->\infty}(D + D^2 + D^3 + \cdots + D^m) = lim_{m->\infty} D(I-D)^{-1}$$

$$= [t_{ij}]\ \ i,j = 1,2,\dots,n \tag{4}$$

Step 4: Construct the causal diagram

Define r and c for $n\times 1$ vectors through the sum of the total relation matrix *T*, as shown in the following Equations (5) and (6):

$$r = [r_i]_{n\times 1} = \left(\sum_{j=1}^{n} t_{ij}\right)_{n\times 1} \tag{5}$$

$$c = [c_j]_{1\times n} = \left(\sum_{i=1}^{n} t_{ij}\right)_{1\times n} \tag{6}$$

Define $t_{ij}\,(i, j=1, 2, \dots, n)$ as the factors in the total relation matrix. Here, r_i

and c_j respectively denote the sum of rows and the sum of columns from the total-relation matrix *T*. The sum of the rows is denoted as vector r_i through Equation (5). The sum of the columns is denoted as c_j through Equation (6). The horizontal axis vector (r_i+c_j), named 'Prominence', is then made by adding r_i to c_j in order to reveal the importance. The vertical axis (r_i-c_j), named 'Relation', is made by subtracting c_j from r_i, which may divide criteria into a cause group and an effect group. When (r_i-c_j) is positive, the criterion belongs to the cause group; otherwise, if (r_i-c_j) is negative, then the criterion belongs to the effect group. The causal diagram can be acquired by mapping the dataset of (r_i+c_j, r_i-c_j), providing valuable insight for making decisions (Chang *et al.*, 2017; Tzeng, Chiang, and Li, 2007; Lu *et al.*, 2013).

3.3 Stage 3: Combine the ANP method for finding the influence weights of the criteria

We conduct the study using DEMATEL and ANP as DANP (DEMATEL-based ANP). The core concept of DANP is to know the different degrees of impact of the dimension from the total impact matrix obtained through DEMATEL. The total influence matrix T of DEMATEL is applied to the super-matrix of ANP. To confirm the influence and importance of each factor, this study adopts an RFID system as a decision-making reference. Yang, Shieh, Leu, and Tzeng (2008) argue that DEMATEL and ANP are suitable for complex real situations. Moreover, the pros of DANP do not need an assumption that the criteria are all independent. Therefore, this study uses DEMATEL to determine the interaction between the factors and to obtain the relationships among them. The normalized direct-relation matrix D of DEMATEL is applied to the super-matrix of DANP. Getting the causal relationship among the factors makes the research proposal more realistic. The operation process of DANP is as follows.

Step 1: Calculate the total influence matrix for criteria T_C

The total influence matrix $T_C = \left[t_{ij}\right]_{n\times n}$ is established using the DEMATEL method. The total influence matrix for the criteria is shown below as Equation (7):

$$T_c = \begin{array}{c} \\ D_1 \begin{array}{c} c_{11} \\ \vdots \\ c_{1m_1} \end{array} \\ \vdots \\ D_i \begin{array}{c} c_{i1} \\ \vdots \\ c_{im_i} \end{array} \\ \vdots \\ D_n \begin{array}{c} c_{n1} \\ \vdots \\ c_{nm_n} \end{array} \end{array} \overset{\begin{array}{ccccc} D_1 & \cdots & D_j & \cdots & D_n \\ c_{11}\cdots c_{1m_1} & & c_{1j}\cdots c_{jm_j} & & c_{n1}\cdots c_{nm_n} \end{array}}{\begin{bmatrix} T_c^{11} & \cdots & T_c^{1j} & \cdots & T_c^{1n} \\ \vdots & & \vdots & & \vdots \\ T_c^{i1} & \cdots & T_c^{ij} & \cdots & T_c^{in} \\ \vdots & & \vdots & & \vdots \\ T_c^{n1} & \cdots & T_c^{nj} & \cdots & T_c^{nn} \end{bmatrix}} \tag{7}$$

Step 2: Calculate the normalized total influence matrix for criteria T_C^{α}

We note T_C^{α} is shown as Equation (8) and is obtained by normalizing the total importance of the factor's effect on the matrix T_C .

$$T_c^{\alpha} = \begin{array}{c} \\ D_1 \begin{array}{c} c_{11} \\ \vdots \\ c_{1m_1} \end{array} \\ \vdots \\ D_i \begin{array}{c} c_{i1} \\ \vdots \\ c_{im_i} \end{array} \\ \vdots \\ D_n \begin{array}{c} c_{n1} \\ \vdots \\ c_{nm_n} \end{array} \end{array} \overset{\begin{array}{ccccc} D_1 & \cdots & D_j & \cdots & D_n \\ c_{11}\cdots c_{1m_1} & & c_{1j}\cdots c_{jm_j} & & c_{n1}\cdots c_{nm_n} \end{array}}{\begin{bmatrix} T_c^{\alpha 11} & \cdots & T_c^{\alpha 1j} & \cdots & T_c^{\alpha 1n} \\ \vdots & & \vdots & & \vdots \\ T_c^{\alpha i1} & \cdots & T_c^{\alpha ij} & \cdots & T_c^{\alpha in} \\ \vdots & & \vdots & & \vdots \\ T_c^{\alpha n1} & \cdots & T_c^{\alpha nj} & \cdots & T_c^{\alpha nn} \end{bmatrix}} \tag{8}$$

Among them, we obtained after normalization $T_C^{\propto 11}$, as shown in Equations (9) and (10). We use the same approach to get $T_C^{\propto nn}$.

$$d_{ci}^{11} = \sum_{j=1}^{m_1} t_{ij}^{11}, i = 1,2, \ldots, m_1 \tag{9}$$

$$T_c^{\alpha 11}=\begin{bmatrix} t_{c1m_1}^{11}/d_{c1}^{11} & \cdots & t_{c1m_1}^{11}/d_{c1}^{11} & \cdots & t_{c1m_1}^{11}/d_{c1}^{11} \\ \vdots & & \vdots & & \vdots \\ t_{c1m_1}^{11}/d_{c1}^{11} & \cdots & t_{c1m_1}^{11}/d_{c1}^{11} & \cdots & t_{c1m_1}^{11}/d_{c1}^{11} \\ \vdots & & \vdots & & \vdots \\ t_{c1m_1}^{11}/d_{c1}^{11} & \cdots & t_{c1m_1}^{11}/d_{c1}^{11} & \cdots & t_{c1m_1}^{11}/d_{c1}^{11} \end{bmatrix}$$

$$=\begin{bmatrix} t_{c11}^{\alpha 11} & \cdots & t_{c1j}^{\alpha 11} & \cdots & t_{c1m_1}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{\alpha 11} & \cdots & t_{cij}^{\alpha 11} & \cdots & t_{cim_1}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{cm_11}^{\alpha 11} & \cdots & t_{cm_1j}^{\alpha 11} & \cdots & t_{cm_1m_1}^{\alpha 11} \end{bmatrix} \quad (10)$$

Here, $t_{cij}^{\alpha 11}=t_{c1m_1}^{11}/d_{c1}^{11}$ represents after normalization of the elements, and t_{cij}^{11} displays how dimension 1 element *i* affects dimension 1 element *j* in the total influence matrix.

Step 3: Calculate the unweighted super-matrix *W*

We convert *W* through the normalization of the total matrix $T_C^{\propto}$. The total impact matrix T_C shows the interdependencies among dimensions and criteria. We convert the normalized influence matrix T_c^{α} to the unweighted matrix $W=(T_C^{\alpha})'$ by the result of the basic concept of dimensions, as shown in Equation (11).

$$W=(T_c)'=\begin{matrix} & & \begin{matrix} D_1 & \cdots & D_i & \cdots & D_n \\ c_{11}\cdots c_{1m_1} & & c_{i1}\cdots c_{im_i} & & c_{n1}\cdots c_{nm_n} \end{matrix} \\ \begin{matrix} D_1 \\ \vdots \\ D_j \\ \vdots \\ D_n \end{matrix} & \begin{matrix} c_{11}\ \vdots\ c_{1m_1} \\ \\ c_{j1}\ \vdots\ c_{jm_j} \\ \\ c_{n1}\ \vdots\ c_{nm_n} \end{matrix} & \begin{bmatrix} W^{11} & \cdots & W^{i1} & \cdots & W^{n1} \\ \vdots & & \vdots & & \vdots \\ W^{1j} & \cdots & W^{ij} & \cdots & W^{nj} \\ \vdots & & \vdots & & \vdots \\ W^{1n} & \cdots & W^{in} & \cdots & W^{nn} \end{bmatrix} \end{matrix} \quad (11)$$

Step 4: Calculate the weighted super-matrix W^{α}

We obtain the weighted super-matrix W^{α} by the weight matrix *W*. We multiply the unweighted super-matrix W by the generalized influence matrix T_D^{α}. Among them, the normalized total influence matrix T_D^{α} can be obtained by using the normalized total influence matrix T_D, and the matrix as shown in Equation (12).

$$T_D = \begin{bmatrix} t_D^{11} & \cdots & t_D^{1j} & \cdots & t_D^{1n} \\ \vdots & & \vdots & & \vdots \\ t_D^{i1} & \cdots & t_D^{ij} & \cdots & t_D^{in} \\ \vdots & & \vdots & & \vdots \\ t_D^{n1} & \cdots & t_D^{nj} & \cdots & t_D^{nn} \end{bmatrix} \tag{12}$$

Thus, the total influence matrix T_D^{α} as shown by Equation (13) can be normalized by the total influence matrix T_D (where $t_D^{\alpha ij} = t_D^{ij} / d_i$ and $d_i = \sum_{j=1}^{n} t_D^{ij} / d_i$).

$$T_D^{\alpha} = \begin{bmatrix} t_D^{11}/d_1 & \cdots & t_D^{1j}/d_1 & \cdots & t_D^{1n}/d_1 \\ \vdots & & \vdots & & \vdots \\ t_D^{i1}/d_i & \cdots & t_D^{ij}/d_i & \cdots & t_D^{in}/d_i \\ \vdots & & \vdots & & \vdots \\ t_D^{n1}/d_n & \cdots & t_D^{nj}/d_n & \cdots & t_D^{nn}/d_n \end{bmatrix} = \begin{bmatrix} t_D^{\alpha 11} & \cdots & t_D^{\alpha 1j} & \cdots & t_D^{\alpha 1n} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha i1} & \cdots & t_D^{\alpha ij} & \cdots & t_D^{\alpha in} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha n1} & \cdots & t_D^{\alpha nj} & \cdots & t_D^{\alpha nn} \end{bmatrix} \tag{13}$$

We next show that the weighted super-matrix W^{α} in Equation (14) is obtained by multiplying the normalized total influence matrix of the dimensions T_D^{α} with the unweighted super-matrix *W*.

$$W^{\alpha} = T_D^{\alpha} W = \begin{bmatrix} t_D^{\alpha 11} \times W^{11} & \cdots & t_D^{\alpha i1} \times W^{i1} & \cdots & t_D^{\alpha n1} \times W^{n1} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1j} \times W^{1j} & \cdots & t_D^{\alpha ij} \times W^{ij} & \cdots & t_D^{\alpha ni} \times W^{ni} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1n} \times W^{1n} & \cdots & t_D^{\alpha in} \times W^{in} & \cdots & t_D^{\alpha nn} \times W^{nn} \end{bmatrix} \quad (14)$$

Step 5: Calculate the limit super-matrix

By multiplying the weighted super-matrix many times to obtain the limit super-matrix, we can get the weight of each evaluation factor. The limit of the super-matrix $\lim_{\alpha -> \infty} W^{\alpha}$, α , is any number. The weight of each evaluation factor can thus be obtained.

This study establishes the effect of the factor using DEMATEL to determine the relationship among factor interactions. In order to give a more perfect reference, we use DANP to find the factor weight. ANP is a generalization of AHP and solves the program or factor dependency and feedback issues.

4. Results

In order to construct a model that affects the adoption of an RFID system, the study uses the modified Delphi method to confirm the dimensions and factors that should be available. Using the results of the DEMATEL method, we obtain the relationship among factors. The DANP method not only analyzes the relationship among the criteria, but also more specifically analyzes the differences among the importance of factors. The results of the study help establish a key factors framework and analyze their interrelations.

4.1 Stage 1: Identify the key factors by using the modified Delphi method

Based on the assessment of the radio frequency system adopted by the care organization, this study develops a five-dimension conceptual framework and prepares a list of preliminary indicators in various fields.

This study summarizes the literature review and interviews with experts and puts forward its subject structure. There are five dimensions, which include twenty-four criteria, that must be considered when adopting the RFID system. There are 14 experts with technical or academic knowledge of technical development or nursing care management. The experts in the decision making and discussion have experience from two years to ten years. Academic experts have five years to ten years of experience. The study data were collected in 2014 through personal interviews with the questionnaire survey. The questionnaires were repeated until the experts' opinions came to an agreement (Saaty, 1990). In determining the indicators, this study designs an assessment questionnaire for the experts, where the importance scale of the criteria is 1, 2, 3, 4, 5, 6, 7: 1(strongly disagree), 2 (disagree), 3 (slightly disagree), 4 (undecided), 5 (slightly agree), 6 (agree), and 7 (strongly disagree). The threshold value of the assessment consistency is set to an average number greater than 5, and the quartile difference is less than 1. A mean value of five points or more indicates that the factor is considered to be important through expert evaluation. A value of quartile difference less than 1 means the opinions of all experts are consistent. In this study, the results of the first round show that no criteria have been removed, and the results are provided for the second confirmation. Finally, all the criteria are given expert consensus (see Table 1).

4.2 Stage 2: Construct the causal diagram by using DEMATEL

Through interviews with the experts and the questionnaire, we can calculate the initial average matrix A. According to the calculation formula of Stage 2, we arrive at the direct influence matrix D and the total relation matrix. The causal diagram (see Fig. 1) or causal diagram of the factor can then be drawn through the total relation matrix. Second, the related and prominent factors are calculated as the coordinates of the X-axis and Y-axis and are displayed in the causal diagram (see Table 2). It is essential to set a threshold value to filter out the negligible effects, in order to explain the structural relationship among the factors for keeping the complexity of the system to a manageable level. This study uses the maximum mean de-entropy algorithm to set the threshold value (Li and Tzeng, 2009; Chen *et al*., 2013). The negligible effects can be filtered out by the threshold value in matrix *T*. Using the values of r*i* (t) and c*i* (t) from the matrix of full direct and indirect-influence relationship, the level of dispatching and of receiving from the influence of factor *i* can be defined. The

Table 1
Determine the factors by modified Delphi method

Dimensions/Criteria	First (1 st)		Second (2 nd)	
	Mean	QD	Mean	QD
Environment (D1)				
C11. Vendors' technology	6.00	0.38	6.29	0.50
C12. Integrated information systems	6.21	0.88	6.07	0.50
C13. Government encouragement	5.29	1.00	5.79	0.50
C14. Electronic Product Code	6.36	0.50	6.14	0.50
Organization (D2)				
C21. Top management support	6.21	0.50	6.36	0.50
C22. Cost-benefit evaluation	5.93	0.00	6.14	0.50
C23. Demand planning	6.21	0.50	6.50	0.50
C24. Collaboration of inter-organization	5.57	0.50	5.79	0.00
Technology (D3)				
C31. Identification rate	6.36	0.50	6.57	0.38
C32. Read Range	6.07	0.50	5.93	0.38
C33. Antenna attachment options	6.36	0.50	6.43	0.50
C34. Technology reliability	6.36	0.50	6.64	0.50
C35. Optional Characters	6.50	0.50	6.36	0.50
C36. System integration technology	6.43	0.50	6.64	0.38
Cost (D4)				
C41. Set-up cost	6.43	0.50	6.50	0.50
C42. Maintenance cost	6.21	0.50	6.21	0.50
C43. System integration costs	6.14	0.50	6.21	0.50
C44. Customized Cost	6.00	0.50	6.07	0.50
C45. Operating costs	6.07	0.88	6.07	0.00
Society (D5)				
C51. Customer satisfaction	5.71	0.38	5.79	0.50
C52. Privacy	6.14	0.88	6.21	0.50
C53. Law and regulation/Policy	6.07	1.00	6.29	0.50
C54. Certification	5.93	0.00	6.21	0.50
C55. Public perception	5.71	0.50	5.79	0.00

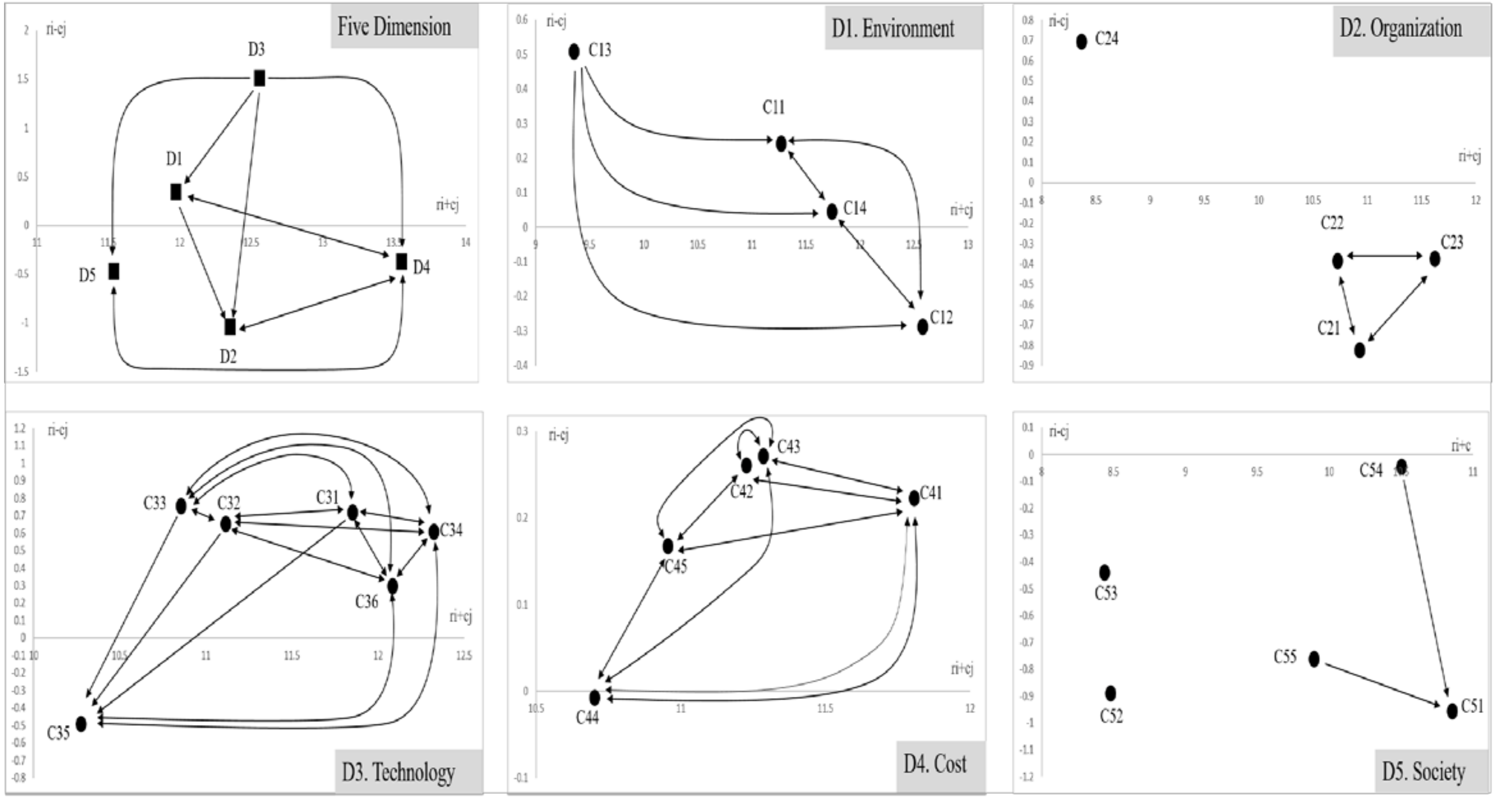

Figure 1
The causal diagram about the relationship among the five dimension and twenty-four criteria

Table 2
The calculated direct and indirect effects of the twenty-four criteria by the DEMATEL method

Dimensions/Criteria	r	c	r + c	r − c
Environment (D1)	6.162	5.811	11.973	0.351
C11. Vendors' technology	5.756	5.512	11.268	0.243
C12. Integrated information systems	6.147	6.433	12.58	−0.286
C13. Government encouragement	4.932	4.421	9.352	0.511
C14. Electronic product code	5.892	5.846	11.738	0.046
Organization (D2)	5.657	6.695	12.351	−1.038
C21. Top management support	5.054	5.876	10.93	−0.822
C22. Cost-benefit evaluation	5.171	5.554	10.725	−0.384
C23. Demand planning	5.624	5.996	11.62	−0.372
C24. Collaboration of inter-organization	4.531	3.833	8.364	0.697
Technology (D3)	7.037	5.519	12.556	1.517
C31.Identification rate	6.286	5.566	11.852	0.72
C32. Read Range	5.883	5.231	11.114	0.652
C33. Antenna attachment options	5.806	5.049	10.855	0.757
C34. Technology reliability	6.466	5.859	12.324	0.607
C35. Optional characters	4.89	5.383	10.273	−0.493
C36. System integration technology	6.191	5.894	12.085	0.297
Cost (D4)	6.59	6.959	13.549	−0.369
C41. Set-up cost	6.015	5.792	11.807	0.223
C42. Maintenance cost	5.744	5.482	11.226	0.261
C43. System integration costs	5.779	5.506	11.285	0.272
C44. Customized cost	5.348	5.355	10.702	−0.007
C45. Operating costs	5.562	5.394	10.956	0.168
Society (D5)	5.537	5.999	11.536	−0.462
C51. Customer satisfaction	4.951	5.906	10.857	−0.955
C52. Privacy	3.795	4.684	8.478	−0.889
C53. Law and regulation/Policy	3.998	4.438	8.435	−0.44
C54. Certification	5.229	5.275	10.503	−0.046
C55. Public perception	4.565	5.328	9.893	−0.762

r: Sum of rows total from the total-relation matrix T
c: Sum of columns total from the total-relation matrix T
r+c: Prominence of factors
r−c: Relation of factors

interrelationship of each factor can be visualized as the oriented graphs on a two-dimensional plane after a certain threshold is set. Li and Tzeng (2009) point out the threshold value can be chosen by the decision maker or by following experts' discussions. The effect in matrix *T* greater than the threshold value appears in the causal diagram.

We finally draw the key factor into a causal diagram. The threshold is used as the screening index, and the causal relationship below the threshold is considered to be low. Through this screening process, the causal relationship can be made clearer. The causal diagram shows that five dimensions have an interdependent relationship. The graph of these the five dimension and twenty-four criteria are depicted in Figure 1; the single-headed arrows represent the direct effect of the factor on others; the double-headed arrows represent effects in both directions. For example, Figure 1 (Five Dimension) shows D3 directly affects D1, D2, D4, and D5. Therefore, it can be concluded that D3 (Technology) is the most influential dimension. In other words, the first stage of adopting an RFID system in nursing care is to confirm the technical capabilities, including the identification rate, read range, and technology reliability. With respect to Figure 1 (D1. Environment), C_{13} directly affects other criteria, and C_{11} is mutually affected by C_{12} and C_{14}. In Figure 1 (D2. Organization), C_{21} is mutually affected by C_{22} and $C_{23.}$ In Figure 1 (D3. Technology), C_{35} is the affecting factor. In addition, C_{31}, C_{32}, C_{33}, C_{34}, and C_{36} are affected by each other. In Figure 1 (D4. Cost), all criteria are affected by each other. For Figure 1 (D5. Society), C_{51} is affected by C_{54} and C_{55}.

4.3 Stage 3: Finding the influence weights of the criteria by using DANP

With the Super Decision software, we can get the weights and order (see Table 3). Through DANP, we obtain the weights of the factors, which shall be considered for adopting RFID system in nursing care. In order to obtain the weight of each factor, an unweighted super-matrix and weighted super-matrix are established by constructing DEMATEL and DANP techniques to construct a comparison between the evaluation models that affect the adoption of the RFID system. The super-matrix limit is used to achieve long-term stable conditions, with each column representing the weight of each factor. The order of the criteria

Table 3
Evaluation the weight of the five dimension and twenty-four criteria by DANP

Dimensions/Criteria	Local weight (Rank)	Global weight (Rank)
Environment (D1)	0.202 (3)	
C11. Vendors' technology	0.193 (3)	0.039 (11)
C12. Integrated information systems	0.530 (1)	0.107 (3)
C13. Government encouragement	0.000 (4)	0.000 (22)
C14. Electronic product code	0.277 (2)	0.056 (8)
Organization (D2)	0.228 (1)	
C21. Top management support	0.271 (2)	0.062 (5)
C22. Cost-benefit evaluation	0.251 (3)	0.057 (7)
C23. Demand planning	0.479 (1)	0.109 (2)
C24. Collaboration of inter-organization	0.000 (4)	0.000 (22)
Technology (D3)	0.181 (5)	
C31.Identification rate	0.142 (3)	0.026 (17)
C32. Read Range	0.079 (5)	0.014 (19)
C33. Antenna attachment options	0.058 (6)	0.011 (20)
C34. Technology reliability	0.273 (2)	0.049 (9)
C35. Optional characters	0.118 (4)	0.021 (18)
C36. System integration technology	0.331 (1)	0.060 (6)
Cost (D4)	0.185 (4)	
C41. Set-up cost	0.376 (1)	0.069 (4)
C42. Maintenance cost	0.156 (3)	0.029 (14)
C43. System integration costs	0.160 (2)	0.030 (13)
C44. Customized cost	0.154 (5)	0.028 (16)
C45. Operating costs	0.155 (4)	0.029 (15)
Society (D5)	0.204 (2)	
C51. Customer satisfaction	0.613 (1)	0.125 (1)
C52. Privacy	0.034 (4)	0.007 (21)
C53. Law and regulation/Policy	0.000 (5)	0.000 (22)
C54. Certification	0.158 (3)	0.032 (12)
C55. Public perception	0.196 (2)	0.040 (10)
Average		0.042

weight is Customer satisfaction (0.125), Demand planning (0.109), Integrated information systems (0.107), Set-up cost (0.069), Top management support (0.062), System integration technology (0.060), Cost-benefit evaluation (0.057), Electronic Product Code (0.056), and Technology reliability (0.049). The nine indicators of the right planting are greater than the average weight (0.042), representing that they are relative important criteria.

5. Conclusions

The goal of care service is to meet the potential needs of the customers as much as possible in order to attract or retain them (Ortíz *et al.*, 2016). The quality of care has been affected recently by the growing shortage of nurses as well as the increased prevalence of chronic diseases. Many countries also have these phenomena, such as in the United States. Although long-term care service in the past few decades has changed, technological innovations have also altered this field (George and Ferraro, 2015). The adoption of new information technology systems in nursing care has occurred in order to overcome many of these challenges and pressure from the external environment of the organization such as high operating costs, poor access, and undesirable outcomes drives (Dey *et al*., 2016; Yee-Loong Chong and Ooi, 2008). Therefore, this study provides a comprehensive assessment framework that identifies important influencing factors and identifies the causal relationships among the factors. It also provides guidance for managers about the improvement of care quality by raising the value of the applied technical system and reducing unnecessary costs.

MCDM in social science and planning is often used as a decision making method, because it can simultaneously consider multiple elements that correspond or conflict with each other. There are three contributions from the methodology of this study. First, we use the modified Delphi method to obtain important and reliable indicators. Experts indicate the importance of the criteria through a few rounds of an assessment and feedback mechanism. After repeated implementation, expert consensus and reliable advice were collected. Second, using the DEMATEL method, the results show that the causal relationship is clearer by visualizing the causal diagram. Finally, DANP was used to calculate the weight of the factors and to sort them. This study examines the interdependence among factors, making the results of the analysis more realistic. The evaluation architecture of this study is comprehensive and pursues more outstanding decision making methods that can help managers improve their planning.

The RFID system is considered to be the most commonly used technique for tracking equipment, supplies, patients, and workers (Meyer and Hoppszaller, 2011). Although RFID systems have been widely used in various fields, the medical field and the care industry have not yet fully adopted them. Reyes *et al*. (2012) point out that more research is needed to understand the RFID implementation challenges so that practitioners can use this information to guide their adoption decisions. The practical contribution of this study regarding the adoption of an RFID system in nursing homes is that it could improve service to an aging society. The service, which considers care needs, could help to change the organization and practice of long-term care and contribute to a change in the culture of care in long-term care settings (Shura, Siders, and Dannefer, 2010).

The results of the study show that the five dimension and twenty-four criteria are used for the implementation of care services. Moreover, the most influential dimension is technology. The dimension that is most related to the other dimensions is cost. The ranking of dimensions by importance is organization, society, environment, cost, and technology. This rank can be used as an effective guide before a nursing care organization adopts an RFID system. The results show that the most important dimension is organizational. The use of technology has a long-term influence on any organization with employees. In the early days, organizations excluded disregarded employees' views or opinions in the adoption of new technologies, but as employees are the main executors of an adoptive action, their positive attitude will help make an adoption plan go more smoothly. Society is ranked as the second most important dimension. The main users are caregivers. Therefore, the organization must carefully assess customers' needs before adopting the new technology. Providing consumers with the right products will achieve a higher willingness to use them. The third important dimension is environment. It is important to have good communication with many related stakeholders during the execution of any program. In other words, a strong relationship of cooperation between the nursing home and other relevant stakeholders helps in the implementation of the program. On the other hand, suppliers and buyers also need to coordinate with each other's professional and technical ability to cooperate with each other or achieve the desired goal. The fourth important dimension is cost. Nursing homes need to find more sponsors, such as seeking assistance from government units or cross-industry cooperation. The last important dimension is environment. One of the key factors of success is overall technical reliability. Excellent technical support will help with the process, and a warranty or service of the technology is a must after adoption.

Consolidating the above results, the contribution of this study focuses on the relative important and influential factors. Technological experts and investors can enhance the application value of an RFID system by improving nursing care service quality and management efficiency. Moreover, as organizations must rely on an open innovation process to solve problems (Chou *et al*., 2016), the RFID system's messaging technology happens to solve the insufficient manpower problem of nursing care. On the other hand, the environment in which customers receive care services under an RFID system means that privacy should not be interrupted and that the customer's message is immediately delivered to the institution. When customers feel that a service has higher value, they will also have higher loyalty to the organization's reputation and brand (Chou and Chen, 2016). In the long run, the trajectory of financial indicators can help determine whether the organization can continue to create value and achieve continuous performance (Liou and Tsai, 2016). The limitation of this study is that it employs the Likert scale to quantify the crisp value of the subject. Future research can apply fuzzy numbers to reduce the deviation of experts' judgments.

Appendix I
Definitions of all criteria

Dimension	Criteria	Definition	Reference
D1. Environment	C11.vendors' technology	A RFID system can track the care service of an institution. Thus, when cooperation between the upstream and downstream of the nursing care industry (hospitals, health examination centers, community support, and pharmacy) is more complete, an organization can provide better services.	Dey *et al*. (2016); Lee and Shim (2007); Mathew *et al*. (2013)
	C12. Integrated information systems	If upstream and downstream suppliers (hospitals, health examination centers, and offices of citizenship) cannot provide the same technology, then the whole supply chain might not be connected and the system will not be effective.	Mathew *et al*. (2013); Thong *et al*. (1996)
	C13. Government encouragement	When adopting new technology, nursing care organizations might encounter enormous expenditures. Support from the government can help lower the financial burden of an organization.	Lin and Ho (2009); Ramanathan *et al*. (2014)
	C14. Electronic product code	Regarding a closed loop system, information exchange in and out of a system is not important. However, with the prevalence of a RFID system, a unified system becomes critical.	Mathew *et al*. (2013); Smith (2005)
D2. Organization	C21. Top management support	For any reform or introduction of new technology by a care organization, high-ranking supervisors' support and identification will lower any possible resistance by the care organization when adopting a RFID system.	Lee and Shim (2007); Mathew *et al*. (2013); Thong *et al*. (1996)
	C22. Cost-benefit evaluation	Since capital might influence the adoption of new technology, complete budgeting will allow a care organization to immediately propose responsive measures when encountering a crisis of capital. Hence, the implementation of the project will not be halted.	Lai and Guynes (1997); Lee and Shim (2007)

Appendix I
Definitions of all criteria (continued)

Dimension	Criteria	Definition	Reference
D2. Organization	C23. Demand planning	In order to precisely satisfy the needs of those with demands, before any adoption a care organization should conduct a thorough demand evaluation on the subjects.	Lai and Guynes (1997); Lee and Shim (2007)
	C24. Collaboration of inter-organization	The process of care requires all organizational employees' cooperation. Employees' close cooperation can lower information asymmetry of a care organization and help with its success during the process of adoption.	Chwelos *et al*. (2001); Lee and Shim (2007); Mathew *et al*. (2013)
D3. Technology	C31. Identification rate	An organization must avoid any interference of external factors and a lower reading rate. It might have to evaluate the suppliers in advance according to their technology maturity and reliability.	Mathew *et al*. (2013); Wamba *et al*. (2013); Wyld (2006)
	C32. Read range	Before adopting RFID system technology, in order to avoid other factors that lower data transmission efficacy of the system, a care organization might have to improve reading distance in advance.	Mathew *et al*. (2013)
	C33. Antenna attachment options	In order to avoid a failure of identification by the system and reduction of efficacy, a care organization might have to cope with factors that will possibly interfere with devices.	Mathew *et al*. (2013)
	C34. Technology reliability	Numerous suppliers design RFID systems. A care organization must first communicate with RFID system suppliers and evaluate the devices designed regarding the criteria of the organization.	Mathew *et al*. (2013); Wamba *et al*. (2013); Wyld (2006)
	C35. Optional characters	Regarding different demands, a RFID system should be wear-resistant, waterproof, and foldable and exhibit continuous data transmission that can influence the efficacy of care.	Mathew *et al*. (2013)

Appendix I
Definitions of all criteria (continued)

Dimension	Criteria	Definition	Reference
D3. Technology	C36. System integration technology	When interfaces between reader/writer and host are not common, users might have to undertake unnecessary expenses that lower the outcome of an organization to adopt a RFID system.	Mathew *et al.* (2013)
D4. Cost	C41. Set-up cost	Construction of a system is an enormous expenditure for an organization at the early stage. An organization might have to assess the budget.	Lee and Shim (2007); Luca *et al.* (2015); Mathew *et al.* (2013)
	C42. Maintenance cost	In order to extend the life of a device, it is essential to regularly maintain, upgrade, and repair the device. Thus, when a care organization adopts new technology, it might have to be concerned about the cost of device maintenance.	Mathew *et al.* (2013)
	C43. System integration costs	In order to combine new and old devices, a care organization might have to modify part of the original functions of a system. A care organization should be concerned about the expenditure caused by technical integration in advance.	Luca et al. (2015); Mathew *et al.* (2013); Ranasinghe *et al.* (2005)
	C44. Customized cost	Applications of RFID systems are broad. However, in order to respond to different users, an organization might have to establish one customized system with RFID system design suppliers to meet the demand of the organization.	Mathew *et al.* (2013)
	C45. Operating costs	For continuous operation of a device, an organization might have to develop a budget according to potential expenditures in the operational process.	Luca *et al.* (2015); Mathew *et al.* (2013)

Appendix I
Definitions of all criteria (continued)

Dimension	Criteria	Definition	Reference
D5. Society	C51. Customer satisfaction	High satisfaction not only enhances an organization's confidence toward continuous promotion and modification, but also results in positive word-of-mouth. Thus, it facilitates future implementation by the organization.	Lee and Shim (2007); Luca *et al*. (2015); Phillips (1966)
	C52. Privacy	Aside from information in advance, in order to enhance users' confidence, an organization must strictly control internal information. Construction of mutual trust can be an extremely critical factor for sustainable operation.	Mathew *et al*. (2013); Ranasinghe *et al*. (2005); Rosenbaum (2014)
	C53. Law and regulation/policy	Procedures in an organization are closely connected and they affect each other. A care organization might have to complement the dimension in advance to adhere to laws. Thus, any reform of laws can lower the loss.	Mathew *et al*. (2013); Rosenbaum (2014)
	C54. Certification	Currently, RFID system products developed by well-known foreign companies must be certified in terms of electromagnetic compatibility, environment, and national product safety. If a care organization can pass the criteria, then it can facilitate the implementation of the project.	Mathew *et al*. (2013); Rosenbaum (2014); Wu *et al*. (2013)
	C55. Public perception	With progress of medical technology and social change, an organization must satisfy social needs. Society also expects positive performance from the organization. The adoption of new technology can influence the social view toward the organization.	Katz and Rice (2009); Strickland and Hunt (2005); Thiesse (2007)

References

Bauer, L. and Bodenheimer, T. (2017). Expanded roles of registered nurses in primary care delivery of the future. *Nurs Outlook*.

Bean, J. F., Vora, A., and Frontera, W. R. (2004). Benefits of exercise for community-dwelling older adults. *Arch Phys Med Rehabil, 85*(7 Suppl 3), S31-42; quiz S43-34.

Chang, D. S., Liu, S. M., and Chen, Y. C. (2017). Applying DEMATEL to assess TRIZ's inventive principles for resolving contradictions in the long-term care cloud system. *Industrial Management and Data Systems, 117*(6), 1244-1262.

Charnes, A., Cooper, W. W., and Ferguson, R. O. (1955). Optimal estimation of executive compensation by linear programming. *Management Science, 1*(2), 138-151.

Chen, Y. and Zhang, F. H. (2008). *A system design for UHF RFID reader.* Paper presented at the Communication Technology, 2008. ICCT 2008. 11th IEEE International Conference on.

Chen, C. A., Lee, H. L., Yang, Y. H., and Lee M. H. (2013). Develop Taiwan's Nation Brand with a cultural perspective. *Chiao Da Management Review, 2*, 181-207.

Chou, C. K. and Chen, M. L. (2016). A qualitative study on perceived value and loyalty: A moderated-mediation framework. *Corporate Management Review, 36*(2), 105-122.

Chou, C., Yang, K. P., and Chiu, Y. J. (2016). Coupled open innovation and innovation performance outcomes: Roles of absorptive capacity. *Corporate Management Review, 36*(1), 37-68.

Chwelos, P., Benbasat, I., and Dexter, A. S. (2001). Empirical test of an EDI adoption model. *Information Systems Research, 12*(3), 304-321.

Clarke, P. and Nieuwenhuijsen, E. R. (2009). Environments for healthy ageing: A critical review. *Maturitas, 64*(1), 14-19.

Dalkey, N. and Helmer, O. (1963). An experimental application of the Delphi method to the use of experts. *Management Science, 9*(3), 458-467.

Damanpour, F. and Schneider, M. (2006). Phases of the adoption of innovation in organizations: Effects of environment, organization and top managers. *British*

Journal of Management, 17(3), 215-236.

Dey, A., Dey, A., Vijayaraman, B., Vijayaraman, B., Choi, J. H., and Choi, J. H. (2016). RFID in US hospitals: An exploratory investigation of technology adoption. *Management Research Review, 39*(4), 399-424.

Flores, C. and Cabigao, E. (2014). *Long-term Care Administration and Management: Effective Practices and Quality Programs in Eldercare*. Springer Publishing Company.

George, L. and Ferraro, K. (2015). *Handbook of Aging and the Social Sciences*. Academic Press.

Gignac, M. A., Cott, C., and Badley, E. M. (2000). Adaptation to chronic illness and disability and its relationship to perceptions of independence and dependence. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 55*(6), 362-372.

Gott, M. and Ingleton, C. (2011). *Living with Ageing and Dying: Palliative and End of Life Care for Older People*. OUP Oxford.

Hayes, B., Bonner, A. N. N., and Pryor, J. (2010). Factors contributing to nurse job satisfaction in the acute hospital setting: A review of recent literature. *Journal of Nursing Management*, *18*(7), 804-814.

Herazo-Padilla, N., Montoya-Torres, J. R., Muñoz-Villamizar, A., Isaza, S. N., and Polo, L. R. (2013). Coupling ant colony optimization and discrete-event simulation to solve a stochastic location-routing problem. Paper presented at the Proceedings of the 2013 Winter Simulation Conference: Simulation: Making Decisions in a Complex World.

Hori, S. and Shimizu, Y. (1999). Designing methods of human interface for supervisory control systems. *Control Engineering Practice, 7*(11), 1413-1419.

Hsu, C. C. and Sandford, B. A. (2007). The Delphi technique: making sense of consensus. *Practical Assessment, Research and Evaluation, 12*(10), 1-8.

Huang, S., Guo, Y., Zha, S., Wang, F., and Fang, W. (2017). A real-time location system based on RFID and UWB for digital manufacturing workshop. *Procedia CIRP, 63*, 132-137.

Hung, S. J. (2011). Activity-based divergent supply chain planning for competitive advantage in the risky global environment: A DEMATEL-ANP fuzzy goal programming approach. *Expert Systems with Applications, 38*(8), 9053-9062.

Iranmanesh, M., Zailani, S., and Nikbin, D. (2017). RFID continuance usage intention in health care industry. *Quality Management in Healthcare, 26*(2), 116-123.

Ismail, N. I., Abdullah, N. H., and Shamsuddin, A. (2015). Adoption of hospital information system (HIS) in Malaysian Public Hospitals. *Procedia - Social and Behavioral Sciences, 172* (Supplement C), 336-343.

Jones, P., Clarke-Hill, C., Hillier, D., and Comfort, D. (2005). The benefits, challenges and impacts of radio frequency identification technology (RFID) for retailers in the UK. *Marketing Intelligence and Planning, 23*(4), 395-402.

Juels, A., Molnar, D., and Wagner, D. (2005). Security and privacy issues in E-passports. Paper presented at the Security and Privacy for Emerging Areas in Communications Networks, 2005. SecureComm 2005. First International Conference on.

Katz, J. E. and Rice, R. E. (2009). Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology. *International Journal of Medical Informatics, 78*(2), 104-114.

Lai, V. S. and Guynes, J. L. (1997). An assessment of the influence of organizational characteristics on information technology adoption decision: a discriminative approach. *IEEE Transactions on Engineering Management, 44*(2), 146-157.

Lee, C. P. and Shim, J. P. (2007). An exploratory study of radio frequency identification (RFID) adoption in the healthcare industry. *European Journal of Information Systems, 16*(6), 712-724.

Li, C. W. and Tzeng, G. H. (2009). Identification of a threshold value for the DEMATEL method using the maximum mean de-entropy algorithm to find critical services provided by a semiconductor intellectual property mall. *Expert Systems with Applications, 36*(6), 9891-9898.

Lim, S. H. and Koh, C. E. (2009). RFID implementation strategy: Perceived risks and organizational fits. *Industrial Management and Data Systems, 109*(8), 1017-1036.

Lin, C. Y. and Ho, Y. H. (2009). An empirical study on the adoption of RFID technology for logistics service providers in China. *International Business Research, 2*(1), 23.

Liou, F. M. and Tsai, Y. H. (2016). Latent trajectories of competitive heterogeneity: Bridging the gap in theories between persistent performance and value creation. *Corporate Management Review, 36*(1), 1-36.

Löfmark, A. and Mårtensson, G. (2017). Validation of the tool assessment of clinical education (AssCE): A study using Delphi method and clinical experts. *Nurse education today, 50,* 82-86.

Luca, G., Riccardo, M., Giovanni, M., Alessandro, P., and Angela, T. (2015). Measuring the benefits of tracking medical treatment through RFId. *International Journal of Productivity and Performance Management, 64*(2), 175-193. 10.1108/IJPPM-10-2013-0171

Lu, M. T., Lin, S. W., and Tzeng, G. H. (2013). Improving RFID adoption in Taiwan's healthcare industry based on a DEMATEL technique with a hybrid MCDM model. *Decision Support Systems, 56,* 259-269.

Mathew, J., John, J., and Kumar, S. (2013). New trends in healthcare supply chain. Paper presented at the International Annual Conference, Production and Operations Management Society, Denver, Colorodo.

Meyer, A. D. and Goes, J. B. (1988). Organizational assimilation of innovations: A multilevel contextual analysis. *Academy of Management Journal, 31*(4), 897-923.

Meyer, H. and Hoppszaller, S. (2011). Maximum protection. Spending remains a priority amid hospital safety challenges. *Health Facilities Management, 24*(10), 21.

Murry, J., John W., and Hammons, J. O. (1995). Delphi: A versatile methodology for conducting qualitative research. *The Review of Higher Education, 18*(4), 423-436.

Najera, P., Lopez, J., and Roman, R. (2011). Real-time location and inpatient care systems based on passive RFID. *Journal of Network and Computer Applications, 34*(3), 980-989.

Omachonu, V. K. and Einspruch, N. G. (2007). Systems engineering in the healthcare service industry. *International Journal of Healthcare Technology and Management, 8*(1-2), 161-172.

Ortíz, M. A., Cómbita, J. P., Hoz, Á. l. A. D. l., Felice, F. D., and Petrillo, A. (2016). An integrated approach of AHP-DEMATEL methods applied for the selection of allied hospitals in outpatient service. *International Journal of*

Medical Engineering and Informatics, 8(2), 87-107.

Ortíz, M. A., Felizzola, H. A., and Isaza, S. N. (2015). A contrast between DEMATEL-ANP and ANP methods for six sigma project selection: a case study in healthcare industry. *BMC Medical Informatics and Decision Making, 15*(3), S3.

Phillips, A. (1966). Patents, potential competition, and technical progress. *The American Economic Review, 56*(1/2), 301-310.

Ramanathan, R., Ramanathan, U., and Ko, L. W. L. (2014). Adoption of RFID technologies in UK logistics: Moderating roles of size, barcode experience and government support. *Expert Systems with Applications*, *41*(1), 230-236.

Ranasinghe, D. C., Engels, D. W., and Cole, P. H. (2005). Low cost RFID systems: confronting security and privacy. *Paper Auto-ID Labs White Paper Journal, 1*.

Reyes, P. M., Li, S., and Visich, J. K. (2012). Accessing antecedents and outcomes of RFID implementation in health care. *International Journal of Production Economics*, *136*(1), 137-150.

Rosenbaum, B. P. (2014). Radio frequency identification (RFID) in health care: Privacy and security concerns limiting adoption. *Journal of Medical Systems, 38*(3), 19.

Saaty, T. L. (1980). *The Analytic Hierarchy Process*.

Saaty, T. L. (1990). An exposition of the AHP in reply to the paper “remarks on the analytic hierarchy process”. *Management Science*, *36*(3), 259-268.

Saaty, T. L. (1996). Decision making with dependence and feedback. *The analytic network process*.

Shumway-Cook, A., Patla, A., Stewart, A., Ferrucci, L., Ciol, M. A., and Guralnik, J. M. (2003). Environmental components of mobility disability in community-living older persons. *Journal of the American Geriatrics Society, 51*(3), 393-398.

Shura, R., Siders, R. A., and Dannefer, D. (2010). Culture change in long-term care: Participatory action research and the role of the resident. *The Gerontologist*, *51*(2), 212-225.

Singh, M. A. F. (2002). Exercise comes of age: rationale and recommendations for a geriatric exercise prescription. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *57*(5), M262-M282.

Smith, A. D. (2005). Exploring radio frequency identification technology and its impact on business systems. *Information Management and Computer Security, 13*(1), 16-28.

Strickland, L. S. and Hunt, L. E. (2005). Technology, security, and individual privacy: New tools, new threats, and new public perceptions. *Journal of the Association for Information Science and Technology, 56*(3), 221-234.

Sugiyama, T. and Thompson, C. W. (2007). Outdoor environments, activity and the well-being of older people: Conceptualising environmental support. *Environment and Planning A, 39*(8), 1943-1960.

Tamura, H. and Akazawa, K. (2005). Stochastic DEMATEL for structural modeling of a complex problematique for realizing safe, secure and reliable society. *Journal of Telecommunications and Information Technology*, 139-146.

Tesch-Romer, C. and Wahl, H. W. (2017). Toward a more comprehensive concept of successful aging: Disability and care needs. *J Gerontol B Psychol Sci Soc Sci, 72*(2), 310-318.

Thiesse, F. (2007). RFID, privacy and the perception of risk: A strategic framework. *The Journal of Strategic Information Systems, 16*(2), 214-232.

Thong, J. Y., Yap, C. S., and Raman, K. (1996). Top management support, external expertise and information systems implementation in small businesses. *Information Systems Research, 7*(2), 248-267.

Tzeng, G. H., Chiang, C. H., and Li, C. W. (2007). Evaluating intertwined effects in e-learning programs: A novel hybrid MCDM model based on factor analysis and DEMATEL. *Expert Systems with Applications, 32*(4), 1028-1044.

Wahl, H. W. and Lang, F. R. (2003). Aging in context across the adult life course: Integrating physical and social environmental research perspectives. *Annual review of gerontology and geriatrics, 23*(1), 1-33.

Wahl, H. W., Iwarsson, S., and Oswald, F. (2012). Aging well and the environment: Toward an integrative model and research agenda for the future. *The Gerontologist, 52*(3), 306-316.

Wamba, S. F., Anand, A., and Carter, L. (2013). A literature review of RFID-enabled healthcare applications and issues. *International Journal of Information Management, 33*(5), 875-891.

Wickboldt, A. K. and Piramuthu, S. (2012). Patient safety through RFID:

Vulnerabilities in recently proposed grouping protocols. *Journal of Medical Systems, 36*(2), 431-435.

World Health Organization (2016). *Multisectoral Action for a Life Course Approach to Healthy Ageing: Draft Global Strategy and Plan of Action on Ageing and Health.* Geneva, Switzerland Retrieved from http://apps.who.int/gb/ebwha/pdf_files/WHA69/A69_17-en.pdf.

Wu, F., Kuo, F., and Liu, L. W. (2005). The application of RFID on drug safety of inpatient nursing healthcare. Paper presented at the Proceedings of the 7th international conference on Electronic commerce.

Wu, W. W. (2008). Choosing knowledge management strategies by using a combined ANP and DEMATEL approach. *Expert Systems with Applications, 35*(3), 828-835.

Wu, Z. Y., Chen, L., and Wu, J. C. (2013). A reliable RFID mutual authentication scheme for healthcare environments. *Journal of Medical Systems, 37*(2), 9917.

Wyld, D. C. (2006). RFID 101: the next big thing for management. *Management Research News, 29*(4), 154-173.

Yang, J. L. and Tzeng, G. H. (2011). An integrated MCDM technique combined with DEMATEL for a novel cluster-weighted with ANP method. *Expert Systems with Applications, 38*(3), 1417-1424.

Yang, T. and Hsieh, C. H. (2009). Six-sigma project selection using national quality award criteria and Delphi fuzzy multiple criteria decision-making method. *Expert Systems with Applications, 36*(4), 7594-7603.

Yang, Y. P. O., Shieh, H. M., Leu, J. D., and Tzeng, G. H. (2008). A novel hybrid MCDM model combined with DEMATEL and ANP with applications. *International Journal of Operations Research, 5*(3), 160-168.

Yee-Loong Chong, A., and Ooi, K. B. (2008). Adoption of interorganizational system standards in supply chains: An empirical analysis of Rosetta Net standards. *Industrial Management and Data Systems, 108*(4), 529-547.

Zadeh, L. A. (1965). Fuzzy sets. *Information and Control, 8*(3), 338-353.