# TRIAL PLAN WITH CAPITATION PAYMENT OF THE NATIONAL HEALTHCARE INSURANCE IN TAIWAN: ESTABLISHING A LOYAL PATIENT SELECTION MODEL

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## Abstract

*Since 2002, the healthcare system in Taiwan has implemented a global budgeting scheme in clinics and hospitals with an expenditure cap. The current mode of payment for medical points in Taiwan is primarily through the fee-for-service (FFS) mechanism. This payment mechanism has diminished the quality of services that clinics and hospitals provide to patients. Furthermore, FFS does not grant incentives that allow providers to invest in preventive healthcare and health promotional activities. Compared with FFS, a payment unit in the capitation mechanism is people rather than the number of patients. That is, the healthier people are, the more reimbursement providers obtain for healthcare. In general, financial risks that confront medical services are primarily assumed by healthcare providers. Therefore, medical teams have to reduce the amount of services and the density of clinical practice, such that the healthcare provider can sustain the quality of medical services. Accordingly, this study develops an approach using stochastic processes with an RFM (Recency, Frequency, Monetary) model is utilized to proceed with the activeness analysis of patients and prognosticate whether patients will remain loyal Therefore, a proper marketing stratagem can be deliberated as a reference for managing the physician–patient relationship; at the same time, this healthcare stratagem is expected to promote the impression of hospitals and enhance management efficiency.*

*Keywords: RFM, Loyal patients.*

# 1 INTRODUCTION

The National Health Insurance Administration (NHIA) in Taiwan commissioned the National Health Research Institutes in 1998 to construct the National Health Insurance Research Database (NHIRD) to conform to requirements (i.e., issue healthcare insurance and increase the service quality to patients) and to ensure the thorough digitization of health insurance data. The current insurance coverage ratio in Taiwan is more than 99%, rendering the health insurance data to reflect the validation data on research in medical-related fields. The outcome can be a reference for medical policies; the database has indeed become an important resource for research. National Health Insurance (NHI) aims to aggregate the strength of the majority of the masses to tackle the financial obstacles of the minority for medical care, thus protecting the health of the Taiwanese and decreasing the economic burden for those who seek medical care.

Since its implementation, the NHI suffered a deficit in financial receipts and expenditures for the first time in 1998. The fiscal problem is always the largest threat to the success of a health insurance system. It is attributed to the hospitalization behavior of people, containment of medical resources, and design of the insurance mechanism. These factors caused the expenditures on the health insurance in Taiwan to become higher than revenues, thus engendering fiscal deficits every year. The announcement of capitation payment was positively anticipated to reform the fiscal problem of the NHI. According to the 44$^{th}$ Article in the NHI Act, "To promote preventive medicine, implement the referral system, and to improve the quality of medicine and treatment, the Insurer should draft the family physicians system. The benefits of the family physicians system should be paid out on a per person basis; annual benefit payment should be based on the patient's age, gender, illness, and other individual expenses after correction." The NHI in Taiwan was implemented with the global budget system in 2002; nevertheless, its payment mechanism remains the fee-for-service (FFS) scheme. The system is dependent on the quantity of services to provide reimbursement. It offers an incentive to medical services that are geared toward disease treatment and containment. Yet the incentive prompts medical organizations to overprovide medical services because of the positive relation of the quantity and reimbursement. On the other hand, incentives that allow providers to invest in preventive healthcare and health promotional activities are not provided.

Another payment mechanism, the capitation payment, allows medical providers to care for the health of insured people and provide the necessary medical treatment with a fixed budget. The insured people are expected to be healthier and the preventive healthcare can be focused to save medical resources. Hence, the capitation payment ensures that medical providers offer the insured people every type of preventive medical knowledge and health examination to avoid illnesses or discover diseases earlier and obtain prompt treatment.

Compared with FFS, a payment unit in capitation is people. The healthier people are, the more reimbursement providers obtain. Therefore, medical teams have to reduce the amount of services and the density of clinical practice to ascertain that medical service expenditures are within fixed incomes. At the same time, medical teams have to focus on the means of maintaining or improving the health of the people, decreasing their medical usage, and increasing their resting income. Scholars refer to this practice as "investing health for people rather than investing in medical treatment." This practice is also an extension of the family physician system. The NHIA has selected seven Taiwan's hospitals to test the capitation payment since 2012. Henceforth, three capitation payment modes have been developed, namely, regional integration, medical treatment in communities, and loyal patients in hospitals.

In the trial of the capitation payment, the mode of loyal patients in hospitals is the most intractable mode compared with the other two modes that select patients according to the region and community. The source of loyal patients in hospitals consists of the following three parts: (1) integrating loyal patients from the integrative plan of constructing a consociating healthcare mode and moving toward gradually to facilitate the medical system; (2) confirming loyal patients by the hospitals themselves; and (3) obtaining from the NHIA a list of people who should be taken care of in service regions. The selective mechanism for loyal patients in the first part of the consociating healthcare mode is as follows: The clinical time of either an outpatient or inpatient, i.e., his/her previous-year visits to modern medical clinics, hospitals or integration team, primary medical centers or regional hospitals integrating local clinics, dominate the total clinical times above 50%. For example, the total clinical times of an outpatient or inpatient are 10 in the previous year, and his/her clinical records in Hospital A partake 6 times, which is equivalent to 60%. That patient can be regarded as loyal. Currently, no systematic method exists for the NHIA or hospitals to select loyal patients; moreover, the autonomy of patients to visit hospitals causes difficulty in seizing their clinical tracks. The process of distinguishing loyal patients is an issue worthy of discussion. For these issues, this study principally aims to select appropriate loyal patients and predict their clinical times and expenditures depending on effective active probabilities as reference for hospitals to track and maintain. Therefore, this study is to achieve four objectives. First, it intends to analyze the activeness of the clinical behavior of patients according to clinical records from the NHI database and to predict the clinical behavior of each patient and that of the aggregate. Second, the study plans to predict whether patients will remain loyal in the future given their activeness. Third, the study aims to analyze clinical times, frequencies, and expenditures and to establish a probabilistic model for hospitals for selecting loyal patients. Finally, the study intends to define loyal customers using a mechanism.

This paper's contribution to literature on loyal patient models of capitation is two-fold. First, this paper utilizes the mathematical model to calculate the probability of continuing hospitalization, substituting the past method of selecting loyal patients according to the percentage of hospitalization frequency in a specific hospital in order to support the mode of loyal patients composed of the trial plan for the capitation mechanism in Taiwan and make it implementable. Second, medical institutions can control and manage overall operating costs based on the predicted individual and overall hospitalization frequency as well as expenses on hospitalization.

This paper is organized as follows. Section 2 describes the literature concerning the study including the capitation payment, loyal patients, and the RFM (Recency, Frequency, Monetary Amount) model. Section 3 expounds the steps of the algorithm, the clinical data of patients, and the validation outcome from the algorithm. Section 4 presents the validation outcome and analysis. Section 5 provides the conclusions and limitations of this study.

# 2 LITERATURE REVIEW

The primary objective of the study is to select appropriate loyal patients and predict their clinical times and expenditures depending on effective active probabilities as reference for hospitals to track and maintain. The discussion is divided into three parts. First, the trial plan of loyal patients with capitation payment is explained. Second, the definition of loyal patients is provided. Finally, an RFM model for calculating the active probabilities of patients and selecting loyal patients is proposed.

## 2.1 Capitation Payment

The NHIA suggested a people-health-oriented solution based on a per-person condition. The Health Maintenance Organization (HMO) is typically the first concept that emerges in the discussion of capitation. The mechanism involves the cooperation of hundreds of private insurance companies and medical organizations to take responsibility for the healthcare of people; meanwhile, only one insurer exists in Taiwan, the NHIA. Furthermore, the HMO is a U.S.-regulated body that requires insurers to go to designated medical units in hospitals except for specific situations; by contrast, the capitation solution in Taiwan retains the principle that people can freely select modes.

Capitation payment is dependent on the number of insured people and their medical requirements (i.e., gender, age, health condition, and standardized mortality), and it will decide annual expenditures for medical service providers in advance instead of considering the actual usage of medical services from the insured people. Hence, the capitation payment is also referred to as a pre-payment system. Balkrishnan et al. (2002) and Fried et al. (2000) argued that the capitation payment system is irrelevant to the provision of medical services, and it can offer a substantial economic incentive to medical organizations to facilitate the delivery of efficient medical services, such as reducing the incidence of diseases by increasing the provision of preventive healthcare services, thus diminishing the usage and expenditures of medical services.

The capitation-payment-plan-and-loyal-patient mode currently includes the insured people whose clinical time ratios in the trial hospitals before the testing of the plan a year ago (July 2010 to June 2011) dominated over 50% as major healthcare individuals and self-selective employees from the hospitals and their dependents form responsible healthcare individuals. To ensure that people obtain complete healthcare, medical teams utilized the energy of healthcare. The government suggested a people-health-oriented trial plan with capitation payment. Medical teams consolidated from the hospitals of local clinics are required to submit a health-facilitated proposal and select a region to implement the plan. In addition to dentists, Chinese medical doctors, and implantation of organs, all of the payment items from the NHI are covered by the plan. The clinical rights of people, issuance of expenditures from medical teams, and examination operation are retained. The plan aims to (1) intensify the provision of preventive healthcare, hygiene education, and individual management service via disease treatment services for facilitating the health of people; (2) promote holistic healthcare as an orientation and facilitate the integration of local medical systems, including hospitals, physician clinics, and dental clinics; and (3) facilitate the health of people and reduce medical waste (NHIA, 2011).

The mode of loyal patients involves a bottom-to-top integration. Hospitals and clinics in the same area organize a medical group and encourage people to visit doctors who belong to the medical group in their respective buildings. The medical providers push preventive healthcare and hygiene education and undertake health-facilitated activities that are designed to provide intense services, promote health, and reduce the frequency of visiting the doctors. The implementation period is from January 1, 2012 to December 31, 2013. The mode of loyal patients in hospitals is currently dependent on the medical loyalty of the past patients as a condition. The trial hospitals of loyal patients mostly do not consolidate with other hospitals as a complete healthcare network. If healthcare individuals will not subsequently visit the doctors, then the ambiguity of healthcare and financial responsibility may ensue; therefore, the medical loyalty of patients is worthy of discussion.

## 2.2 Loyal Patients

In a general enterprise, Oliver (1997) defined loyalty as the state of repeatedly purchasing the same product or service without considering the cost and ignoring other possible choices. He categorized loyalty into behavioral loyalty and attitudinal loyalty. The behavioral loyalty pertains to the actual customer purchasing behavior, whereas the attitudinal loyalty connotes the psychological aspect of the customer loyalty. Jones and Sasser (1998) classified the measurement of the customer loyalty into three dimensions, namely, intent to repurchase (i.e., measures the future intent of customers to repurchase a product or service from a company); primary behavior (i.e., consists of recent customer purchasing times, purchasing frequencies, dollar volume, amounts, and purchasing intent), and secondary behavior (customer behavior involving the recommendation of companies to other customers). Bowen and Shoemarker (1998) defined the customer loyalty as the intent of customers to repurchase and their willingness to become a part of the enterprise. Cunningham (1956), Day (1969), Monroe and Guiltinan (1975) used repeat buying as a measure for the customer loyalty.

In the medical industry, Peltier et al. (1999) suggested that the loyalty of patients is a concept of behavioral intention, and such behavioral intention is categorized into (1) clinical behavior that involves reverting to the original medical providers to seek a solution to the same healthcare problem, (2) behavior that accepts the same medical institution and uses services from different providers, and (3) behavior that entails recommending the original medical providers to others. With regard to measuring the loyalty of patients to hospitals or physicians, Macstravic (1987) suggested that loyalty is determined by their preference for a specific hospital or physician on the basis of the attitudinal aspect, as well as by their consistent behavior toward a specific hospital or physician.

Reichheld and Sasser (1990) indicated that a company that retains 5% of its current customers could generate nearly 100% profit. Peppers and Rogers (1993) similarly reported that the cost of sustaining old customers is six to nine times higher than exploring new customers. In the business environment in which information rapidly flows, creating customer value is the principal resource for maintaining competitive strength, and customer retention is one of the most critical factors in the profitability of an enterprise. Vilifredo Pareto (1906) suggested the 80/20 principle, which states that 80% of revenues are derived from 20% of key customers. This principle has since been extensively implemented in operations management. In the healthcare industry, determining 20% valuable customers and providing them with healthcare allows hospitals to gain the largest benefit; thus, searching for loyal customers is highly important in the management of hospitals. Macstravic (1987) cited three major factors in acquiring loyal patients in the current environment, namely, the containment of cost and the prediction of benefits; increasing the quality of clinics; and boosting the revenues of hospitals. In the medical industry, customer relationship pertains to every type of interactive relationship between hospitals and patients (Howard 1999; Coile 2001). Hospitals can achieve sustainability and development by altering their management mode, increasing the loyalty of patients, and establishing long-term customer relationships.

Based on the literature review, scholars differed in their explanations for measuring the customer loyalty; nevertheless, the majority used repeat buying as an index for measuring the customer loyalty. Customers announce long-term relationships with a product or service through repurchasing. Hence, the study defines the actual clinical times of customers as an index for measuring their loyalty and calculates a variable of active probability to accurately predict the future clinical behavior of patients (customers).

### 2.3 RFM Model

The advancement of computer technology and the mature application of database systems have increased the usage of the RFM as an important application in database marketing. An RFM model measures customer loyalty and the contributions of customers to companies via the most recent purchasing day (Recency), purchasing frequency in a specific period (Frequency), and the average dollar volume or total dollar volume within a specific period (Monetary). Enterprises can predict future behaviors according to the past trading records of customers. Hughes (1996) indicated that the average is typically used in an RFM model; utilizing the three indexes can measure the relationship between an enterprise and its customers to assess the valuations of each customer on which to base the development of a customer relationship strategy. Hughes (1994) provided the following definitions for the three indexes:

(1) Recency pertains to the most recent day, which is the time between the last purchasing day and the analyzing point. In general, the closer the last clinical time of a patient, the higher his/her probability of coming to see a doctor, which indicates a higher index score. Otherwise, if the time of the most recent purchasing day is more distant, then the "purchasing" continuity of the patient decreases, signifying that the patient may have left. When deciding the importance of a patient based on recency, the attributes of a product such as durability and consumability should be considered as well. The level of importance of patients cannot be determined solely on the basis of recency.

(2) Frequency denotes the total times during a period, such as a season, a month, or a week. In general, the higher the purchasing frequency of a customer, the higher the interactive level becomes; a

company uses this aspect as a basis for determining the level of customer loyalty. Hospitals consider the valuation and loyalty of customers to be higher when the clinical times are higher.

(3) Monetary amount calculates the total dollar volume within a specific period. In general, the total dollar volume of products purchased by a customer represents his/her interest index on the product, which is the actual monetary contribution to a company. The higher the dollar volume on a product of a customer implies that he/she bought this product copiously, and that his/her need for the product is higher. Similarly, when the clinical expenditures of a patient are higher, hospitals consider the customer as one with a higher valuation. However, to avoid the low number of clinical times of new patients as well as their low clinical dollar volume and subsequently omit their importance, hospitals should allow the average dollar volume to supersede those whose clinical times and dollar volume are extremely low.

In this study, the three indexes of RFM are recency (time between the last clinical time and the observation time of a patient), clinical frequency (clinical times of a patient within a specific period), and clinical dollar volume (total medical expenditures of a patient within a specific period). Aside from these indexes, stochastic processes are included as an approach to predict the loyalty of patietns.

# 3 RESEARCH METHOD

The paper calculates the individual active probabilities of patients based on the method developed by Schmittlein et al.(1987). Moreover, it calculates the future expected clinical times and expected medical expenditures based on the method suggested by Schmittlein and Peterson (1994). These methods are modified and integrated in the paper.

## 3.1 Variables, Notations and Assumptions

The model developed by Schmittlein et al. (1987) considers three types of data in the past trading history of customers, that is, the purchasing information of a customer = (X, t, T). In this paper, X denotes the number of repeat clinic visits in observation time (0, T), t pertains to the last clinical time, and T represents the observation time. The information will be utilized for calculating the active probabilities of patients. Before proposing the research approach, we describe the following eight assumptions:

(1) Poisson-distributed clinical behaviors: When patients are active, their clinics X in time period of length t are Poisson random variables with clinic rate λ.

(2) Exponential-distributed attrition: Any patient is regarded as being active for some time $\tau$ . After the time, the patient will not visit the clinic in the hospital. The attrition is assumed to transpire with some rate $\mu$ .

(3) Clinic rates: The clinic rate λ's of different patients are distributed according to a gamma distribution.

(4) Attrition rates: The dropout rate μ's of different patients are distributed according to a gamma distribution.

(5) Independence: λ and μ are independent.

(6) Patient-level assumption: Let $Z_i$ denote the expenditure volume of clinic i (i=1,2,…,X) and θ represent average expenditure volume per re-clinic. The set of $Z_i$ are normal random variables with mean θ and some variance $\sigma_w^2$, which is constant across patients.

(7) Average expenditure assumption: Let E[θ] denote the overall average expenditure volume. The average volume per clinic θ is assumed to vary across customers according to a normal distribution with mean E[θ] and $\sigma_A^2$. $\sigma_A^2$ is the variance in the average amount across customers.

(8) Independence from clinics and attrition: The distribution of average expenditure θ across customers is assumed to be independent of the distributions of clinic rate λ and attrition rate μ.

### 3.2 Active probabilities

Based on the preceding assumptions and given that μ and λ are typically unknown in general; the distributions for clinic and attrition are mixed up as compound distributions, respectively. Therefore, four parameters α, β, r, δ will emerge accordingly, where α and β belong to the clinic process, whereas r and s belong to the attrition process. The three cases for calculating the probability that a patient remains active are shown in Eqs. (1) to (3).

Case 1: $\alpha > \beta$

$$\mathrm{P}(\tau > \mathrm{T} \mid \gamma, \delta, \alpha > \beta, X = x, t, T) = \frac{1}{\left\{1 + \frac{\delta}{\gamma+\delta+x}\left(\frac{\beta+T}{\alpha+t}\right)^{\delta}\left[\left[\left(\frac{\alpha+T}{\alpha+t}\right)^{\gamma+x} - 1\right] F(\gamma+\delta+x, \delta+1, \gamma+\delta+x+1, \frac{\alpha-\beta}{\alpha+t})\right]\right\}} \quad (1)$$

Case 2: $\alpha < \beta$

$$\mathrm{P}(\tau > \mathrm{T} \mid \gamma, \delta, \alpha > \beta, X = x, t, T) = \frac{1}{\left\{1 + \frac{\delta}{\gamma+\delta+x}\left(\frac{\alpha+T}{\beta+t}\right)^{\delta}\left[\left[\left(\frac{\beta+T}{\alpha+t}\right)^{\gamma+x} - 1\right] F(\gamma+\delta+x, \delta+1, \gamma+\delta+x+1, \frac{\beta-\alpha}{\beta+t})\right]\right\}} \quad (2)$$

Case 3: $\alpha = \beta$

$$\mathrm{P}(\tau > \mathrm{T} \mid \gamma, \delta, \alpha > \beta, X = x, t, T) = \frac{1}{\left\{1 + \frac{\delta}{\gamma+\delta+x}\left[\left[\left(\frac{\alpha+T}{\alpha+t}\right)^{\gamma+x+\delta} - 1\right]\right]\right\}} \quad (3)$$

Here, F(;;) is the Gauss hyper geometric function.

### 3.3 Expected clinic expenditures

The confidence that should be placed in the observed clinic expenditure $Z_i$ is reliability coefficient $\rho_X$. Therefore, the expected clinic expenditures can be defined as Eq. (4) and the reliability coefficient can be defined as Eq.(5)

$$\bar{Z} = \sum_{i=1}^{X} Z_i \Big/ X \quad (4)$$

$$\rho_X = \frac{\sigma_A^2}{\left[\sigma_A^2 + \left(\frac{\sigma_w^2}{X}\right)\right]} \tag{5}$$

The expected future expenditure per re-clinic could be defined as Eq.(6)

$$E[\theta \mid Z_1, Z_2, \ldots, Z_X] = \left(\frac{X\sigma_A^2}{X\sigma_A^2 + \sigma_w^2}\right)\overline{Z} + \left(\frac{\sigma_w^2}{X\sigma_A^2 + \sigma_w^2}\right)E[\theta] \tag{6}$$

### 3.4 Loyal patients

Let ε, χ be the thresholds for active probabilities and expected expenditure volume. The definitions for a patient are given by $\mathrm{P}(\tau > \mathrm{T} \mid \gamma, \delta, \alpha > \beta, \mathrm{X} = t, T) > \varepsilon$ in which a loyal customer is determined for one level, and $E(\theta \mid Z_1, Z_2, \ldots, Z_X) \geq \chi$ in which a loyal customer is determined for another level. Therefore, three levels of loyal patients emerge. First, patients where their

$$\mathrm{P}(\tau > \mathrm{T} \mid \gamma, \delta, \alpha > \beta, \mathrm{X} = t, T) > \varepsilon \tag{7}$$

Second, patients where their

$$E(\theta \mid Z_1, Z_2, \ldots, Z_X) \geq \chi \tag{8}$$

Third, patients where

$$\mathrm{P}(\tau > \mathrm{T} \mid \gamma, \delta, \alpha > \beta, \mathrm{X} = t, T) > \varepsilon \text{ and } E(\theta \mid Z_1, Z_2, \ldots, Z_X) \geq \chi \tag{9}$$

### 3.5 Process of the algorithm

In combining the aforementioned explanations, a process can be generated for calculating the probabilities of continuing hospitalization and the expected expenditure volume. The use of this method helps identify the individual loyal patients and obtain the number of aggregate loyal patients.

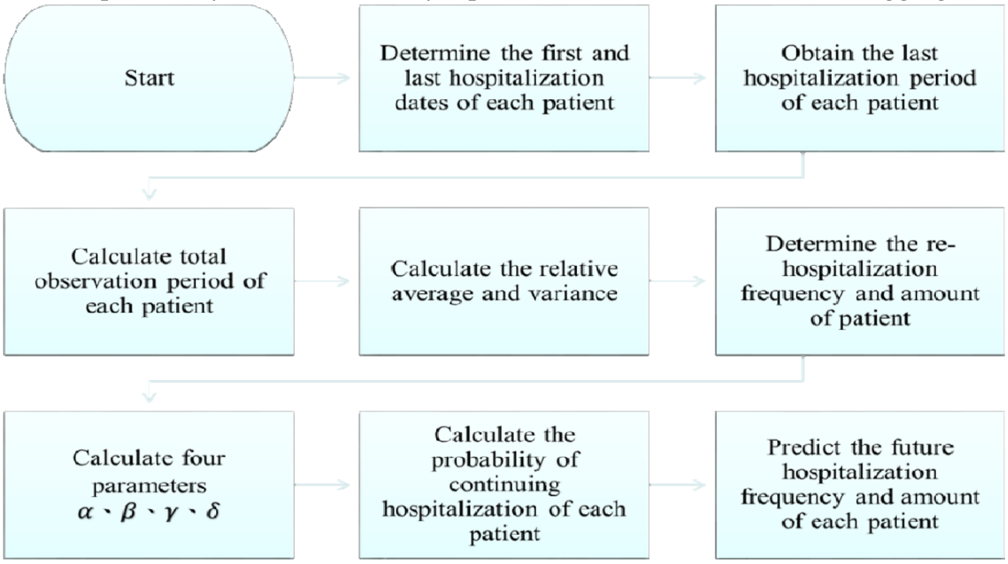


*Figure 1. Process for predictions.*

# 4 EMPIRICAL RESULT

This study considers the actual medical records of patients in a certain medical center in Taiwan as examples from the period spanning 36 months from January 2011 to December 2013. A total of 8000 patients and more than 50,000 medical records were randomly selected to conduct the analysis. The material considers 30 days as the unit. The anterior 24 terms were used as training materials, whereas the latter 12 terms were used as testing materials. January 2011 was the first period and December 2012 was the 24th period.

## 4.1 Patient's material

According to method proposed by Schmittlien et al. (1987), the estimated probability of continuing hospitalization $\alpha$ , $\beta$ , $\gamma$ and $\delta$ should first be calculated. Table 1 shows the medical records of 8000 patients. The medical records are divided into 24 periods with 30 days considered as one unit, to calculate the average re-hospitalization frequency and variance of patients in each period. The frequencies are 0.8229 and 1.5766 in period 1, 1.3050 and 3.5339 in period 2, and 20.2916 and 426.2432 in period 24. Table 1 shows the accumulated value of each period.

| Period | Average re-hospitalization frequency | Variance re-hospitalization frequency | Period | Average re-hospitalization frequency | Variance re-hospitalization frequency |
|---|---|---|---|---|---|
| 1 | 0.82 | 1.58 | 13 | 5.77 | 67.65 |
| 2 | 1.31 | 3.53 | 14 | 6.24 | 77.55 |
| 3 | 1.72 | 5.97 | 15 | 6.77 | 90.27 |
| 4 | 2.12 | 9.32 | 16 | 7.34 | 104.71 |
| 5 | 2.48 | 13.00 | 17 | 7.93 | 118.76 |
| 6 | 2.86 | 17.31 | 18 | 8.74 | 136.83 |
| 7 | 3.25 | 21.99 | 19 | 9.62 | 157.23 |
| 8 | 3.61 | 27.52 | 20 | 10.60 | 179.26 |
| 9 | 4.00 | 33.89 | 21 | 12.01 | 209.88 |
| 10 | 4.41 | 41.06 | 22 | 13.73 | 243.40 |
| 11 | 4.83 | 48.57 | 23 | 16.71 | 302.21 |
| 12 | 5.30 | 57.98 | 24 | 20.29 | 426.24 |

*Table 1. Average re-hospitalization frequency and variance of patients in each period*

Equation (5) in Section 3.2 $\alpha<\beta$ is used to calculate the probability of continuing hospitalization of each patient, as shown in Table 2. If the last hospitalization period is the same, we can legitimately believe that when the re-transaction times are lesser, the probability of continuing hospitalization is lower. Table 2 shows that the last transaction periods of two patients, namely 1022659 and 1117883 are 24 and their re-hospitalization frequencies are 25 and 35, respectively. Hence, their probabilities of continuing hospitalization are 0.9659 and 1, respectively. Therefore, the probability of continuing hospitalization of patient 1022659 is lower than that for patient 1117883, which is deemed to be very reasonable. However, based on more cases, the results show that if the re-hospitalization frequency is higher, the probability of continuing hospitalization is not definitely higher. The last transaction periods of patients 1189042 and 1259316 are 16 and that their re-hospitalization frequencies are 8 and 1, respectively. Hence, their probabilities of continuing hospitalization are 0.5418 and 0.8233, respectively. Therefore, the probability of continuing hospitalization of patient 1189042 is lower than that of patient 1259316. In this study, the true medical records are compared with the expected probability of continuing hospitalization. Patient 1189042 has been hospitalized eight times during the period of 2011−2012, but, only once 2013. Patient 1259316 was hospitalized once during the period of 2011−2012, but three times in 2013. Therefore, the probability model has very high accuracy of prediction. This model changes our general logical thinking because it is not a simple RFM. The model considers the presence of regularity of hospitalization. Some patients may have been hospitalized in this hospital at the beginning, but the frequency of hospitalization declines sharply at the later stage. Thus, although this patient may have been hospitalized several times, they may still be lost. By comparing these patients with those with lower probability of continuing hospitalization, a pattern may emerge. Lesser hospitalization frequency could imply that a patient is still alive and thus, has higher probability of continuing hospitalization.

| ID | t | X | Probability | ID | t | X | Probability |
|---|---|---|---|---|---|---|---|
| 1001133 | 1 | 2 | 0.88 | 20517042 | 0 | 0 | 0.13 |
| 1002248 | 20 | 7 | 0.94 | 20517535 | 0 | 0 | 0.13 |
| 1005337 | 0 | 0 | 0.17 | 20517999 | 2 | 1 | 0.07 |
| 1016452 | 21 | 5 | 0.91 | 20518046 | 0 | 0 | 0.14 |
| 1022659 | 24 | 25 | 0.97 | 20518131 | 2 | 3 | 0.00 |
| 1073590 | 14 | 1 | 1.00 | 20519281 | 0 | 0 | 0.14 |
| 1096479 | 3 | 7 | 0.00 | 20520384 | 0 | 0 | 0.14 |
| 1117883 | 24 | 35 | 1.00 | 20520802 | 0 | 0 | 0.14 |
| 1129633 | 1 | 1 | 0.14 | 20520838 | 0 | 0 | 0.14 |
| 1150744 | 12 | 8 | 0.18 | 20520970 | 1 | 2 | 0.01 |
| 1151006 | 21 | 5 | 0.95 | 20521581 | 0 | 0 | 0.14 |
| 1171757 | 24 | 30 | 1.00 | 20522062 | 15 | 5 | 0.52 |
| 1189042 | 16 | 8 | 0.54 | 20522257 | 22 | 17 | 1.00 |
| 1206601 | 3 | 5 | 0.00 | 20522289 | 0 | 0 | 0.14 |
| 1248356 | 14 | 22 | 0.00 | 20522464 | 18 | 4 | 0.81 |
| 1252384 | 24 | 30 | 1.00 | 20523334 | 0 | 0 | 0.14 |
| 1259316 | 16 | 1 | 0.82 | 20524665 | 4 | 2 | 0.06 |
| 1260384 | 15 | 1 | 0.97 | 20525191 | 20 | 12 | 0.92 |
| 1326813 | 0 | 0 | 0.89 | 20532548 | 6 | 5 | 0.01 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 20489653 | 22 | 30 | 0.56 | 29628218 | 0 | 0 | 0.67 |
| 20515762 | 0 | 0 | 0.13 | 29636138 | 0 | 0 | 0.89 |
| 20516374 | 0 | 0 | 0.13 | 29638311 | 0 | 0 | 0.89 |

*Table 2. Probability of continuing hospitalization*

### 4.2 Overall prediction

The overall prediction is calculated through taking absolute value after the actual hospitalization frequency and expenses of all patients minus the predicted hospitalization frequency and expenses by our model. This result shows 8000 patients are predicted be hospitalized 2043 times in the coming 30 days, and incur medical expenses amounting to NTD$ 6,622,881.44. Actually, the 8000 patients were hospitalized 2256 times in the coming 30 days, incurring NTD$ 7,865,386.95 in medical expenses. The 8000 patients are predicted to be hospitalized 4014.44 times in the coming 60 days, spending NTD$ 13,024,546.82 on medical expenses. In actuality, the 8000 patients were hospitalized 4257 times in 60 days, spending NTD$ 14,617,094.58 in medical expenses. Accordingly, 30 days are accumulated in each period. In Taiwan, patients have very high right of free medical choice. The test results with very high accuracy have predicted the hospitalization behavior of patients. The test results are shown in Table 3.

| Period | Hospitalization frequency | | | Hospitalization expenses | | |
|---|---|---|---|---|---|---|
| | Actual | prediction | Accuracy of overall prediction | Actual | prediction | Accuracy of overall prediction |
| P=1 | 2256 | 2042.61 | 90.54% | $7,865,386.95 | $6,622,881.44 | 84.20% |
| P=2 | 4257 | 4014.44 | 94.30% | $14,617,094.58 | $13,024,546.82 | 89.10% |
| P=3 | 6285 | 5923.49 | 94.25% | $20,665,815.17 | $19,228,747.80 | 93.05% |
| P=4 | 8352 | 7776.05 | 93.10% | $27,103,716.40 | $25,254,426.52 | 93.18% |
| P=5 | 10431 | 9577.26 | 91.82% | $33,853,060.99 | $31,117,140.27 | 91.92% |
| P=6 | 12445 | 11331.38 | 91.05% | $40,385,434.68 | $36,829,952.73 | 91.20% |
| P=7 | 14442 | 13042.05 | 90.31% | $47,075,542.56 | $42,404,024.92 | 90.08% |
| P=8 | 16497 | 14712.39 | 89.18% | $54,229,047.59 | $47,849,025.11 | 88.24% |
| P=9 | 18477 | 16345.11 | 88.46% | $61,182,233.47 | $53,173,423.90 | 86.91% |
| P=10 | 20362 | 17942.63 | 88.12% | $66,978,704.75 | $58,384,712.92 | 87.17% |
| P=11 | 22274 | 19507.06 | 87.58% | $72,992,923.97 | $63,489,571.21 | 86.98% |
| P=12 | 24191 | 21040.31 | 86.98% | $79,424,707.85 | $68,493,994.33 | 86.24% |

*Table 3. Overall prediction results of hospitalization frequency and expenses*

### 4.3 The individual prediction

Based on the actual hospitalization frequency and expenses of each patient, if the actual value is located in the confidence interval of the standard deviation of the prediction 1 is given to represent the hospitalization behavior of the patient. Our prediction is correct. For example, if patient 101133 is predicted to have 0.1−1 times of hospitalization behavior in the next 30 days. The patient is not hospitalized within the period. Therefore, 0 is given to represent a incorrect prediction. The same patient is predicted to have 0−2 times of hospitalization behavior within the next 60 days. The patient was hospitalized once within the 60 days. Therefore, 1 is given to represent a correct prediction. Similarity, patient 101133 is predicted to spend NTD $1578.341−NTD $8259.56 in medical expenses in the next 30 days. However, this patient does not spend money. Therefore, 0 is given to represent an incorrect prediction. The same patient is predicted to spend NTD $3892.708−NTD $23353.81 of the medical expenses within 90 days. This patient spends NTD $3992.00 in medical expenses within 90 days. Thus, 1 is given to represent a correct prediction. Finally, based on the accuracy of prediction of individual patients, the prediction for each patient in each term is summed to obtain the overall accuracy of individual patient. Fig.2 shows that the accuracy of individual prediction is more stable in the prediction of amount of medical expense and fluctuated slightly in the prediction of hospitalization frequency. This study believes that the medical expenses are in a fixed interval based on disease conditions and expenses for drugs under the National Health Insurance System. For hospitalization frequency however, predicting this factor for individual patients can be very difficult under a highly free hospitalization system. The results of this study shows high accuracy of the prediction and high credibility, regardless of hospitalization frequency or medical expenses. Therefore, the study could help hospitals understand the hospitalization behavior of patients in advance, and provide them with the best care.

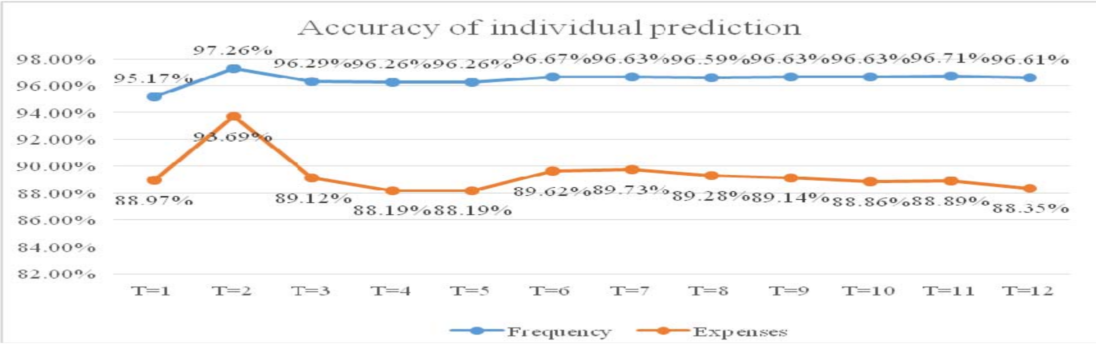


*Figure 2. Accuracy of individual prediction*

### 4.4 Loyal patient

Based on the model developed in this study, the top 2000 patients were selected from total 8000 patients as the loyal patients according to the declining order of ranking of the probability of continuing hospitalization. This method can prevent the selected loyal patients from seeking medical treatment in other medical institutions, causing difficulties for medical professionals to gain a full picture of the patient's health. The average probability of continuing hospitalization of 2000 patients selected by this study is 0.96308. This number shows that the probability of continuing hospitalization of these patients in the future will be as high as up to 96%. In this case, doctors can have a deeper understanding of the conditions of patients and administer the correct treatment, thereby halting the progression of the disease. Hence, the essence of capitation can be achieved. The care method of considering people as a unit, patients can become healthier, and the medical institutions will gain higher benefits, thereby ensuring that the win-win purpose is achieved.

## 5 CONCLUSIONS

This paper conducted an analysis on 8000 patients provided by a certain medical center. Overall and individual predictions were made based on hospitalization frequency and medical expenses of patients. The accuracy of overall predictability was as high as 84%. The overall hospitalization frequency and estimated medical expenses of the cared objects can be controlled accurately. Cost control and prediction of future benefits for medical institutions can also be achieved. For example, for the procurement of the medical equipment, provided the institution is aware of the number of patients that the equipment will be used for, the costs can be controlled, and the benefits of the hospital can be increased by predicting the future benefits of this medical equipment. Capitation aims to enable the cared objects to become healthier, thereby reducing their hospitalization frequency and improving the quality of medical care, which in the end, will result the medical institutions to obtain higher revenues.

For the loyal patient selection mechanism, this paper selected 0.96308 as the average probability of continuing hospitalization for 2000 patients. The average probability implies that patients in this hospital had 96% probability of continuing hospitalization in this hospital. In stable medical conditions, doctors can control the conditions of patients and provide them with the correct health care concept to aid them in preventing the progression of the disease and improving quality of medical care. The loyal patient model is very important for both of patients and doctors. With the rise in population aging and chronic diseases becoming increasingly serious, loyal patients (those who continue to seek hospitalization in the same hospital) require excellent long-term care. Long-term care can help improve the quality of services, as doctors have more time to analyze the condition of diseases and provide the necessary and timely care, resulting in a decrease in medical expenses. Thus, capitation can be achieved. The care method that involves regarding people as a unit can result in healthier patients and more benefits for medical institutions, enabling the achievement of the win-win purpose.

However, due to the limitations of the existing framework, extreme patients cannot be selected for further investigation due to the difficult acquirement of materials. The proposed model can be used to make predictions and conduct analysis of medical records, thus selecting loyal patients as the cared objects. In the present study, only the hospitalization date and expenses of patients were considered. Thus, difficulties are encountered when identifying whether loyal patients have been selected because particular stress is placed on a certain department. Hence, in future studies, classification of patients should be based on different departments and then conduct an analysis. A prediction can be made for a certain department, which could provide support for hospitals. The differences in behaviors of hospitalization patients in different departments can also be determined.

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