Employing Fuzzy-Based CVP Analysis for Activity-Based Costing for Maintenance Service Providers

Patcharaporn Yanpirat and Jittarat Maneewan

***Abstract*—The objective of this paper is to propose a framework for profit planning or the pricing of a maintenance service under imprecise information by organizations adopting an Activity-Based Costing system. Fuzzy-based Cost-Volume-Profit (FCVP) analysis with a case-based application is presented. The findings reveal the fuzzy rules that can fulfill operational decisions to enhance the competitiveness of the organization.**

***Index Terms*—activity-based costing, CVP analysis, fuzzy logic, maintenance service pricing**

I. Introduction

Activity-based costing (ABC) is a costing approach that assigns resource costs to cost objects such as products, services, or customers based on the activities performed. It has gained recognition by being more accurate cost estimation and by providing traceable cost information when compared with traditional costing (TC) system. TC is a volume-based overhead costing system. This approach relies on the assumption that each cost object uses the same amount of overhead. It uses single or second-stage allocation bases on the unit-level characteristics of the cost object and, therefore each cost object will be charged the same amount. In addition, it focuses on measuring and controlling direct costs [1]. An ABC system differs from a TC system in two significant ways. First, the cost pools of a TC system are defined as plant or departments whereas ABC defines them as activities. Second, a TC system uses one or two cost drivers whereas the ABC system uses multiple cost drivers that are related to unit-level, batch-level and product-level characteristics [2] to allocate the overhead costs of the activities to the cost objects. Moreover, the TC system serves well and is sufficient when technology is stable, when the variety of products is limited, and when indirect costs are insignificant relative to direct costs [3]. With the TC system under the contemporary business environment, cost distortions will increase as firms increase in variety of product, volume, size, complexity, and resources used, and as costs incurred on supporting activities increase. Therefore, this system tends to over-cost for large-size or high-volume products, and to under-cost for small-size or low-volume products when product diversity exists within the same operation [4]. Under the aforementioned circumstances, ABC has major advantages over TC because of its ability to trace overhead cost, which allows for a more accurate unit costing. ABC helps to reduce cost distortions and provides more accurate costing of the cost objects. Inaccurate cost information can lead to undesirable strategic results, such as unrealistic pricing, wrong product-line decisions, ineffective resource allocation and finally to lower competitive advantage as a consequence [5]. Even though developing an ABC system is expensive and time consuming, many firms realize its benefit by trading off its cost. It is implemented in various types of business but mainly by manufacturing firms. With the successful existing implementation of ABC, its extensions are to marketing, service, and not-for-profit organizations such as logistics management [6], education [7, 8], banking [9], and IT investment [10], etc. In the field of maintenance, the related literature, especially on costing and pricing, received much less attention. To adopt ABC in maintenance, [11] and [12] to propose a framework and its application in the costing of the in-house planned maintenance of an agricultural service organization, the findings show its ability to capture the planned maintenance cost elements and to provide information to improve the cost efficiency of the organization's overall maintenance system. However, the proposed framework is still limited to in-house costing; therefore, the feasibility of an application of ABC in a maintenance service organization is an interesting issue. Not only service costing, but also service pricing is a primary concern especially in small and medium size organizations that lack the experience of using statistical and mathematical analyses in formulating decision strategies. The objective of this paper is to propose a maintenance pricing framework for small or medium size organizations which implement the ABC system without any experience of using statistical and mathematical analyses. On the other hand, they can use the proposed framework to make decisions on profit planning or pricing under conditions of imprecise information for maintenance service operations. In Section II, a framework for profit planning under conditions of imprecise information for maintenance service is introduced. In Section III, the proposed framework is employed to illustrate its application in a case study company. In Section IV, the implementation issue of the framework is drawn in the conclusion.

This work was supported in part by Graduate Program in Engineering Management and partial financial support by Graduate School, Kasetsart University (Bangkhen Campus).

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ISBN: 978-988-19251-9-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

II. The Framework of Profit Planning Under Conditions of Imprecise Information for A Maintenance Service Provider

Cost-volume-profit (CVP) analysis is a method for analyzing the relationship between costs; fixed and variable costs, output level and profit level serving for operating decisions and marketing decisions such as setting prices, make or buy decisions on a given product or services, and replacing a piece of equipment, etc. With the restrictive assumptions on the certainty conditions of the traditional CVP analysis, an application in real-world decisions that encounter uncertainty and risk is the limitation of this method. Although probabilistic and stochastic approaches could be used to relax such restrictions, experience and knowledge of statistics are required, which is inflexible in cases of unavailable data and in dynamic business conditions that vary over time. In addition, for imprecise information such as sales demand, variable costs and fixed costs that are not constant over the planning horizon, an application of the fuzzy logic concept to the traditional CVP analysis is proposed to overcome such obstacles in [13]. The CVP analysis for ABC is presented in [14] and provides a numerical example for a single product. Therefore, the framework on multiple products with fuzzy-based CVP analysis for an ABC system is proposed as follows. First, the framework of maintenance service costing under the ABC system is proposed. Second, the CVP model for ABC system is developed. Third, its extension on the fuzzy logic concept will be integrated into the CVP model to generate the decision rules under the condition of imprecise available data.

A. *Maintenance Service Costing for ABC System*

The framework for a maintenance service costing system is proposed under the following assumptions. Cost accumulation is job costing under the cost measurement of standard costing, and overhead assignment is under activity-based costing. Therefore, all maintenance service costs incurred are assigned to jobs using standard costs and standard quantities for direct materials, direct labor, and overheads. The standard cost elements of direct materials and direct labor are the same as those proposed by [11] which is the common practice for maintenance service providers. Direct materials are all materials and component parts that can be traced to each maintenance job at the standard rate and standard quantity based on the invoice for materials. Direct labor is all of the skilled or semi-skilled labor that works on each job. Both direct costs will be assigned directly to the particular service job. For overhead, in other words support activities in the ABC system, the standard rate and standard cost drivers for the particular activity will be costed at a predetermined rate. The basic supporting document is the job cost sheet that contains the necessary information, depending on the required information of the organization.

The proposed framework for the support activities of the ABC system for maintenance service, whether in-house or outsourcing services, will use a two-stage cost assignment procedure. It starts from identifying resource costs, cost pools, and cost objects and then allocates resource costs to cost pools at the first stage and is followed by the cost pools to cost objects in the second stage. In the TC system, the cost pools are the company or departments whereas activities and/or activity centers are the cost pools in ABC. The TC system uses a cost driver such as direct labor hour or the number of jobs as the single companywide rate or departmental rates to assign support/overhead costs in the second stage, whereas ABC uses resource/activity consumption cost drivers in both stages, which provide more accurate product/service costs than TC. Both stages are shown in Fig. 1 and explained in detail as follows.

--Identify the resource costs and activities used for providing the maintenance services. Resource costs can be classified with respect to the way in which activities consume resources. In maintenance service, they are a unit/job-level activity, batch/customer-level activity, and facility/business-sustaining activity.

--Find the resource consumption cost drivers for the particular activity; which are the factors selected to approximate resources consumed by an activity.

--Assign the cost of the activities based on resource consumption.

--Determine the activity cost driver that corresponds to the particular cost hierarchies. There are three criteria for selecting allocation bases to select cost drivers. They are causal relationship which selects a cost driver that causes the cost, benefit involved by which costs are assigned in proportion to the benefits obtained, and reasonableness or fairness which is used when some costs cannot be related to the maintenance service with respect to causality or benefits received [15].

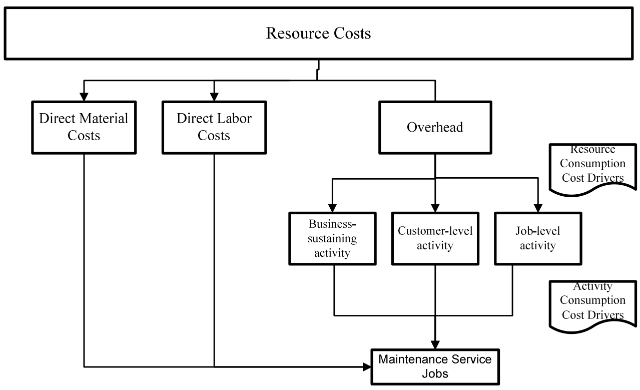

Fig. 1. Cost assignment framework for maintenance service provider under the ABC system

-- Allocate activity costs using the selected cost driver as an allocation base. Calculate activity rate for the particular activity by dividing the total activity cost by level of cost drivers consumed.

--Calculate the maintenance service costs for the particular job based on the estimated activities performed, including activities related to the main functions and support functions of the business.

In cases where there are many resource costs and activities, the hierarchy of cost allocation may be complex, so the use of an expense-activity-dependence (EAD) matrix and an activity-product-dependence (APD) matrix could be an alternative technique to simplify the implementation and to communicate the ABC within the organization [16].

ISBN: 978-988-19251-9-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

B. CVP Model for ABC System

Where cost elements are classified by the aforementioned method, based on the product/service costing, they have to reclassified, corresponding to the restricted requirement in the traditional CVP model, into fixed costs and variable costs including the activities of the main functions and support functions related to providing the maintenance service. Based on ABC, maintenance service cost is assigned and accumulated to each particular maintenance service type, and therefore the activity-based CVP model for each maintenance service type is developed with the following data requirement.

--Cost of business-sustaining activity which is characterized as fixed costs: TFC^B. It does not vary with the activity cost driver.

--For each customer, it is similar to cost at batch-level activities because one customer may demand the service for more than one job. It is defined as TFC^{Cus} which does vary with the activity cost driver. It is able to convert to the cost at job-level activity using the number of jobs for each customer.

--Every service job consists of unit variable costs for the activity-based cost driver plus direct materials cost and direct labor cost.

The traditional CVP model as in (1) is developed for the activity-based CVP model as in equations (2)-(5).

$$N = PQ - TFC - vQ \tag{1}$$

$$N_i = P_i Q_i - \left(TFC_i^{VB} + TFC_i^{AB}\right) - \left(v_i^{AB} + v_i^{VB}\right)Q_i \tag{2}$$

$$TFC_i^{AB} = v_i^{Cus} C_i = v_i^{Cus} \frac{Q_i}{m} \tag{3}$$

$$N_i = P_i Q_i - TFC_i^{VB} - v_i^{Cus} \frac{Q_i}{m} - \left(v_i^{AB+VB}\right)Q_i \tag{4}$$

$$N_i = P_i Q_i - TFC_i^{VB} - \left(\frac{v_i^{Cus}}{m} + v_i^{AB+VB}\right)Q_i \tag{5}$$

where:

i	=	type of maintenance service; i = 1, 2, …., J
m	=	number of jobs per customer
C	=	number of customers
N	=	net profit
P	=	price per job
TFC	=	total fixed costs for the traditional CVP model
TFC^{VB}	=	cost of business-sustaining activity which does not vary with the activity cost driver
TFC^{AB}	=	costs of non-flexible resources committed to customer-level activities which vary with the activity cost driver
v	=	unit variable cost per job for the particular of maintenance service type
v_i^{Cus}	=	unit variable cost per customer
v_i^{AB}	=	unit variable cost per job for the activity-based cost driver
v_i^{VB}	=	unit variable cost per job consisting of direct materials cost and direct labor cost
v^{AB+VB}	=	total unit variable cost per job for both of activity-based and volume-based cost drivers
Q	=	number of jobs

C. Fuzzy-Based CVP Model for ABC System

The activity-based CVP model for a particular maintenance service type as shown in equation (5) still realizes the deterministic conditions of the traditional CVP analysis. Under real world problems facing uncertainty with imprecise information or imprecise knowledge of the decision maker, the utilization of the fuzzy set concept is employed to modify the above model.

--Construct triangular membership functions of the input variables which could be based on experience, guesses, and the rule-of-thumb judgments of the experts or decision makers. As a result, the linguistic variables such as service price, number of jobs, fixed cost, variable cost, and profit are formulated with non-crisp information and are consistent with the imprecise nature of those variables [13].

--Establish a fuzzy rule for a particular uncertainty variable. The number of the rules depends on the number of hedges for each fuzzy set. In cases where profit is the output variable, the level of total profit will be derived from the combination of the distinct fuzzy rules among the given input variables.

--Generate fuzzy rules for output variables using an activity-based CVP model as in equation (5) combined with the developed fuzzy rules of the input variables.

An example of profit planning, the various alternatives for making decisions under the combinations of the fuzzy rules with respect to the given uncertainty variables, are obtained as a result. Not only are the relationship scenarios among the uncertainty variables revealed, but also the decision makers are enabled to foresee the results of the selection strategies, which is similar to the what-if analysis results.

III. CASE APPLICATION

A. Background of the Case Company

The main lines of business of the company case are the supply of blowers and compressors used in material handling in manufacturing firms and also the provision of services to customers implementing planned preventive maintenance, repair, and overhaul for both kinds of equipment. Referring to customer evaluation on the maintenance service of the company, the overall performance on the quality of service is high when compared with competitors, except on price. Investigating the root cause, it reveals that the company implements cost accumulation via job costing, standard cost measurement and overhead cost allocation with a TC system. All overhead costs, whether related to the main functions or support functions are allocated to the two main lines of business in equal proportions. Thereafter, a single companywide rate of allocated overhead will be allocated to the particular maintenance services at the same rate based on direct labor hours for the entire type of service. As a result, it determines the uncompetitive prices of the services in comparison with competitors, which as a consequence affect the profitability of the company.

B. Implementation of the Framework

In accordance with the proposed ABC framework, cost hierarchy, cost assignment and overhead allocation are undertaken for budgeting as shown in Fig.2.

Based on the business process and with the limited available historical data including financial and non financial data, 23 resource costs to account for 7 activity centers and 41 activities, which are classified into 24 company-sustaining activities, 4 customer-level activities and 13 job-level activity for 26 types of services are manipulated in combination with the techniques of the expense-activity-dependence (EAD) matrix and the activity-product-dependence (APD) matrix for simplification. Lastly, with the assignment of direct materials and direct labor cost traced directly to each type of service and the total overhead cost whether from the main function activities or the support function activities of those three activity levels with respect to the given level of cost driver, the total cost of the particular maintenance service type is obtained. An example is shown in Table 1.

TABLE I
TOTAL COST OF JOBS CLASSIFIED BY TYPE OF MAINTENANCE SERVICE

Job code	TFC^{VB}	v_i^{Cus}/m	v_i^{AB}	v_i^{VB}	v
GM-A1-IN	1,789	140	899	615	1,655
⋮	⋮	⋮	⋮	⋮	⋮
GM-A8-IN	13,821	231	1,693	3,542	7,400
GM-A9-IN	11,605	237	2,308	4,719	7,044
⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮
VM-B11-OUT	9,648	281	9,045	28,396	33,729

C. Profit Planning under the Imprecise Information

While the distortion of maintenance service cost is reduced by adopting the ABC system, the fuzziness in the service price is involved because the current price is determined under the TC system leading to uncompetitive pricing as mentioned. In addition, the demand for a service is also difficult to forecast, and is, in practice, often based on the experience of the sales manager. Therefore, the CVP equation for each type of maintenance service can be formulated under profit maximization as shown in the example in equations (6)-(9).

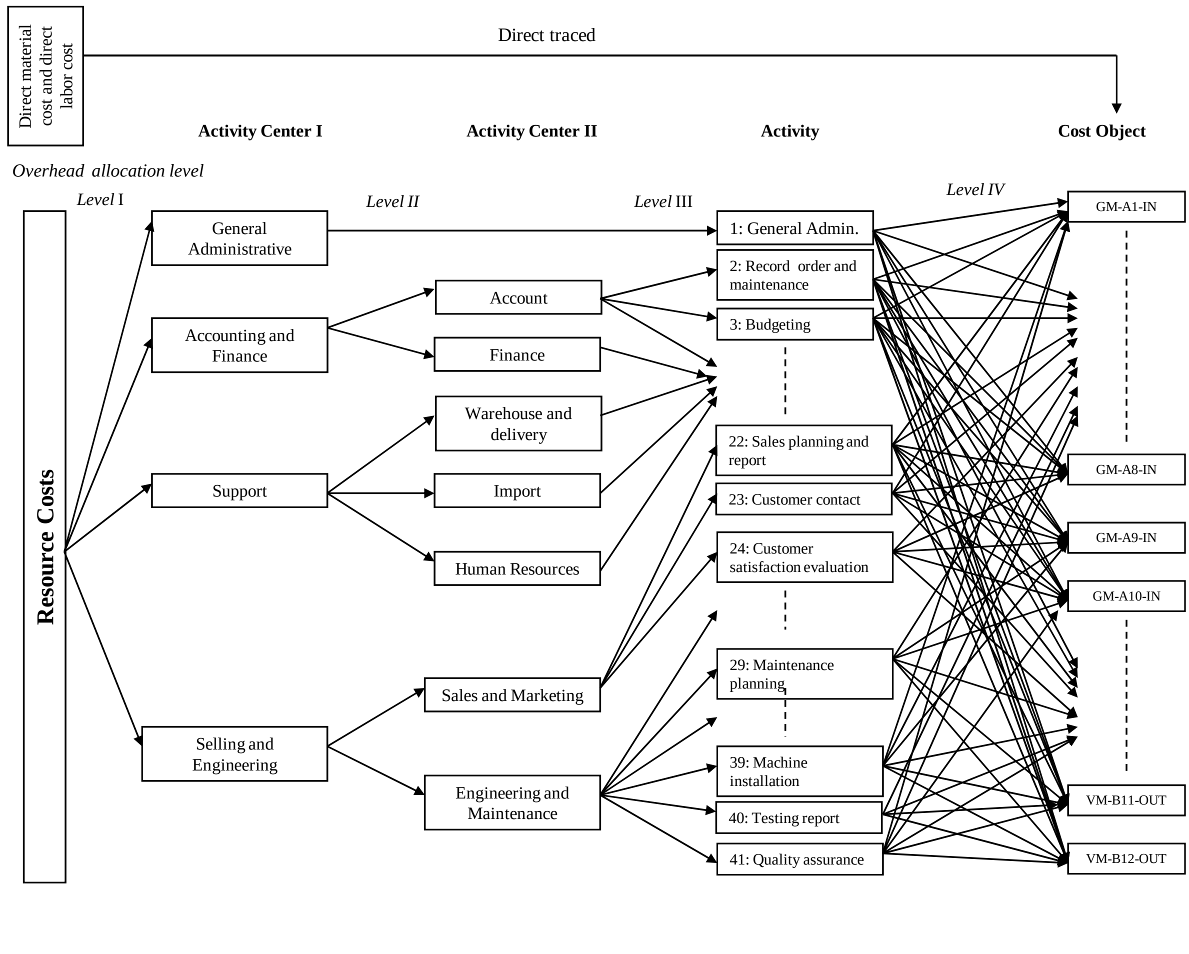

Fig. 2. Cost hierarchy for cost assignment and overhead allocation framework of the company case

ISBN: 978-988-19251-9-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

$$GM-A1-IN: \quad N_1 = P_1Q_1 - 1{,}789 - 1{,}655Q_1 \tag{6}$$

$$\vdots \qquad \vdots$$

$$GM-A8-IN: \quad N_8 = P_8Q_8 - 13{,}821 - 7{,}400Q_8 \tag{7}$$

$$GM-A9-IN: \quad N_9 = P_9Q_9 - 11{,}605 - 7{,}044Q_9 \tag{8}$$

$$\vdots \qquad \vdots$$

$$VM-B12-OUT: \quad N_{26} = P_{26}Q_{26} - 4{,}645 - 34{,}517Q_{26} \tag{9}$$

An example of service type GM-A1-IN will be presented in this paper because the rest will be undertaken with the same procedures. Dealing with the uncertainties for making a decision on profit planning, fuzzy service price, fixed cost, variable cost and fuzzy service volume will be treated as input variables while profit is a fuzzy output variable. The membership functions of fuzzy input variables are constructed based on the policy of anticipated managers of various related departments of the company based on experience and rule-of-thumb as shown in Table 2. Low, moderate and high levels of service price are defined at 0-15%, 10-25%, and 20-35% respectively, marked up from the estimated total cost obtained from the ABC system. For service volume per budgeted period, the low and high levels are defined at their possible values in providing the service whereas moderate level is at the service volume of the previous year.

TABLE II
MEMBERSHIP FUNCTIONS OF INPUT VARIABLES

Input variable	Level	Range
Service price (USD)	Low	2,548-2,930
	Moderate	2,802-3,185
	High	3,057-3,439
Service volume (Job)	Low	2-4
	Moderate	3-5
	High	4-6

The fuzzy set of membership functions relates to maintenance service price level as defined in equation (10) [13].

$$P = \sum_{l=1}^{3} P_l \tag{10}$$

Where P_l is universe fuzzy subset of price levels; l is an indicator of service price level, l = 1, 2, 3, representing low, moderate, and high, respectively. An example for l =1 is illustrated in equations (11).

$$P_1 = \sum_{j=1}^{3} \frac{\mu_{P_1}(x_j)}{x_j} = (x; a, b, c) \tag{11}$$

where $b = \dfrac{a+c}{2}$, x is the elements of fuzzy subset P_1 and $\mu_{P_1}(x_j)$ is its corresponding membership value with respect to low price. Thus, membership functions for low, medium, and high price levels are illustrated in equations (12)-(14), respectively and in Fig 3.

$$P_1 = (x; 2548, 2739, 2930) \tag{12}$$

$$P_2 = (x; 2802, 2993, 3185) \tag{13}$$

$$P_3 = (x; 3057, 3248, 3439) \tag{14}$$

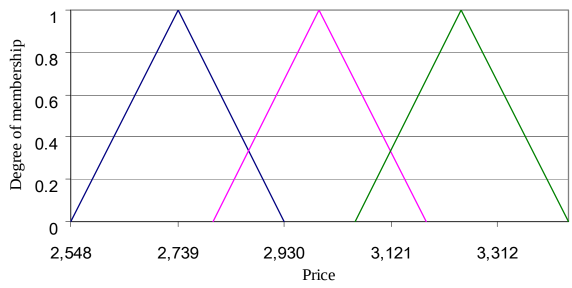

Fig. 3. Membership functions of price levels

Similarly, the fuzzy set of membership functions for service volume is as shown in Fig. 4.

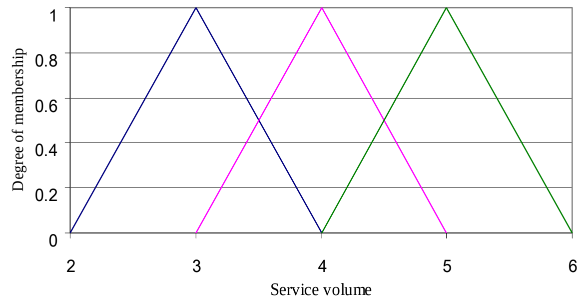

Fig. 4. Membership functions of service volume levels

The next step is to establish the fuzzy rules associated with profit levels. The total number of rules is formulated from the combination of two fuzzy input variables as shown in Table 3.

TABLE III
FUZZY RULES OF INPUT VARIABLES

Rule no.	Price level	Service volume level
1	High	Low
2	High	Medium
3	High	High
4	Medium	Low
5	Medium	Medium
6	Medium	High
7	Low	Low
8	Low	Medium
9	Low	High

Based on the membership function of input variables in Table 2 combined with the fuzzy rules in Table 3, substitute their values in equation (6), thus the profit levels are calculated as in Table 4. At this stage, a special program like MATHLAB can be used for the computation or to portray the relationship among profit and the variations of the input variables where the expenses are high and require some expertise. For small and medium companies only EXCEL can be used with a lower cost of implementation. From Table 4, the membership functions of profit levels can be determined by using equations (15)-(17) [17] as shown in Table 5 and Fig. 5. With respect to Tables 3-5, the fuzzy rules for profit planning under the uncertainties are developed as shown in Table 6.

$$d = \frac{W_{\max} - W_{\min}}{K} \tag{15}$$

ISBN: 978-988-19251-9-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

$$W_0 = W_{\min} \tag{16}$$

$$W_k = W_{k-1} + d \text{ ; k = 1, 2, 3, ..., K} \tag{17}$$

where

d = distance between two adjacent linguistic values
$W_{\max}$ = maximum profit value
$W_{\min}$ = minimum profit value
K = number of linguistic values

TABLE IV
COMPUTATION RESULTS OF PROFIT VARIABLE

Rule no.	Price level	Service volume level	Profit level
1	3,248	3	2,991
2	3,248	4	4,584
3	3,248	5	6,177
⋮	⋮	⋮	⋮
7	2,739	3	1,462
8	2,739	4	2,546
9	2,739	5	3,629

TABLE V
MEMBERSHIP FUNCTIONS OF OUTPUT VARIABLES

Output variable	Level	Range ($)
Profit	Very low	1,462 - 2,405
	Low	2,405 - 3,348
	Moderate	3,348 - 4,291
	High	4,291 - 5,234
	Very high	5,234 - 6,177

Thus, membership functions of profit levels are shown in Fig. 5.

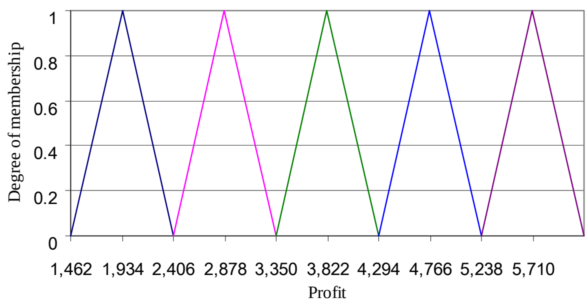

Fig.5. Membership functions of profit levels

TABLE VI
FUZZY RULES OF PROFIT PLANNING

Rule no.	Price level	Service volume level	Profit level
1	High	Low	Low
2	High	Moderate	High
3	High	High	Very high
4	Moderate	Low	Very low
5	Moderate	Moderate	Moderate
6	Moderate	High	High
7	Low	Low	Very low
8	Low	Moderate	Low
9	Low	High	Moderate

In accordance with the profit rules in Table 6, much information can be drawn such as rule 1, if the company plans to increase profit from a low level at $1,462 - 2,405 to a moderate level at $3,348 - 4,291, there are two options which could be undertaken by rules 5 and 9. The first is to increase the service volume from 2-4 jobs per year to 3-5 jobs per year while the price level could be reduced from $3,057-3,439 to $2,802-3,185, whereas fixed and variable costs are constant over the planning horizon. The second is to increase the service volume from 2-4 jobs per year to 4-6 jobs per year while the price level could be reduced from $3,057-3,439 to $2,548-2,930. Where current pricing strategy encounters an uncompetitive price as mentioned earlier, enhancing competitiveness via price reduction could be achieved by using rule 6 with the compensate of profit level. The proposed model provides valuable information for operations under conditions of uncertainty of service price, service volume, and the profit of the company at prompt yielding less time consumed as well as enhancing user-friendliness.

IV. CONCLUSION

The proposed CVP analysis is a practical approach for implementation in a multiple product CVP analysis. The maintenance service cost for the entire service type is estimated under the ABC system in providing valuable information for the budgeting process. Although only one type of maintenance service illustrates profit planning, the rest of the service types could be extended with the same procedure, except that the linguistic values for the particular variables are different from one to another depending on the degree of imprecise information and the experience of anticipated decision makers. Taking the benefits from the ABC system, profit planning or pricing under limited or imprecise information utilizing fuzzy logic could be simplified to set its rules.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the selected case company for providing data and to the Department of Industrial Engineering, Faculty of Engineering, Kasetsart University (Bangkhen Campus) for its contribution in publishing this paper.

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ISBN: 978-988-19251-9-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)