

The Development of a Qualitative Dynamic Attribute Value Model for Healthcare Institutes

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(Received 3 Mar 2010; accepted 27 Sep 2010)

Abstract

Background: Understanding customers has become an urgent topic for increasing competitiveness. The purpose of the study was to develop a qualitative dynamic attribute value model which provides insight into the customers' value for healthcare institute managers by conducting the initial open-ended questionnaire survey to select participants purposefully.

Methods: A total number of 427 questionnaires was conducted in two hospitals in Taiwan (one district hospital with 635 beds and one academic hospital with 2495 beds) and 419 questionnaires were received in nine weeks. Then, apply qualitative in-depth interviews to explore customers' perspective of values for building a model of partial differential equations.

Results: This study concludes nine categories of value, including cost, equipment, physician background, physician care, environment, timing arrangement, relationship, brand image and additional value, to construct objective network for customer value and qualitative dynamic attribute value model where the network shows the value process of loyalty development via its effect on customer satisfaction, customer relationship, customer loyalty and healthcare service.

Conclusion: One set predicts the customer relationship based on commitment, including service quality, communication and empathy. As the same time, customer loyalty based on trust, involves buzz marketing, brand and image. Customer value of the current instance is useful for traversing original customer attributes and identifying customers on different service share.

Keywords: *Dynamic attribute value model, Healthcare institute, Customer value, Customer attributes, Ill-posed equation*

Introduction

Facing the competitive healthcare environment, healthcare marketing professionals realize that word of mouth is the most influential form of advertising for physician and hospital services (1). How do managers of healthcare institutes estimate what patients want? Why patients do chose to come rather than another? How to understand healthcare institutes' customer has become a popular research topic (2-6). Prior research applied questionnaire survey or qualitative research to explore static phenomenon. However, change in the social environment is a dynamic and nonlinear phenomenon which includes a variety of traits, that are not easy to visualize but can be expressed as multiple variables (7). Hence, using only qualitative methods to describe dynamic and complicated systems can not only impede the description, but also make it difficult to describe unexpected behaviors (8). Identifying and sustain-

ing a customer's value to build a value model is one of the best ways to invest in valuable customers. The purpose of this study was to develop a qualitative dynamic attribute value model, based on approaches of Keeney and Ma, et. al., which provides insight into customers' value for healthcare services (9-11).

Literature Review

Customer value

Hilliard defines customer value as an interactive relativistic preference experience which refers to the evaluation of some objective by some customers (12). Holbrook defines three key dimensions of consumer value: self-oriented, reactive, and extrinsic (13). Oliver reports that quality is an important input issue to satisfaction through the comparison of performance to valued standards. Indeed, qualities enhance satisfaction and value, which provides additional satisfaction, the satis-

fraction deriving from quality and then from value (14). Hwang, et al. try to calculate customer value through current value, potential value and customer loyalty (15). Few studies construct the value theory of customers and define variety meanings in different field (10). In particular, rare of them use qualitative research methods to collect data on customer value for healthcare marketing. Customer needs and available resources are important drives of acquisition decisions for products and services (16). Identifying the customer value can promote measure and reward performance of companies. Comprehending customer value and profitable customers are essential to retain customers (15).

Difficult objectives to be measured

Healthcare institute managers like to encourage employees to promote high morale that would lead to more enjoyable surroundings to work that could provide high quality service in healthcare system. The morale objective is very important, however, measuring morale is very difficult. Although, the consequences of such decision are uncertain due to the objective of culture or policy, the value model is still a utility function (10).

Theoretical Customer Value Calculations

Keeney uses qualitative method to explore and classify value model including four steps: develop a list of values, convert each value that obtains from customers to an objective, structure objectives, and specifying measures for the objectives (9, 10). Kenny focuses on telecommunication sector, which belongs to the service industry. Because the healthcare service belongs to service industry, the current study can well adapt the theoretical approach.

Combining the attributes

Define a value model as a function u , which refers to an objective function and it, assigns to each consequence x where a number $u(x)$ reflects the relative desirability of that consequence. Therefore, different types of value models are appropriate for different decision contexts. Then, construct the quantitative value model by (a) combining the various attributes, (b) scaling the relative

value of different levels of each attribute, and (c) determining the value tradeoffs between different levels of achievement on different objectives.

In order to combine various attributes, the research uses independence concepts analogous to probabilistic independence for developing models of physical behavior relationships. Verify the independence concepts as appropriate, and assign relative values to subsets of consequences without worrying about what the other attribute levels are. Keeney uses three main independence concepts to develop value models, including additive independence, preferential independence and utility independence (10). Derivation of additive value model and multiplicative value model is shown in Appendix 1.

Multi-Attribute Customer Value Model

Combines multi-attribute decision model and single attribute customer value model to develop a multi-dimension attribute customer value model for healthcare services as shown in Appendix 1. The single attribute customer value model can only describe single attribute of the environment (10). However, the healthcare industry is a complex system, and its service quality, perceived value and customer loyalty interrelates and influences each other. Describing a systematic model must also describe each factor as well as their relationship. In attempting to better consider general types of uncertainties, the traditional theory of partial differential equations is applicable to both in analysis and synthesis for the research framework.

Fortunately, the concept of partial differential equations is applicable to the uncertain nonlinear dynamic system of the characteristics behaviors. Partial differential equation model can be used to solve many dynamic and nonlinear physical systems. Under various conditions, compute the solution with known inputs to predict how the system will behave (17). According to Duchateau's prospects, parabolic equations model physical behavior including non-steady conduction, non-steady diffusion. Parabolic equations describe irreversible processes like conduction and diffusion. In business operating environment, bad word of mouth or bad

repetition are irreversible in customers' mind. This situation is coincident with customer relationship management's theory, which the cost of earning a customer back will be five times of retaining a customer (18).

A partial differential equation problem is well posed if it satisfies the following:

- Existence: There exists at least one solution.
- Uniqueness: There is only one solution.
- Stability: The solution depends continuously on the data.

The partial differential equation model is shown in Appendix 1.

Materials and Methods

This study includes using an initial open-ended questionnaire survey to select participants purposefully. Then, apply the method of qualitative in-depth interviews to explore and identify customers' (respondents') attitudes, behaviors, and perspective of values. Qualitative in-depth interviews are an exploration research with the ability of giving well-grounded, rich descriptions and explanations (19-23). Indeed, the method explores greater concepts and meaning than questionnaires. Furthermore, apply the concept of partial differential equations to exploring attributes for building a qualitative dynamic attribute value model with Keeney's and Ma, et al. approaches (9, 10, 11).

Apply a convenient sampling procedure to inpatients, outpatients, and employees from two hospitals with willing to complete questionnaires. Researchers deliver a total number of 427 questionnaires and receive 419 questionnaires, which results in a 98% responses rate in the initial survey. Data from 406 respondents are usable for the study. Offer each qualified individuals a US\$6.5

gift for participating, and interview those who agree to participate immediately. The selected two hospitals contain two types of classified levels of medical institutes proved by the Bureau of National Health Insurance (BNHI). Hospital A is a district hospital with 635 beds, whose population numbers are 1,103,642 in northern Taiwan and Hospital B is an academic hospital with 2495 beds, whose population numbers are 1,528,261 in southern Taiwan. The survey is designed to gather information on customer's perspective about service quality of hospital and to explore interpretations of various customer value situations. Table 1 presents sample items of the survey.

Interviews

Each of the interviews last from 20-30 min and is open-ended with interview guides to ensure coverage of issues relevant to the researchers. During interviews, encourage case study participants to think aloud and provide why they select specific values to be important and how it relates to other components with valued linkages. Apply Schoenfeld's think aloud protocol methods to collect data where the researcher should interact with each subject by encouraging, guiding, questioning, and searching during interviews (7).

The interview situations include classification of the subject's meanings by the researchers and reflections from the subjects. The purpose is to help subjects to express their ideas more clearly. Table 2 presents the questions in identifying customer's values. Consider all of these issues in designing an objective from patients and develop a set of objectives to the relationship network for healthcare resources.

Table 1: Sample items from initial survey

1. Complete the following: A service quality is
3. What image or characteristic comes to your mind when you think the hospital A /B?
7. Indicate how you would/ would not recommend your friends come to this hospital?
10. Consider the following similes: A physician is like a News broadcaster, Entertainer, Coach, Orchestra conductor, Teacher or Friend
 - a. Choose a simile that you believe best describe a physician and explain your choice.
 - b. Choose a simile that you believe does not describe a physician very well and explain your choice.

Table 2: Summary of open-ended questions in identifying customer's values

<p><i>Encouragement:</i> I believe you can do this question.</p> <ol style="list-style-type: none">1. Explain, in your own words, what is a definition of value. You did a good job on the previous one.2. What is your concern about the healthcare service? Why?3. How do you feel about the healthcare service?4. What image or characteristic comes to your mind when you choose a hospital?5. What is the specific value that hospital can offer?6. How can hospital managers redesign existing product (or strategy) to improve the services?7. How can the current healthcare marketing system surmount the obstacles? <p><i>Guidance:</i></p> <ol style="list-style-type: none">1. What is wrong or right with your hospital?2. Is there any problem in current healthcare service? Give me an example.3. What needs to be improved? Is this enough to guarantee that the situation becomes well? What do you really mean by this? <p><i>Questioning:</i></p> <ol style="list-style-type: none">1. What are your ambitions?2. What limitations are placed upon you?3. What specific service do customers want? <p><i>Searching:</i></p> <ol style="list-style-type: none">1. What values do you have for your customers and your employees?2. Why is the value important?3. What do you mean by this value?4. How valuable are certain demographic profile and diagnosis history to a customer?
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Field Notes from Individual Customer Interviews

Researchers discuss observation field notes from October, November, and December, 2006 weekly. The weekly discussions influence the specific questions in subsequent interviews. Use the initial responses to expand customers' definition of value. In order to better understand each statement value, transcribe and order all records of the customers' verbal statements during interview sessions chronologically. The researchers write field notes after reviewing audiotapes of each customer's performances. The data set provides an opportunity to analyze the subjects' attitudes and behaviors. The coding was carried out by two experts and consequences were compared to ensure the coders were in agreement with each other. If the coders failed to agree with each other, they needed to discuss the issues on which they disagreed, with each coder explaining his/her understanding of the meaning of the themes as well as the reasons for the coding, to ensure that a consensus could be reached for the coding. The consequences were compared three times in order to obtain the coding consequences.

Reliability

In order to ensure the reliability of classified variables in terms of attributes of customer values, it is essential to include a reliability test in any content analysis (24). The interjudge reliability approach was adopted in this study to test the reliability of the sample. Based on this approach, each coder measured the reliability of the items in accordance with the standards of the intercoder agreement. For the content of the same interview, all two coders performed the classification and intercoder reliability is 0.8781 and 0.8502. Wimmer and Dominick recommended that the reliability should be above 0.90, in order to complete with the most basic requirements (25). In this study, the reliability of the content analysis is 0.9553, a level that people are clearly willing to accept.

Qualitative Value Modeling

The modeling process of Keeney and Ma, et al. includes a detail discussion for the model by recognizing relevant data and making them as objectives. Then, describes processes for congregating objectives as an objective function. An extension

of Keeney's concepts of value-focused thinking is a more comprehensive manner to develop objectives from patients' point of value in healthcare services. Four steps to build a qualitative model of value are as follows:

Step 1: Identify customer values: Identify customer value from his/her perspective, which usually personal interviews or focus groups determine. The foundation for model of values is asking individual to express his/her value without ranking or priorities. To expand the logical list, the researchers encourage subjects think aloud.

Step 2: Compare each value that obtains from customers' perceptions to an objective: Structure customer values into a hierarchy of basic objective for understanding whether an improvement of certain values lead to a competitive advantage. It is necessary to compare each value from customers' perceptions.

Step 3: Identify design objectives: Upon building up the respective objectives, it is eventually possible to design and link objectives through a bottom-up process with researchers' knowledge and understanding of customers' particular part of the objective. In effect, it is compatible with reminiscent of strategic thinking. On the other hand, use a strategic level in a top-down way to investigate various objectives.

Step 4: Develop the relationship network: Focuses on how strongly different design characteristics affect individual customer values. It is eventually possible to complete the network by connecting the informational linkages, which join the objective from each customer.

The researchers ask why this is important (26). Each answer is subject to the same question, continuing this process until extract a value. Classify the customer values into different objectives from a customer's answer of questionnaires. Basic objectives and each corresponding attributes are the ground for a qualitative dynamic attribute value model.

Data Collection and Analysis

Quantative Data

Two hundred and sixteen patients from hospital A, 163 patients from hospital B, 15 employees

from hospital A, and 12 employees from hospital B volunteer to participate in the survey. Of the qualified potential participants, 387 refuse to participate in the interviews. Select 19 participants from the results of initial survey for interview. After identifying subjects' attributes of customer values, interview 16 different subjects including 4 physicians and 12 patients during the two weeks after treatment. The researchers inform participants that this study takes about 20-30 min. Upon agreeing for interview several weeks later, the researchers re-contact those who agree to collect information and select 10 participants. With the exception of the fact that completes the second interviews over the telephone, the procedure is identical to that in the original interviews. In order to make sure a participant's mandarin language is within the structured framework of customer value, repeating participant's response to prove the own revealing (9, 10, 11) Accomplish the process to identify types of available service quality and classify customer values in health-care services. According to the logic of dynamic attribute value models, use the index of value models as the theoretical exploration (27).

Qualitative Data

Collect data primarily through clinical interviews in a one-on-one setting cover a period of first 9 weeks from October 2006 at the different times of days in hospitals. Focus the interview on customer's responses about hospital (including why they select important specific values and how it relates to other components with valued linkages). Use the pseudonyms 01 to 10. 05 is an employee and 01, 03, 06, 08, as well as 09 are patients from Hospital B, which is an academic hospital in southern Taiwan with 2495 beds and 82% occupancy rate. 02, 04, 07 and 10 are patients from Hospital A which is a district hospital in northern Taiwan with 635 beds and 78.2% occupancy rate.

Category Development and Reliability

Three judges who are familiar with the topic of customer value sort the think aloud responses

into categories and field notes that reflect the sources of value focused thinking. Judges A and B develop a classification scheme that consists of 15 mutually exclusive and exhaustive categories for the 10 participants. Judges A and B independently classify each of the interviews into the categories to derive customer value with healthcare service. Resolve all disagreements through discussions. Judge C sorts the 10 responses based on the categories, which Judges A and B develop. Use the percentage agreement statistics to calculate the interjudge reliability between Judge C and Judge A, B (two-way comparison). Interjudge reliability is 80% for the customer value incidents.

Table 3 shows that the Fig. 1 is respectably high according to 9 categories. Perreault and Leigh point out that the percentage agreement statistic is useful for understanding interjudge reliability when the number of categories is large (28). Eventually, calculate the alternate index of reliability, denoting by I_r , where I_r is a model of the level of agreement and it might has a true level of reliability. Besides, the index focuses not only on the agreement between judges but also overall coding process. The I_r is .88 among Judge B, Judge C and Judge A for both satisfying and dissatisfying incidents.

Table 3: Value with healthcare service from the customers' point of view

Item	Categories	Components of objective
W1	Cost	<ol style="list-style-type: none"> 1. Low price. 2. Low co-payment if illness can be cured. 3. Handled in an acceptable manner.
W2	Equipment	<ol style="list-style-type: none"> 1. High quality of medical supplies. 2. Modern equipment. 3. Software (Standard Operation Procedure, SOP training). 4. Hardware (e.g. location, decoration).
W3	Physician Background	<ol style="list-style-type: none"> 1. Physicians' expertise. 2. Physician's technological skill. 3. Outstanding physician.
W4	Physician Care	<ol style="list-style-type: none"> 1. Courtesy of physician. 2. Amount of time the physician spent with patient. 3. Communication skill (e.g. languages barriers).
W5	Environment	<ol style="list-style-type: none"> 1. Good surrounding. 2. Patients' recreation room on ward (e.g. library, coffee room).
W6	Timing Arrangement	<ol style="list-style-type: none"> 1. Equitable diagnosis timing to each customer. 2. Equitable treatment timing to each customer. 3. Timing of patient's discharge from hospital. 4. Time for talking about patient's feeling or worries.
W7	Relationship	<ol style="list-style-type: none"> 1. Guidance and support patients. 2. Trust (e.g. empathy, sympathy, word of mouth). 3. Commitment (e.g. complaint feedback--care center/e-mail/1-800 numbers).
W8	Brand Image	<ol style="list-style-type: none"> 1. LOGO. 2. Brand identifies (e.g. free medical treatment/ oral hygiene guidance). 3. Brand awareness.
W9	Additional value (Differentiate)	<ol style="list-style-type: none"> 1. Professional management (e.g. internal customer--experience inherits/specific labor division/occupational training). 2. Clinic different characteristics (e.g. health insurance).

Results

This study concludes nine categories of value, including cost, equipment, physician background, physicaian care, environment, timing arrangement,

relationship, brand image and additional value, to construct objective network for customer value and qualitative dynamic attribute value model which is proper to healthcare institute managers and

offers a fitting way of conceptualizing the relationships among core elements (e.g. customer satisfaction, customer relationship, loyalty, health service performance). According to categories of hierarchy in Table 3, Fig. 1 shows the study's objective network of healthcare services where the network shows that the value process of loyalty

de-velopment via its effect on customer satisfaction, customer relationship, customer loyalty and healthcare service. One set predicts the customer relationship based on comminment, including service quality, communication and empahty. As the same time, customer loyalty based on trust, involves buzz marketing, brand and image.

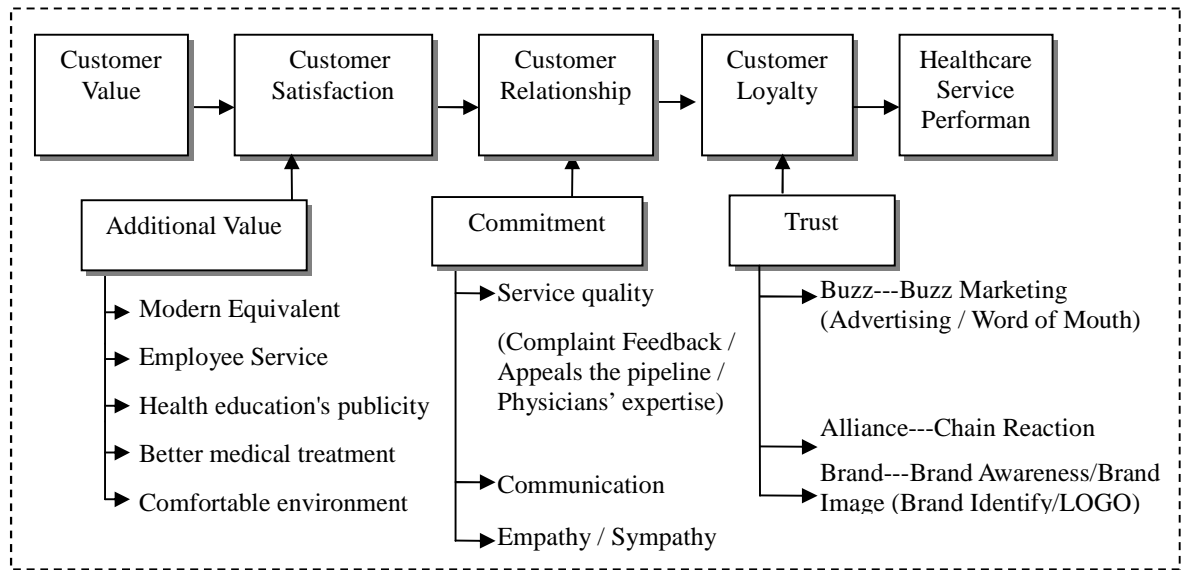


Fig. 1: Major values of healthcare services

Discussion

Value modeling: Combining the Attributes

A primary function of qualitative dynamic attribute value model is the direct and powerful contribution to the decision situation. Combine various attributes including customer value, customer satisfaction, customer relationship, customer loyalty to derive general dynamic value models. Performance of healthcare service has the characteristics of existence, uniqueness and stability where the characteristics are not coincident with the properties of Hadamard's well-posed problem (18).

If it satisfies all three requirements, then the problem is well-posed. Otherwise, the problem is ill-Posed. Therefore, the study uses ill-posed equation to develop new model and describe its detail as follows.

Definition 1. Define a boundary number B on $\mathcal{R}(-\infty, +\infty)$ to be a number.

Consider an initial value problem for equation (5) and $f(x)$ represents a given function of x . Denote the value of $u(x, t)$ by $g(x) = u(x, t)$ at the time t, where $g(x)$ denotes the dynamic attribute value model. Then $g(x)$ is relative to f by

$$g(x) = \sum_{n=1}^{\infty} f_n \sin(nx) \exp[-nT]$$

$$T > 0, n = 1, 2, 3, \dots \dots \dots (6)$$

Calculate different customer value according to different period of time (T). The series for $g(x)$ converges uniformly on $[0, 1]$ to $g(x)$ by Weierstrass M – test

$$\left| \sum_{n=1}^{\infty} f_n \sin(nx) \exp[-nT] \right| \leq$$

$$\sum_{n=1}^{\infty} f_n \exp[-nT]$$

Moreover, for every integer m, the series

$(d/dx)^m \sum_{n=1}^{\infty} f_n \sin(nx) \exp[-nT]$ converges uniformly on $[0, 1]$ to $g^{(m)}(x)$. Therefore, $g(x)$ must be a C^∞ function independent of how smooth $f(x)$ is. The value $g(x) = u(x, T)$ depends continuously on the initial time. Individual customer may show distinguish attributes. According to categories in Table 3, define a weighting function w_k to represent the nine categories for adjustment on customer value model. Express the weighting function w_k as

$$w_k = \begin{cases} 1, & \text{if the category exists} \\ 0, & \text{Otherwise} \end{cases}$$

Rewrite the overall dynamic customer value of healthcare service as

$G_r = \sum_{k=1}^9 w_k g_r(x)$, $r=1, 2 \dots m$, where r represents each individual customer; k represents category.

For example, according to categories in Table 3, if the first attribute exist, then w_1 will be 1. On the contrary, if the first attribute does not exist, w_1 will be 0. $g_1(x)$ stands for one customer. Therefore, the dynamic customer value can be evaluated.

Uses of Value models

Uses of value model are various. Values play an important role in healthcare service for different decision situations.

Evaluating and Creating Choices

Because sequences of various choices are a continuous function of time within the dynamic value models, managers can calculate the relative worthwhile of various choices. Meanwhile, the reason of why one choice replaces the other choice at a given period is apparent. However, managers may change the importance of target consumers' rank with a specific attribute (29). For example, the cost of new equipments and reducing waiting time for outpatient services are important factors to introduce a new service in healthcare institutes. However, cost and waiting time would

not be important factors for specific customers anymore, when provide a new service with a comfortable environment and equipments (30). Creating new choices are always better than simply choosing from the available choices. The development of well understanding of values about how those choices will be helpful on the creativity of designing new choices. For example, the cost and new equipments are important for customers. Therefore, develop a new differential service with higher co-payment for those customers who concern high quality of medical supplies and modern equipments but ignore high cost. Eventually, construct new choices for different customer segmentations.

Designing Healthcare Service

Value of prospective customers varies and influences the success of service greatly. The distinguished value models for individual customer are helpful on understanding potential customers. Instead of combining these models for averaging the value, use full set of models to calculate what different services potential customers prefer and how much will they pay for the improvement of service quality. Therefore, understanding the influencing factors of developing a new service, managers can make reasoned judgments about the service's chances of successful. Meanwhile, many strategies for providing health care services tailored to meet consumer's need will enhance their core competence for sustaining management in the healthcare institutes and satisfy customer needs (31).

Assisting Quick Decision Making

The operating environment of Taiwan's healthcare institutes has facing fierier competition. Thus, managers need to make many decisions quickly and many of them may have the same value attributes. For example, if the physician care and relationship attributes have the same value model, managers can use the same model for guiding decision making. Therefore, managers can speed up actions with the clear specification of value in advance and further enhance the competitiveness of the healthcare institutes. Meanwhile, managers can change the

attributes and estimate how and what affects these changes will have. Of course, managers can modify services by adding non-existing benefits or by modifying the level of existing benefits. Once managers understand how target consumers react to different attributes, they can promote the most desiring attributes of their existing services. Repositioning an existing plan provides the strategic advantage (3). If healthcare managers have a clearer understanding of the dynamic value of customers, healthcare institutes' management is more efficient. Once managers identify the dynamic value model, it is clear to sustain strategy of customers' care for preventing losing its core value in an increasingly competitive market. In several ways the managers can add value to the care of customers with complex issues: (a) a more integrated brand image (including brand identify or LOGO) and experts together from multiple clinics for designing treatment plans collectively; (b) commitment is one of the best ways to maintain customer relationship, focusing on the needs of customers rather than physicians; (c) honest to customers (outcome of the treatment cannot be known beforehand) is the best way to increase customer loyalty. To recapitulate, the developed dynamic attribute value model will help you in three major ways: recognition and identification of decision opportunities, creation of better alternatives for decision-making, and development of an enduring set of rules for healthcare institutes.

Limitations

The study was conducted via convenient sampling due to our specific subjects. The sampling method here could have inadvertently introduced some selections bias in the choice of participants. Therefore, our sample may not be fully representative of the entire population due to possible sample selection bias. Consider further research to apply the study's qualitative dynamic attribute model in other sectors. Meanwhile, the developed value model could be validated in different types of healthcare institutes.

Ethical Considerations

All ethical issues including plagiarism, Informed

Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc have been completely observed by the author.

Acknowledgements

The author would like to thank the National Science Council of the Republic of China, Taiwan, for the financial support of this research under Contract No. NSC 95-2221-E-327-001. The author is also most grateful for the constructive suggestions of the anonymous reviewers all of which has led to the making of several corrections and suggestions that have greatly aided in the presentation of this paper. The author declares with no conflicts of interest.

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Appendix 1

Additive value model and multiplicative value model

■ Additive value model: If all combinations of attributes are additive independent, express the utility function as equation (1):

$$u(x_1, \dots, x_n) = \sum_{i=1}^n k_i u_i(x_i) \dots\dots\dots (1),$$

where u is the valuation function, x_i is the inference value and K_i is the positive scaling constants summing to one.

■ Multiplicative value model: If each pair of attributes is preferentially independent of the others and if one attribute is utility independent of the others, then express the utility function as equation (2):

$$1 + ku(x_1, \dots, x_n) = \prod_{i=1}^n [1 + kk_i u_i(x_i)] \dots\dots\dots (2),$$

where u is valuation function, x_i is the inference value and k_i is the scaling constants and k is an additional scaling constant.

Multi-Attribute Attribute Customer Value Model

Express the multi-attribute decision model (32, 33); as equation (3):

$$\varphi_r = \varphi(S_r) = \sum_{k=1}^n \omega_k \varphi_k(X_{rk}) \quad r=1, 2, 3, \dots, m \dots$$

(3), where $\varphi(S_r)$ is a value function of different S_r , ω_k is weight and $\varphi_k(X_{rk})$ is value function of attribute X_{rk} , respectively. $S = \{S_1, S_2, \dots, S_m\}$: a direct set of m possible alternatives. $\omega = (\omega_1, \omega_2, \dots, \omega_m)^T$: the vector of the relative

importance or weights on the attributes, where

$$\sum_{k=1}^n \omega_k = 1, \omega_k \geq 0, k = 1, 2, \dots, n$$

Furthermore, express the function for different S_r as equation (4):

$$\varphi_r = \sum_{k=1}^n \omega_k a_{rk} \quad , \quad r=1, 2, 3, \dots, m \dots\dots\dots (4),$$

where a_{rk} is the comparing scale of X_{rk} after normalization.

Partial Differential Equation Model

Let $x(t) \in \mathfrak{R}^n$, $y(t) \in \mathfrak{R}^m$ denotes states of the system and $u(t) \in \mathfrak{R}^p$ is the control inputs. $u = u(x, t)$ denote a solution for the initial boundary value problem and equation (5) presents an initial value problem. According to additive multi-attribute value model, replace the structure of weighting-set by initial value of equation because the weight of every attributes should be greater than zero (28).

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2} \quad \text{in } \Omega \dots\dots\dots (5)$$

$u(x, 0) = f(x) \quad 0 \leq x \leq 1; u(0, t) = u(1, t) = 0 \quad 0 \leq t \leq T$
 where Ω denotes the rectangle $[0, 1] \times [0, T]$. If $f(x)$ is available, then compute $u(x, T)$ for any positive value of T .