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Dental Service Cost Analysis Using Time-Driven Activity-Based Costing



Abstract: - This research has the objective to analyze dental service costs of the case study dental clinic using Time-Driven Activity-Based Costing (TDABC). The study was conducted in teaching clinic where dental services were provided by undergraduate-level dentistry students under the supervision of the teachers of Dentistry Faculty, and where there were also dental assistants on hand to provide service support. The research studied only five treatment procedures with a maximum frequency of service use, cumulatively totaling 80%, according to the Pareto principle. The research started from studying various activities in the processes of providing each category of dentistry service. Then, the dental service costs using TDABC were analyzed by estimating from two key parameters: the capacity cost rate and the time taken for each activity of the treatment procedure. The study found that Sealant Compounds, Tooth Extraction, Preventive Resin Restoration, Composite Fillings and Stainless Steel Crown had treatment costs of 623, 594, 669, 642 and 761 Thai Baht/treatment respectively. This research enabled the case study dental clinic to identify its costs for each treatment procedure, and also calculate profit and loss by comparison with income from service users. These data could also be used to determine more appropriate service charges for each category of treatment.

Keywords: Dental Service Cost, Teaching Clinic, Time-Driven Activity-Based Costing, TDABC

I. INTRODUCTION

The case study dental clinic in this research is a pediatric dental clinic and part of the Dental Hospital. The Dental Hospital is affiliated to a state university in Thailand. The case study clinic is a teaching clinic for conducting tutorials about providing dental services to children, students of all ages and the general public. The institution also provides technical services to the community of preventative dental advice and treatment. Dental services are provided by undergraduate and postgraduate students of dentistry under the oversight of teachers in the Faculty of Dentistry. Services also include specialist pediatric dentistry provided by members of the faculty. Service charges are maintained below market rates with subsidies from the government. Patients also have a number of state entitlements to pay for the services. Until now, the case study clinic only submitted annual accounts, and there has not been any study of the costs of providing dental services. This resulted in not knowing the true service costs of the clinic, and so hindered efforts to cut costs. Executives of the Dental Hospital and this case study dental clinic were therefore interested to analyze the costs of providing service for various dental procedures, to assist in planning operations. In addition, the research results can be used as an example case for analyzing the cost of providing dental services to other clinics in the Dental Hospital.

Time-Driven Activity-Based Costing (TDABC) was developed from Activity-Based Costing (ABC). TDABC uses time as the driver for costs, allowing allocation of indirect costs into the product more reasonable. The concept is that all resources used have a capacity measurable with units of time of operation. It is necessary to study the time of each activity. TDABC analysis has two key parameters to estimate costs, which are the capacity cost rate and the time taken to conduct each activity [1].

Of previous studies, [2][3] applied TDABC to dental practice to identify dental service costs accurately. In the aforementioned research, activities were analyzed by showing process flow diagrams, with cost calculations separated for each activity. Activities were then classified into value added activity and non-value added activity. It was then possible to reduce the time for sub-activities as a guide to reduce costs. Executives can use these data to make management decisions in the future.

Therefore, for this research, researchers proposed a method to analyze the cost of providing dental services at the case study dental clinic by using the TDABC, to be apprised of the dental services costs in each category. This

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enables analysis of profit and loss in providing dental services, as a guideline for determining dental service charges more reasonably.

II. RESEARCH METHODOLOGY AND RESULTS

This research conducted its study specifically at a teaching clinic in which services were provided by undergraduate students of dentistry under the supervision of teachers from the Faculty of Dentistry, and with dental assistants on hand to provide service support. This particular clinic offers a wide range of treatments and services, so researchers studied only the most frequently-given treatments, making up 80%, according to the Pareto Principle. This covered five categories of treatment which were Sealant Compounds, Tooth Extraction, Preventive Resin Restoration, Composite Fillings and Stainless Steel Crown. The research conducted studies of the process for each procedure, from when the patient first arrived for treatment until all the manual work had been completed.

Research procedure [1] was as follows: (1) Activity centers and sub-activities in the dental service process were identified, (2) Compiled data of overall resources used, (3) Estimated practical capacity, (4) Calculated capacity cost rate, (5) Identified time driver and studied time taken for each sub-activity, (6) Constructed time equations and (7) Calculated the costs of providing each category of dental services. Conducting the research following these steps had the following research results:

A. Identifying Activity Centers and Sub-Activities in the Process of Providing Dental Services

Researchers then studied the process of providing dental services for each treatment from the patient starting the service until the final procedure of cleaning the equipment. Fig. 1 shows a typical process flow chart for Tooth Extraction. Three activity centers were identified and divided into sub-activities as follows:

1) Pre-treatment activity center with sub-activities from setting out the treatment plan to preparing the patient for treatment, with a total of 7 sub-activities.

2) Ongoing treatment activity center with sub-activities from investigating the state of dentition to providing dental advice to parents, consisting of 13 sub-activities.

3) Post-treatment activity center procedures from removing protective covers and equipment to placing equipment in a sterile bag, comprising 5 sub-activities

Every treatment contained the same processes of pre- and post- treatment activity centers, but the activities were different in the ongoing treatment activity center.

B. Compiling Data On Costs of All Resources Supplied

This stage of the process was compiling data on cost of all resources supplied in the process of providing dental services, and the number of patients receiving service in one fiscal year, i.e. from 1 October 2019 to 30 September 2020. These cost data could be subdivided into two categories: (1) Direct costs which were direct material costs and (2) Indirect costs such as indirect material costs, overhead costs, and including the salaries of teachers from the Dentistry Faculty and dental assistants. For these, it was not possible to state a direct association with any treatment procedure. In this latter case, it was necessary to allocate the cost contribution for each activity used in each treatment with the TDABC method. The overall costs are shown in Table I, with the exchange rate at the time of research being 35 Thai Baht/1 US Dollar.

C. Estimating Practical Capacity

This stage of the process was estimating practical capacity of available resources for each year in units of time. For the purposes of this research, this was considered in four groups,

who were dental students, dental assistants, dentistry teachers and tools/machinery.

Determining time at work in the undergraduate teaching clinic for dentistry students and dental assistants was set at 306 periods which were each 3 hours long, and 2.5 hours long for dentistry teachers (not including breaks,

training sessions or downtime to maintain equipment) with details in Table I. Regarding this, the number of personnel shown in the table was the equivalent number of personnel per year. For instance, in actual fact, there were more than 2 dentistry teachers. They rotated in supervising the undergraduate dentistry students in groups of 2 per period, to total 306 periods. The researchers thus considered this to be the equivalent of 2 people. The cases of dentistry students and dental assistants were considered in the same manner. Also, among the dentistry students, different groups of students alternate between the tasks of being dental assistants and performing treatments on patients.

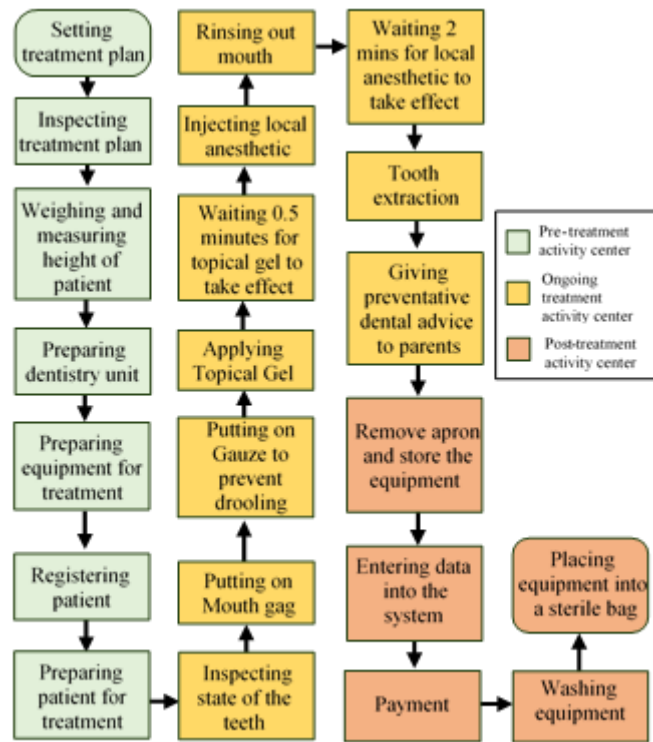


Fig. 1. Process flow chart for Tooth Extraction procedure

As for the practical capacity of tools and machinery, the calculation was only for that part of time when they were being used for teaching at the undergraduate level, and the uses of tools and machinery differed at each activity center.

TABLE. I Capacity cost rate classified by activity center (Thai Baht/minute)

	Number of equivalent personnel or tools	Cost of all resources supplied (Thai Baht/year)	Practical capacity (minute/year)	Activity center capacity cost rate (Thai Baht/minute)		
				Pre-treatment	Ongoing treatment	Post-treatment
Dentistry students	20	0	1,101,600	0.00	0.00	0.00
Dental assistants	4	490,423	220,320	2.23	2.23	2.23
Teachers of Dentistry Faculty	2	1,084,560	91,800	11.81	11.81	0.00
Tools and machinery	56	413,895	821,896	0.27	0.72	0.29

D. Calculating the Capacity Cost Rate

Capacity cost rate (Thai Baht/minute) can be calculated according to (1).

$$\text{Capacity cost rate} = \frac{\text{Cost of all resources supplied}}{\text{Practical capacity}} \quad (1)$$

Table I shows the capacity cost rate of dentistry students, dental assistants, dentistry faculty teachers and tools/machinery, calculated according to activity center. It can be seen that the capacity cost rate of dentistry students was equal to zero, as there was no labor cost for the dentistry students. The capacity cost rate for tools and machinery was not equal at each activity center.

TABLE II. Number of time drivers for each sub-activity per year, and time taken for each time driver in minutes at the ongoing treatment activity center of Tooth Extraction

	Activity	Time Driver	Time/Time Driver (Min.)	Number of time drivers/year				
				Dentistry students (principal providers)	Dentistry students (Assistants)	Teachers of Dentistry Faculty	Dental assistants	Tools and machinery
1	Dentistry students inspecting the state of patients' teeth	No. of times (X ₁)	2.65	317	317	-	-	317
2	Dentistry students (assistants) assisting teachers during the dental inspection	No. of times (X ₂)	2.12	-	317	-	-	317
3	Dentistry teachers and dental assistants looking after dentistry students during treatment sessions	No. of cycles (X ₃)	79.95	-	-	109	109	-
4	Dental assistants handing out dentistry tools and materials	No. of cycles (X ₄)	47.97	-	-	-	109	-
5	Dentistry students applying mouth gag to patients	No. of times (X ₅)	0.20	317	317	-	-	317
6	Dentistry students applying Gauze to prevent patients' drooling	No. of times (X ₆)	0.33	317	317	-	-	317
7	Dentistry students applying topical gel to patients	No. of teeth (X ₇)	1.05	396	396	-	-	396
8	Dentistry students waiting 0.5 minutes for topical gel to take effect	No. of teeth (X ₈)	0.50	396	396	-	-	396
9	Dentistry students injecting local anesthetic	No. of teeth (X ₉)	0.87	396	396	-	-	396

10	Dentistry students (assistants) rinsing the patient's mouth	No. of times (X ₁₀)	0.23	-	317	-	-	317
11	Dentistry students waiting 2 minutes for local anesthetic to take effect	No. of teeth (X ₁₁)	2.00	396	396	-	-	396
12	Dentistry students extracting the patient's teeth	No. of teeth (X ₁₂)	1.84	396	396	-	-	396
13	Dentistry students providing preventative dental advice to parents	No. of times (X ₁₃)	1.46	317	317	-	-	317

E. Identifying the Time Driver, Studying Time Used for Each Sub-Activity and Constructing the Time Equations

This process was identifying the time driver of each sub-activity. The time driver means the factor or variable driving the requirement to use time in performing the activity, which is the driver generating costs. In TDABC, time is used as the cost driver.

Subsequently, researchers conducted a study of time used in each sub-activity by directly timing the activity under the principles of Time and Motion studies. Table II shows the number of time drivers in each sub-activity arising during one year of research, and also the time taken for each time driver of the activity center during the ongoing treatment of Tooth Extraction. Regarding this, the analysis of data from other activity centers (pre- and post-treatment), as well as the analysis of data for providing other categories of dental services, are not presented here, but can be conducted in the same manner.

Subsequent to this was construction of the time equation [1] for each dentistry service separated by category of activity center and category of personnel. The time equation (2) shows the total time taken to perform an activity.

$$T_i = \beta_0 + \beta_i X_i \tag{2}$$

where

T_i = the time needed to perform an activity (minute).

β₀ = the standard time to perform the basic activity (minute)

β_i = the estimated time to perform the incremental activity (minute)

X_i = the quantity of the incremental activity (time)

For example, from Table II, it was possible to construct a time equation for the ongoing treatment activity center of Tooth Extraction by dentistry students who were the principal treatment providers, as in (3).

$$\begin{aligned}
 &T_{\text{Dentistry students (Principal treatment providers)}} \\
 &= 2.65X_1 + 0.20X_5 + 0.33X_6 + 1.05X_7 + 0.50X_8 + 0.87X_9 \\
 &\quad + 2.00X_{11} + 1.84X_{12} + 1.46X_{13} \tag{3}
 \end{aligned}$$

When the number of time drivers per year in Table II for each sub-activity were inserted into (3), it was possible to find the total time of the ongoing treatment activity center of Tooth Extraction for dentistry students who were the principal treatment providers, per year as in (4) as follows:

$$T_{\text{Dentistry students (Principal treatment providers)}}$$

$$\begin{aligned}
&= (2.65 \times 317) + (0.20 \times 317) + (0.33 \times 317) + (1.05 \times 396) \\
&\quad + (0.50 \times 396) + (0.87 \times 396) + (2.00 \times 396) + (1.84 \times 396) \\
&\quad + (1.46 \times 317) \\
&= 3,950 \text{ minutes per year} \qquad (4)
\end{aligned}$$

After that, when the total time was calculated for dentistry students to provide assistance, the time obtained at the ongoing treatment activity center for Tooth Extraction of dentistry students was equivalent to 8,645 minutes per year. The total time of dental assistants, teachers of dentistry and tools and machinery at the ongoing treatment activity center for Tooth Extraction are shown in Table III.

F. Calculating Costs for Providing Each Category of Dental Services

When the total time taken at the ongoing treatment activity center of dentistry students, dental assistants, dentistry teachers and tools/machinery were multiplied with the capacity cost rate, this obtained the total activity cost for each group as shown in Table III. When this was all combined, the total activity cost of the ongoing treatment activity center for Tooth Extraction was equal to 137,399 Thai Baht.

TABLE III. Total activity cost for each group at the ongoing treatment activity center for Tooth Extraction

	Total time (minutes)	Capacity cost rate (Thai Baht/minute)	Total activity cost (Thai Baht)
Dentistry students	8,645	0	0
Dental assistants	13,944	2.23	31,095
Dentistry teachers	8,715	11.81	102,924
Tools and machinery	4,695	0.72	3,380
Total			137,399

Subsequently, when the total activity costs of all three activity centers (pre-treatment, ongoing treatment and post-treatment) were combined, the total activity costs were obtained for providing each category of dental services. For instance, for Tooth Extraction, the costs of the pre-treatment, ongoing treatment and post treatment activity centers were, equal to 39,918 Thai Baht, 137,399 Thai Baht and 5,554 Thai Baht respectively, then the total activity cost of Tooth Extractions was equal to 182,871 Thai Baht/year. From here, when the total activity costs of Tooth Extractions per year were divided by the number of tooth extractions per year (in this case it was 317 extractions per year), the average cost per one tooth extraction was 577 Thai Baht as shown in Table IV. Table IV shows the average activity cost of procedure for each treatment for all five categories under research.

TABLE IV. Average activity cost per treatment of each treatment (Thai Baht)

	Total activity costs/year (Thai Baht)	No. of treatments/year	Average activity cost/treatment (Thai Baht)
Sealant Compounds	330,829	573	577
Tooth Extraction	182,871	317	577
PRR	229,065	386	593
Composite Fillings	161,301	274	589
Stainless Steel Crown	106,061	174	610

From here was calculated the average service cost per treatment obtained from totaling the average activity cost per treatment combined with the average direct cost of raw material per treatment. Such direct material costs comprised medical materials and medication used in the treatment. For Tooth Extraction, this was disposable needles, 2% scandonest and topical anesthetic gel, which total to 17 Thai Baht per treatment. Therefore, a Tooth Extraction had an average service cost per treatment of 594 Thai Baht. Details of the average activity cost per treatment, the average cost of materials per treatment and the average cost of providing treatment services in each

category are shown in Table V.

A comparison was then made between the average service cost per treatment with the service charge received from the patient for each treatment. Profit or loss was thus obtained for each treatment procedure as shown in Table V. It can be seen that every treatment procedure was running at a loss. For instance, while a Tooth Extraction had average service cost of 594 Thai Baht per treatment, the service charge received from the patient of 150 Thai Baht per treatment represented a loss of 444 Thai Baht per treatment.

TABLE V. Comparison of average cost per treatment and service charge received from patient

Treatment	Average cost of materials/treatment (Thai Baht)	Average activity cost /treatment (Thai Baht)	Average service cost/treatment (Thai Baht)	Service charge received from patient/treatment (Thai Baht)	Profit or Loss/treatment (Thai Baht)
Sealant Compounds	46	577	623	200	-423
Tooth Extraction	17	577	594	150	-444
PRR	76	593	669	250	-419
Composite Fillings	53	589	642	260	-382
Stainless Steel Crown	151	610	761	500	-261

III. CONCLUSION AND DISCUSSION

This research has presented a method for cost analysis of providing dental services at the case study dental clinic, using TDABC. The steps of the analysis can be done by: (1) identifying activity centers and sub-activities in the dental service process, (2) compiling data of overall resources used, (3) estimating practical capacity, (4) calculating capacity cost rate, (5) identifying time driver and studying time taken for each sub-activity, (6) constructing time equations and (7) calculating the costs of providing each category of dental services.

Five categories of treatment were studied with the objective to learn the costs of providing dental services for each category of treatment. The results of this research had also enabled analysis of profit or loss in providing each category of dental services. Results of the research showed that every category of treatment was running at a loss. However, as the case study clinic receives some budgetary support from the state, it is still viable despite facing losses. Even so, in the future, the state sector will be increasingly pushing each department and agency to find income and survive by itself. The results of this research can then be used as a guideline for executives in determining dental service fees more reasonably. As well as this, in this research, dentistry students were the primary treatment providers, but as there was no cost for the students' labor, the capacity cost rate was zero. This may make the costs calculated to be less than the costs of providing dental services at other premises which would have the labor costs of dentists.

The results of this research may also be used for "*capacity utilization analysis*", with the difference between practical capacity and used time being unused capacity. If this unused capacity is multiplied by the capacity cost rate, unused capacity costs are obtained. This research discovered that total unused capacity costs were 978,781 Thai Baht. Also, analysis of sub-activities enables the identification of non-value added activity. This provides a path to reducing costs in the future. The analysis of capacity utilization is a strong point of the TDABC technique, which is superior to other costing techniques which cannot clearly distinguish unused capacity costs.

Another advantage of TDABC is the ability to analyze complex activities efficiently [4]. In this research, the activities arising in each category of treatment are complex and different for each patient. The TDABC system can analyze complex activities with a time equation, from the time the patient begins receiving the service until it

is completed. If any patient does not have any sub-activity, then that sub-activity need not be stated in the time equation to find the total time.

However, TDABC has the weak point of difficulty in collecting the time data, and timing activities to find the time taken to do them. This may in itself take time and it is also an opportunity for error [5]. In this research, treatment provided by each dentistry student takes different amounts of time, depending on the individual skill of each student. Another point is that this clinic is a pediatric dentistry clinic, and the behavior of each child shows different levels of cooperation. The result is that making timings under the principles of Motion and Time Study requires a large number of timings for each sub-activity, to make the final results more credible.

Previous research had found that concerning the process and method of applying TDABC to dentistry or healthcare in general, that despite having similar processes, the details of the application were different depending on the context in which they were used. For instance, [6] performed a calculation of capacity cost rate for all personnel in the activity center as a single rate. However, in this research, researchers analyzed the capacity cost rate separately for each group of personnel. This made the calculation more complex, and separate time equations had to be constructed for each group of personnel. However, this enabled a more accurate calculation of costs, which better reflected reality.

As for research in the future, it may be possible to apply the principles of Fuzzy Logic to the TDABC technique [7], as this principle is appropriate for activities which are uncertain about the time taken for each patient. As well, there may be analysis of costs with other costing methods such as traditional costing or the ABC method, to obtain results which can be used to compare with the TDABC method.

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