Analyzing Patient Value by Modifying RFM Model With Consideration of The Limitation of Service Throughput: An Investigation of Dental Health Care

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ABSTRACT

The Requency-Frequency-Monetary (RFM) model was commonly used to describe customer value. However, there are some deficiency in the RFM model and should be overcame. This study proposed a new concept of customer value analysis in the service system of health care with consideration of the limitation of service throughput. We proposed a modified RFM model and focused on the adjustment of the Monetary measure which took account of the length of customer stay. In this study, the proposed model was applied to dental care service, and the customers' value are measured more accurate and more approaching to the characteristics of the service system. Patient segmentation was performed by integrated customer value matrix and traditional/modified RFM model. The results of this study show that the number of patients, the average age, and the average treatment duration of the target patient segment obtained from the proposed FRM model were slightly reduced, but the average monetary and average modified monetary were superior to those of the target patients obtained from the traditional RFM model. The results indicated that the modified model proposed by this study performs more objective and effective segmentation of target patients.

KEYWORDS

Data mining; FRM model; target customer segment; customer relationship management; dental care.

1. Introduction

Customer relationship management (CRM) is important in running a successful business. Based on the customer-centric service philosophy, business will effectively grasp customers’ needs and behaviors to develop stronger relationships with their customers. Businesses make good CRM strategies to obtain, maintain and even increase valuable customers. With the growing prospects of information technology (IT), business moves forward in IT adaption to understanding the customers' needs and preferences to obtain a competitive advantage for meeting the opportunities and challenges in the industry. According to the analysis, business provides customized information to the customers to enhance their transaction frequency and loyalty. Customer segmentation is one of the core functions of CRM.

Customer segmentation is the process of classifying customers into groups based on historical transaction records. An ideal customer segment should be internally homogeneous (i.e. all customers within the segment have similar preferences and characteristics), but externally heterogeneous. Businesses can provide differential services for distinguish groups of customers. Especially, to retaining the target customers with high value, businesses plan a market strategy carefully. These high-value customers will contribute highest profit to the business. Typically 80% of corporate profits come from 20% of the customers (80-20 rule). Moreover, it is now generally accepted that it costs about five times as much to gain a new customer as it does to
retain an existing one [1]. Studies show that raising 5% in customer retention can increase profits by more than 25 percent. Therefore, business can establish well relationship with their customers and allocate scarce resources effectively by segmenting customers and identifying the target customers.

Recency-Frequency-Monetary (FRM) model is one of the most frequently adopted methods of customer value analysis. Hughes (1994) proposed the RFM model which utilizes three index, Recency, Frequency, and Monetary, to evaluate customer value is an important technique of customer segmentation. Compared with more sophisticated modeling approaches, RFM model is relative easy to use and is becoming a popular customer segmentation tool for many industry, such as retailers, banking, and telecommunications etc. In these applications, the throughput of a service system is not limited by the time occupation of a customer; contrarily, it may be possible that the longer customers stay in the system, the higher the chance of customers will spend more. However, in some service systems, the consumption of scarce resources by customers will affect the service capability of the system. Take the service system of health care as an example: the capacity of inpatient services is restricted to the number of beds. That is, the longer patients’ length of stay, the fewer the number of inpatients will be served [2]. For the outpatient services, the number of patients seen in each clinic session is an important factor to measure the outpatient performance [3]. The consultation time of doctors is limited. Therefore, the longer the treatment duration, the fewer the number of patients can be seen in each session. However, in the dental health care system, the average time of patient treatment is longer than other departments. Hence, the treatment duration for patients in such system is more important for patient grouping. Therefore, using the traditional RFM model for patient segmentation in dental care is inappropriate and should be modified.

The dental care industry in Taiwan is highly competitive. Dental clinics are everywhere. According to the statistics of the Department of Health, the number of dental clinics in Taiwan increased from 5,659 in 2001 to 6557 as of end of 2014 (an increase of up to 15.9%). Among which, up to 96% of the dental clinics participated in the National Health Insurance (NHI) program [4]. It shows that the competition is very intense in the dental industry. The NHI program of Taiwan provides universal and comprehensive health insurance with low copayment for dental care, and are only limited to basic preventive care, prosthesis, restoration, and endodontic therapy which contribute limited revenues to the dental institutes. As people’s living standards have improved, demands for health care are no longer limited to pain treatment. Demand for out-of-pocket cosmetic services (such as orthodontics, whitening, and implants) have also increased substantially. To increase revenues, dental institutes have actively developed many out-of-pocket treatments and programs. However, as the dental care services market is extremely competitive, patient relationship management has become an important topic in the dental care industry [5]. If dental institutes can effectively analyze patient characteristics and understand their needs, design specific medical services for different patient groups, and timely provide appropriate medical services, they could effectively improve their service quality and patient satisfaction and thus strengthen their competitiveness.

The characteristics of the service system discussed in this study are as follows: the throughput of the system is highly correlated to the duration required for customers receiving services. We proposed the modified RFM model (RFMt), which has modified the method...
of calculating the monetary value (M value) used in the traditional RFM model, and takes into account the factor of time to enhance the accuracy of customer value analysis. Such approach will closely to the characteristics of the service system and hence facilitate subsequent patient grouping. In this study, the dental care system was investigated. The remainder of this paper is structured as follows. A literature review of the related work is provided in the second section. In the third section, we describe the material and method used in the study. Afterwards, the results obtained are presented and discussed. The final section draws some conclusions and possible lines for future work.

2. Related Works

This section will review the relevant literatures on the customer value analysis, the RFM model, and the customer value matrix.

2.1 Customer value analysis

The customer value analysis is used to analyze the profit contribution made by customers to companies. It analyzes the value of customers to companies based on their historical consumption data and is also known as the customer profitability analysis. Companies can use it for customer classification. The RFM model is one of the most commonly used approaches for companies to evaluate customer value. It describes consumer consumption behavior using only three dimensions of variables (recency, frequency, monetary). Recency refers to the period of time starting from the most recent purchase date to the date of analysis. Generally speaking, the closer the most recent purchase date to the date of analysis, the higher the possibility the customers will make another purchase. Hence, it will score higher in the indicator of Recency. Frequency refers to the times of customer consumption within a specific analysis period. It is expected that the higher the purchase frequency of customers, the higher the customer loyalty and customer value to the company. Monetary refers to the total customer consumption amount within a specific analysis period. It is expected that the higher the value of monetary, the higher the profit contributions made to the company by customers and the higher the customer value.

Literatures pointed out that the RFM model can effectively segment target customers. However, a number of studies also indicated that there are deficiencies in the RFM model which are generally divided into two types: the issue of weighs of the three RFM indicators and the integrity of customer value analysis, as illustrated in the following. (1) The weighs of the three RFM indicators. When Hughes developed the original RFM model, he treated the three indicators as equally important. However, Stone [8] had a different opinion and
proposed that the importance of the three variables, recency, frequency, and monetary, should vary depending on the industry applied;

(2) **The integrity of customer value analysis.** Some scholars tried to add new variables to make a more complete description of the consumer behavior characteristics in the RFM model. Yet et al. [9] proposed to perform the target market segmentation analysis on direct marketing by adding two parameters, time since first purchase (T) and churn probability (C) into the RFMTC marketing model. Since the RFM model cannot differentiate the long-term or short-term relationships between customers and companies [10]. But customer loyalty which is an important measurement of the relationship between customers and companies, should be established by maintaining long-term relationship. Therefore, Chang & Tsay extended the RFM model by taking into account the factor of length (L) and proposed another model called LRFM. The index “L” was defined as the period of time starting from the first purchase to the most recent purchase. In their study, index “L” was taken as an important indicator in measuring customer loyalty [11].

2.3 Target customer segmentation

The customer value matrix is a simple and powerful approach to customer segmentation. Marcus simplified the RFM analysis to focus on the customer-value based variables, frequency and monetary, to best express the value of customer; and introduced the concept of the Boston Consulting Group’s (BCG) Growth-Share-Matrix to the analysis of customer segmentation to identify the target customer effectively [12]. The BCG’s Growth-Share-Matrix provides a framework for resources allocation in the given market share position and growth potential of a given set of business opportunities. BCG Growth-Share-Matrix is an effective analytical tool and easy-to-understand. It utilized a 2×2 matrix to segment business opportunities into four clearly defined groups for decision-making purposes. As is the case with BCG’s Growth-Share-Matrix, a significant benefit of the customer value matrix is its ability to suggest viable marketing strategies for each segment.

![Figure 1 the customer value matrix](image)

3. Material and Method

In this study, dental care service was used as an example to investigate the proposed RFM<sub>t</sub> model. In the dental clinic, the service throughput is limited by the time available to the dentists. If we use the traditional RFM model, the factor of monetary performs patient segmentation based merely on the total amount of clinical expenditure, which makes it difficult to objectively present the patient value. Therefore, the analysis in this study considered the treatment duration to modify the measure of monetary. The modification method is as follows: the monetary value for each patient equals the total amount of his/her clinical expenditure divided by the treatment duration. This is to convert monetary into clinical expenditure per unit time so that the patient value can be measured more objectively.

**Data**

This study used a database of discharged adult patients from the department of dentistry at a regional hospital in Taiwan's most populous region. With a high density of dental care centers, the competition of the dental care market around the studied hospital is much...
fiercer than that of markets in other areas of Taiwan. Therefore, establishing good relationship with patients to enhance the loyalty to gain a competitive advantage are crucial issues for dental service providers.

We selected the data of dental treatment of adult patients who were over 18 years old. The selected data were comprised of 3,135 patients who visit this dental center with the total of 24,870 times from 1 July 2010 to 30 June 2013. The profile for a patient record consisted of chart number, gender, birthday, date of the first visit, start time and end time of each treatment, total amount of fee of per visit.

The required data for the patients value analysis and the subsequent patient segmentation included patient medical record number, date of birth, date of the first visit, date of each visit, start and end time of consultation, treatment item, amount of expenditure, etc. "start time of consultation" and "end time of consultation" were used to calculate the duration of each dental treatment received by the patient. Furthermore, we conducted a value analysis for each patient represented by four indicators, recency, frequency, monetary, and modified monetary. The calculation method is as follows:

1. Recency: the time interval between the most recent date of treatment and the analysis closing date.
2. Frequency: the visit frequency between July 1, 2010 and June 30, 2013.
3. Monetary: the total amount of clinic expenditure between July 1, 2010 and June 30, 2013.
4. Modified monetary: the total amount of the modified clinic expenditure per treatment between July 1, 2010 and June 30, 2013, that is, the total amount of each clinical expenditure divided by the duration (in hours) of the current treatment, \[ M_t = \sum_{j} \frac{M_{ij}}{t_{ij}}. \]

### Segmentation

This study combined the clustering analysis and the customer value matrix to perform patient segmentation. Prior to the clustering analysis, the variables for grouping needed to be normalized. The normalization method in this study was to convert the variable value to \([0, 1]\). It is expected that the greater the patient visit frequency (F value) and the total amount of expenditure per unit time (M and Mt value) the better. We can convert using formula (1). It is expected that the closer the most recent visit date, the smaller of the R value is the better. We can use formula (2) for data normalization.

\[
x' = \frac{(x - x_{\min})}{(x_{\max} - x_{\min})}
\]

\[
y' = \frac{(x_{\max} - x)}{(x_{\max} - x_{\min})}
\]

When performing the patient grouping, we used the normalized value of variables to conduct the k-means clustering analysis and divided the patients into several groups. We then used the concept of the customer value matrix to define the target patients. Since the customer value matrix was a 2 × 2 matrix with two variables, we divided the customers into four categories. In this study, two most important variables, frequency and monetary, were selected to identify the target patients. The traditional RFM and the RFMt model proposed in the study were analyzed in the clustering analysis method using the SPSS software as the analysis tool. Lastly, the characteristics of the target patients obtained by the two models were compared.

### 4. Results and Discussions

Out of the 3135 selected patients, there were more female patients (1635, 52.2%) than male. The distribution of age was mainly concentrated between 18-24 years of age.
accounting for 27.4%, and the elders of 65 and older accounted for 5.5% (shown in Table 1). Additionally, the patient value was analyzed according to the demographic variables, and the average values are aggregated in Table 2. From the analysis we found that the average frequency, average total amount of clinic expenditure, and the average treatment duration of male patients are slightly higher than female; and that the average visit frequency, average total amount of clinic expenditure for patients below 34 years of age are higher than the patients of other age groups, whereas their average treatment duration is relatively shorter. The clustering analysis results of the RFM and the RFMt model was integrated into customer value matrix to identify the target patients respectively. We compared the target patients obtained from the two models (the RFM and the RFMt model) and developed Table 3. The target patients of both models, patients between 18-24 years of age were the largest patient group. We further analyzed the factors for this phenomenon and found that the reason being the percentage of patients required for orthodontics in such age group is higher than the other age groups. The costs for orthodontics are high and are not covered in the NHI program and frequent visits are required. Additionally, the dental problem for patients in such age group is comparatively simpler and therefore requires shorter treatment duration. As a result, the patients in such age group are more likely to be classified as the target patients. With respect to the target segment patient distribution, the number of patients obtained from the RFM and the RFMt model accounts for 24.8% and 23.3% respectively. Both the average monetary and the average modified monetary of the target patients obtained from the RFMt model are higher than those obtained from the traditional RFM model. It is also because the RFMt model proposed by this study takes into account the treatment duration, the average treatment duration of the target patients is lower than that obtained from the RFM model.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Groups</th>
<th>Number (%)</th>
<th>Recency</th>
<th>Frequency</th>
<th>Monetary</th>
<th>Modified Monetary</th>
<th>Treatment Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
<td>1500 (47.8)</td>
<td>191.41</td>
<td>8.01</td>
<td>29714.71</td>
<td>60971.70</td>
<td>41.31</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1635 (52.2)</td>
<td>206.35</td>
<td>7.86</td>
<td>27330.08</td>
<td>60139.98</td>
<td>39.64</td>
</tr>
<tr>
<td>Age</td>
<td>Under 25</td>
<td>858 (27.4)</td>
<td>173.03</td>
<td>8.64</td>
<td>32364.05</td>
<td>77806.54</td>
<td>40.63</td>
</tr>
<tr>
<td></td>
<td>25 - 34</td>
<td>574 (18.3)</td>
<td>219.41</td>
<td>8.69</td>
<td>31995.43</td>
<td>71918.63</td>
<td>41.90</td>
</tr>
<tr>
<td></td>
<td>35 - 44</td>
<td>536 (17.1)</td>
<td>201.49</td>
<td>7.71</td>
<td>26792.57</td>
<td>49538.90</td>
<td>43.53</td>
</tr>
<tr>
<td></td>
<td>45 - 54</td>
<td>620 (19.8)</td>
<td>192.28</td>
<td>7.67</td>
<td>27878.50</td>
<td>55057.31</td>
<td>45.15</td>
</tr>
<tr>
<td></td>
<td>55 - 64</td>
<td>375 (11.9)</td>
<td>207.80</td>
<td>7.10</td>
<td>24533.80</td>
<td>45357.27</td>
<td>46.83</td>
</tr>
<tr>
<td></td>
<td>≥ 65</td>
<td>172 (5.5)</td>
<td>261.38</td>
<td>5.31</td>
<td>13240.38</td>
<td>23544.99</td>
<td>46.71</td>
</tr>
</tbody>
</table>

Table 1. The description of the patient value

<table>
<thead>
<tr>
<th></th>
<th>Max. Value</th>
<th>Min. Value</th>
<th>Mean Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recency</td>
<td>890</td>
<td>1</td>
<td>199.2</td>
</tr>
<tr>
<td>Frequency</td>
<td>54</td>
<td>1</td>
<td>7.9</td>
</tr>
<tr>
<td>Monetary</td>
<td>577454</td>
<td>100</td>
<td>28471.1</td>
</tr>
<tr>
<td>Modified Monetary</td>
<td>1740075</td>
<td>60</td>
<td>60537.9</td>
</tr>
</tbody>
</table>
Table 3. The comparison the result of patient segments obtained from RFM and RFMt model

<table>
<thead>
<tr>
<th>Model</th>
<th>Category</th>
<th>Number of patients</th>
<th>Average age</th>
<th>Average recency</th>
<th>Average frequency</th>
<th>Average monetary</th>
<th>Average modified monetary</th>
<th>Average treatment duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Best</td>
<td>776</td>
<td>33.9</td>
<td>85.4</td>
<td>18.3</td>
<td>88167.0</td>
<td>186085.0</td>
<td>40.09</td>
</tr>
<tr>
<td>RFM</td>
<td>Frequency</td>
<td>395</td>
<td>45.5</td>
<td>131.4</td>
<td>10.2</td>
<td>15073.1</td>
<td>35727.6</td>
<td>40.66</td>
</tr>
<tr>
<td></td>
<td>Spender</td>
<td>95</td>
<td>30.3</td>
<td>198.2</td>
<td>5.2</td>
<td>44466.0</td>
<td>77250.8</td>
<td>49.30</td>
</tr>
<tr>
<td></td>
<td>Uncertain</td>
<td>1869</td>
<td>39.4</td>
<td>260.8</td>
<td>3.3</td>
<td>5704.1</td>
<td>12805.4</td>
<td>40.42</td>
</tr>
<tr>
<td></td>
<td>Best</td>
<td>731</td>
<td>33.3</td>
<td>86.6</td>
<td>18.6</td>
<td>90140.5</td>
<td>198766.1</td>
<td>39.12</td>
</tr>
<tr>
<td>RFMt</td>
<td>Frequency</td>
<td>440</td>
<td>45.3</td>
<td>124.7</td>
<td>10.6</td>
<td>19269.9</td>
<td>30037.3</td>
<td>43.40</td>
</tr>
<tr>
<td></td>
<td>Spender</td>
<td>88</td>
<td>27.5</td>
<td>185.9</td>
<td>5.3</td>
<td>33436.6</td>
<td>113794.7</td>
<td>32.58</td>
</tr>
<tr>
<td></td>
<td>Uncertain</td>
<td>1876</td>
<td>39.5</td>
<td>261.2</td>
<td>3.3</td>
<td>6366.1</td>
<td>11331.6</td>
<td>41.72</td>
</tr>
</tbody>
</table>

Furthermore, we investigated the difference of the characteristics of the target patients between the traditional RFM model and the proposed RFMt model. For the target patients obtained from the RFM model, in the group of 45-54 age, there are 17.8% patients classified as non-target patients in the RFMt model. The reason may be that the patients in this age group are more willing to actively solve their dental problems to maintain good life quality. However, as the dental problems become more complex, longer treatment duration is needed. Hence, in addition to providing dental treatment, we need to strengthen the concept of oral health care in this group of patients and remind them to come back on a regular basis in order to avoid the deterioration of dental health problems.

5. Conclusions

As medical institutions become completely informationalized, a huge database of medical records has been accumulated. It has become an urgent issue to grasp the information that is useful to the medical operations and provide a reference to develop or improve their operating directions. This study applied the concept of customer segmentation of marketing management in dental health care, hoping to perform the segmentation of the target patients more appropriately, provide reference for managers to formulate strategies, and enable more efficient allocation of medical resources. Considering the length of treatment duration would affect the characteristics of the service throughput, this study modified the customer value analysis of the traditional RFM model. The results show that the proposed RFMt model can more effectively identify the target patients; according to the characteristics of segmentation and the characteristics of each group of patients, decision-makers can use the RFMt model as a reference for patient relationship management.

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