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Fuzzy Logic Application in Activity-Based Costing System for Small and Medium Size Manufacturing Enterprises

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ABSTRACT

Activity-Based Costing (ABC) has received extensive attention during the past decade because it achieves improved accuracy in allocating costs, by using multiple cost drivers to correlate the activities with the products that are associated with the resources consumed by those activities. The complexity and uncertainty in determining Cost Drivers (CDs) limit its use. This paper presents the use of Fuzzy Logic (FL) in tackling the complexity and uncertainty in implementing the ABC system in Small and Medium Size Manufacturing Enterprises (SMMEs). Specifically, this paper examines two new concepts: Multi Criteria Cost Driver (MCCD) and Production Line Cost Driver (PLCD). By using MCCD, all related cost drivers are integrated in one suitable cost driver to relate the expenses to the activities. The multi criteria cost driver which emerges from using Fuzzy Logic increases the ABC system reliability. Moreover, complexity is reduced by applying ABC system; since production line cost driver is developed to select one cost driver for each production line instead of one cost driver for each product. The results showed that combining Fuzzy Logic with ABC system improves the ability to decrease uncertainty and complexity in ABC system for Small and Medium Size Manufacturing Enterprises.

KEYWORDS: Activity-Based Costing; Fuzzy Logic; Cost Drivers, Multi Criteria Cost Driver, Production Line Cost Driver.

1. INTRODUCTION

The Activity-Based Costing (ABC) system has emerged in recent years to provide managers with more accurate cost information about operations and to help them deal with the difficulty of traditional costing system (Cooper and Kaplan, 1991). The ABC system organizes spending on resources for the products that are produced and delivered to customers, and it reflects the actual underlying economics of production and, thereby, provides better guidance to managers for decisions on the pricing, management-customer relationships, product mixing, product designing, processing improvement activities and technology acquisition (Cooper and Kaplan, 1991; Atkinson et al., 2001).

In order to manage today's manufacturing organization; managers require information which is relevant, accurate and readily available in order to formulate operational functional strategies and to make decisions. Although production systems have changed to meet the changing needs of the marketplace, managers and accountants have become dissatisfied with the conventional costing systems and have expressed concerns about their suitability in the modern manufacturing environments. To face this challenge, some companies tend to develop their conventional costing system. Consequently, ABC has emerged as an alternative choice. Others try to integrate Artificial Intelligence techniques with ABC system in order to reduce ABC problems. As far as this research is concerned, a new approach of combining ABC system and FL is considered as a new addition to literature.

In order to provide efficient and effective decisions-supporting manufacturing companies, costing methods should assess and trace costs and revenue; handle both overhead and direct costs; handle uncertainty and provide decision support for the process of designing (Bras and Emblemsvag, 1995). Although ABC system achieves these points better than traditional methods, it still has a

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drawback especially in determining cost drivers. More specifically, it is often very unlikely that the collected data related to cost drivers are accurate, and also, the level of abstraction which the costing system requires in order to operate does not allow accurate measurements. In this case, Fuzzy Logic (FL) is the choice (Benedicenti et al., 1998). Therefore, a new model that is based on using FL to employ scientific methods combined with financial/ production managers' experiences in ABC system is of a great value.

Fuzzy Logic can address complex control problems such as robotic arm movement, chemical or manufacturing process control and antiskid braking systems with more precision and accuracy than traditional control techniques. It is a method for coping with unreliable data in business process modeling and a powerful methodology to benefit from engineers' expertise in the products in a short period of time and to reduce the source of human error. Also, it is a way for expressing the operational codes of a system in linguistic terms such as "little", "some", or "a few" instead of using mathematical equations (Wang, 1994; Altrock, 1997). FL is implemented in three phases: fuzzification (crisp input to fuzzy set mapping), inference (fuzzy rule generation), and finally defuzzification (fuzzy to crisp output transformation) (Wang, 1994).

Small and Medium Manufacturing Companies (SMMEs) can be defined in different ways. One common definition of SMEs is based on quantitative parameters. They are capital investments on plant and machinery, number of workers employed, total sales, level of the technology used and market share. The number of employees, small number of variables, decision making process which depends on personal factors and financial practices that do not distinguish between business and private assets, all are main features of SMMEs. The complexity and uncertainty in these features directly affect the way in which the costing system is designed and operated.

The objective of this paper is to develop a logical model that faces the ABC system problems such as complexity and uncertainty by using Fuzzy Logic. This model presents a suitable costing system to improve SMMEs performance, this costing system has the ability to assist in making customer, product and process improvement decisions. Integrating the developed FL with ABC model is adapted by one of SMMEs and used as a case study.

2. LITERATURE REVIEW

Many researchers discussed the ABC in terms of tools, techniques, advantages, disadvantages, challenges and methods of improvement. As an example, French and Fischer (2001) have developed an ABC system estimating process to help estimators customize project's activities, resource and productivity rates based on resource preferences and the particular features in a given product model. They have implemented and tested the process in a prototype called Activity-Based Cost Estimating (ABCE) which creates a set of project specific activities that are needed in the cost estimate, and then they identified the features that require the activities execution, the resources that execute the activities, and the activities' labor and material costs. Chan et al. (2000) invoked an empirical approach to design an ABC system template and to illustrate how it can be used as a tool for easy assimilation in a Small and Medium Size Enterprises (SME) contextual environment. The approach uses the Promise Conceptual Model as an interactive platform to exploit different best practices as tools for implementation. The assimilation process has been quite successful in a number of aspects exhibiting encouraging results valuable for further investigation.

Bras and Emblemsvag (1995) developed an ABC model to be used in the design of remanufacturing under the presence of uncertainty. The core of their method is a combination of ABC and uncertainty to identify the effect of changes in the design's parameters on the cost. To deal with fuzziness in the design, they have identified a suitable type of distribution to be used as well as the means, left deviation and right deviation. The uncertainty is modeled by assigning distributions to every number in the model. Kirche et al. (2005) developed a promise management model in make-to-order manufacturing environment to maximize profit through combining ABC and constraints-based approach to assess order profit.

Fuzzy Logic system has been utilized in different fields starting from control systems up to management fields. For example, Facchinetti et al. (2003) created an FL approach to provide a system that is able to evaluate bank credit worthiness, and they compared traditional and FL techniques. The results obtained show that the fuzzy expert system offers a better measurement of the discriminate power of the model and more transparency of classification decisions. Chen and Weng (2002) proposed a fuzzy approach to evaluate quality improvement alternatives because of its fuzzy nature. An evidence fusion technique, namely Choquet Fuzzy Integral, is employed to aggregate the quality cost information. A composite index is determined to find the alternative best quality improvement and a numerical example is used to demonstrate the applicability of the approach.

Bouchereau and Rowlands (2000) demonstrated how techniques such as fuzzy logic, artificial neural network and the Taguchi method can be combined with Quality Function Deployment (QFD) to resolve some of its drawbacks. They reviewed the synergy between QFD and the three methods and techniques. Korvn and Shipley (2001) designed a fuzzy controller to adjust sample sizes according to potential fuzzy loss penalties. Their model allows the decision maker to consider the cost of quality, and it incorporates the decision makers' belief in the inflexibility required for quality control in the process of developing a fuzzy controller, a matter that suggests a sampling program to be followed. Kahraman et al. (2003) used a fuzzy Analytic Hierarchy Process (AHP) to select the best supplying firm that provides the highest satisfaction for the criteria determined. They interviewed the purchasing manager of the manufacturing companies to determine the most important criteria in selecting their supplying firms.

To our knowledge, there was no attempt to combine directly FL and ABC. However, some attempts indirectly relate the two together. Homburg (2004) used simulations and mixed integer programming to analyze the extension of the sub optimality incurred by ABC heuristics. He analyzed the effects of establishing cost drivers that correspond to a higher cost level. Kim and Han (2003) proposed hybrid Artificial Intelligence (AI) techniques to resolve two problems associated with ABC, i.e., selecting relevant cost drivers and nonlinear cost behavior patterns.

3. ABC-FL MODEL DEVELOPMENT

A new model is developed to solve the problem of selecting Cost Drivers (CD) by combining two approaches; ABC and FL (see Figure 1). The model shows that FL is employed in three areas; first, attributing resources to activities which are used when there is a lack of knowledge of resource consumption per activity. Second, determining the activity cost drivers which are used when the cost activities are known, without any precise knowledge of the contribution of activities at each product line. Finally, it is used in determining the resource cost driver which is available when there is no knowledge of how much resources were consumed during each activity contributed to each product line.

The new model takes into consideration all the criteria that relate overhead expenses to activities by using FL to select the most suitable cost drivers. Also, selecting suitable cost drivers to relate activities to production lines emerges the production line cost driver which selects one cost driver to each production line. It is found that more than one criterion is usually impacted in selecting CDs for the maintenance expenses; maintenance duration, maintenance effort and the accuracy level of this information. These different criteria are used as inputs of FL to generate the suitable cost driver as FL output. Thus, this cost driver is called Multi Criteria Cost Driver (MCCD). Using Production Line Cost Driver (PLCD) means that only one cost driver for each production line is used, which means a reduction in the complexity in implementing ABC in SMMEs. The overall cost for each product is calculated after determining the variable overhead costs for each PL. The detailed description of the new model is as follows:

Identification of Activities

First of all, the expenses categories are examined, and all of the information needed to perform the expenses analysis is usually obtained from the company's financial statements and from the organization's accounting records. In order to use ABC-FL Model, the complete process is divided into a set of activities. These activities are the direct or indirect activities which are generated in response to product demand, or the indirect activities that support product demand generated from other activities. Activities which describe manufacturing operations and how they are consuming operation resources are the main ones. In order to establish the needed activities for ABC, homogeneous processes are grouped together. Once the main activities are defined, the total cost of each activity can be calculated. Then the expenses categories related to each activity are identified.

Relating Expenses to Activities

Activities that contribute to each variable overhead expense are identified. Roztocki et al. (1999) provided an efficient and systematic method for expenses consumption identification through the use of an Expense Activity-Dependence (EAD) Matrix. The expense categories represent the columns of the EAD matrix where the identified activities represent the rows. If the activity (i) contributes to the expense category (j); a check mark is placed in the cell (i,j). To correlate the variable overhead expenses with each activity, cost drivers, which are also called first stage CDs, have to be identified for each expense category. Then, each cell in EAD Matrix that contains a check-mark is replaced by a proportion. This proportion is determined by selecting suitable cost drivers using FL.

Using FL to determine CDs and then to attribute the expenses to activities is based on the following procedure:

a) Fuzzification: All input and output variables are determined and the relation between them is stated in simple words (Little, few, large…etc.).
b) Knowledge base: In a knowledge base, the Membership Function (MF) and the set of rules in IF-THEN form are also decided for the relationships between the input and the output variables by the experts.
c) Firing the rules: By firing the rules, the expert's decision is simulated based on fuzzy concepts.
d) Finding the results (defuzzification): The FL outputs are converted into crisp (not fuzzy) values by the Center Of Area (COA) method.
e) Normalizing the results to the cost drivers

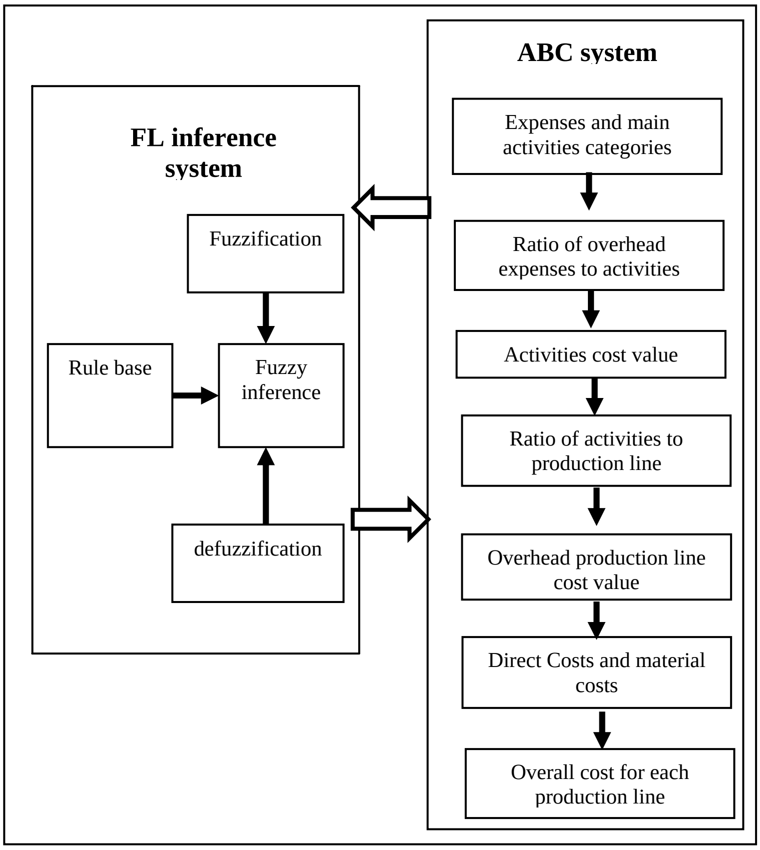

Figure 1. The New ABC-FL Model.

Figure 2 (a, b and c) shows the successive steps of the employment of FL in selecting CDs. As an example, "maintenance" expenses are shared by "mixing" activities. Three inputs are selected to determine the CD; machine hours (hr), labor hours and the complexity of operation. Labor hours and the complexity of operation are aggregated in one input called "others". This means that three criteria are taken into consideration during CD selection. Therefore, the CD is called the Multi Criteria CD. After that, the cost of each activity is evaluated by using the following equation:

$$TCA(i) = \sum_{j=1}^{m} Expense(j) \times EAD\ ratio\ (i, j) \ldots (1)$$

Where:

TCA (i) = Total cost of activity (i)

m= Number of expense categories

Expense (j) = Cost value of expense category (j)

EAD (i, j) = Entry (i,j) of Expense Activity-Dependence Matrix

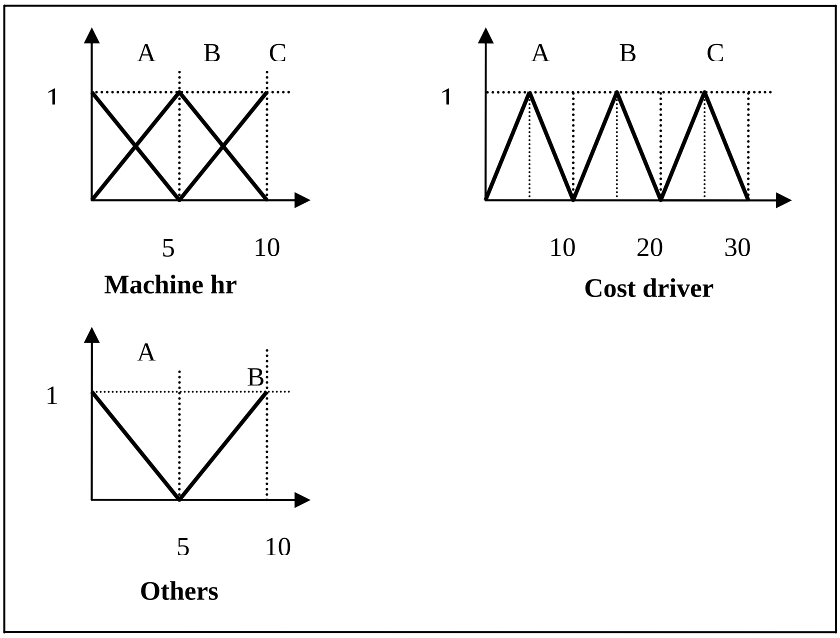

Figure 2 (a). An Example of FL System with Two Inputs and the One Output (CD).

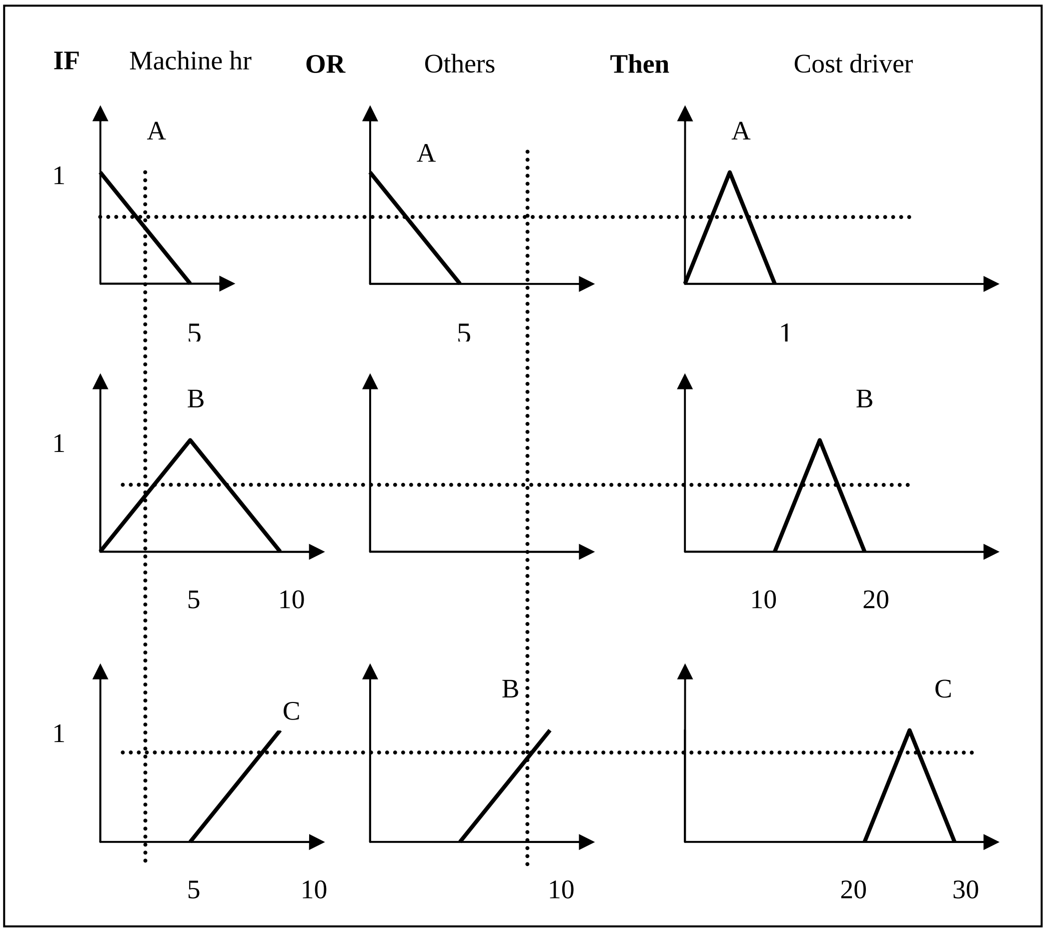

Figure 2 (b). An Example of FL System Rules for Two Selected Inputs and an Output.

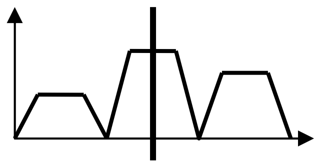

Figure 2 (c). An Example of FL System Defuzzification.

Relating Activities to Production Lines

The activities consumed by each production line are identified and the Activity-Production Line-Dependence (AP_LD) matrix is created. AP_LD matrix is a modified matrix from Roztocki et al. (1999) matrix. Activities represent the columns of the AP_LD matrix, whereas production lines represent the rows. If the production line (i) consumes the activity (j), a check-mark will be placed in the cell (i,j). To correlate the activities with each production line, the second stage cost drivers has to be identified. So, each cell that contains a check-mark in AP_LD is replaced by a proportion. This proportion is determined by the second stage cost drivers using FL. In order to use FL, the same procedure as in the one determining first stage cost drivers is followed. To obtain the variable overhead cost of each production line, the following equation is applied:

$$OCP(i) = \sum_{J=1}^{N} TCA(j) \times AP_L D \, ratio\,(i, j) \; \ldots \; (2)$$

Where:

OCP(i) = overhead cost of production line i.

N= Number of activities.

Expense (j) = Cost value of activity j

AP_LD *(i, j) = Entry (i,j) of Activity- Production line-Dependence matrix.*

Once the variable overhead cost of each production line is determined, the direct cost which includes the fixed overhead cost, direct material and direct labor cost is added to calculate the overall cost for each product. Standard spreadsheets and Matlab software are used to facilitate obtaining the results.

4. MODEL IMPLEMENTATION

A Jordanian company in the households and toiletries industry is used for the implementation of the ABC-FL model. The company is currently staffed with more than 80 employees and produces a wide range of high quality products that can be categorized as: body care, hair care, oral care, baby care, insecticides, detergents/ antiseptics and air fresheners. The company's production lines and activities include three production lines that produce a wide variety of households and toiletries products, i.e., Powder line, Cream line, and Liquid line. Each production line follows the same sequence of operations starting from raw materials up to freight and distribution. The following procedure shows the steps of implementing ABC-FL model at the company, which includes identification of activities, relating expenses to activities, and relating activities to production lines.

Identification of Activities

Overhead expenses at the company are mainly divided into two categories. The first category is the variable overhead costs which deal with industrial cost directly related to the production process and they are changed continuously with the changes in the production quantity. The variable overhead costs are distributed among the production lines in order to identify the contribution of each production line to these costs. Table (1) shows some examples of the variable overhead expenses categories and their respective cost drivers which are the basis to determine the Membership Functions (MFs) and their ranges in order to be used in FL system. The second category is the overhead costs which are related to the administration and other expenses. These costs are equally distributed among all products; so, there is no need to determine the shared percentage of each production line. Table (2) shows an example of the equally distributed overhead costs.

Table (1): Examples of the Variable Overhead Expenses' Categories.

No.	Expenses' Categories	Cost (JD)	Proposed Cost drivers
1	Salary expenses	20,251.53	Labor hours
2	Cars depreciation expenses	3,511.66	Distances and number of uses
3	Cars expenses	6,249.72	Distances and number of uses
4	Traveling expenses	1,606.30	Distances and number of uses
5	Transporting expenses	2,148.51	Distances and number of uses

Table (2): Example of Equally Distributed Overhead Costs.

No.	Expenses	Cost (JD)
1	Salary expenses	81,766.23
2	Social security expenses	4,943.00
3	Traveling and transporting	8,261.41
4	Office expenses	3,647.22
5	Phone, fax& mail box expenses	7,661.92
6	Stamps fees	6,944.57
7	Hosting expenses	1,791.24

Table (3): The Main Activities and their Respective Cost Drivers.

No.	Activity's name	Cost driver(s)
1	Raw material stores	-Total size of material for each production line
2	Mixing	-Time (machine hours, labor hours) -Quantity mixed
3	Inspection	-Total labor hours
4	Filling	-Total labor hours
5	Finished goods stores	-Space that each production line occupies
6	Freight and distribution	-Distance and amount of petrol consumed -No. of units produced of each product.

Table (4): EAD Matrix for HTM Company with Check Mark and Proportions.

Expenses Activities	Depreciation of tools	Cars depreciation expenses	Maintenance	Depreciation of production materials
Raw material stores	✓ 0.112	✓ 0.613		
Inspection				
Mixing	✓ 0.324		✓ 0.325	✓ 0.257
Filling	✓ 0.554		✓ 0.675	✓ 0.743
Finished goods stores	✓ 0.01			
Freight and distribution		✓ 0.387		

After determining expenses' categories, the activities and cost pool are identified. Production activities that are performed to produce different products in different production lines are divided into a set of main activities. Table (3) summarizes the main activities and their respective cost drivers. The respective cost drivers are the basis for choosing the suitable MFs for Fuzzy Logic.

Relating Expenses to Activities

The activities in the main set are contributed to variable overhead expenses. To determine which activities are related to the specific variable overhead expenses, the EAD Matrix is established. By the assistance of the financial/production managers and the technicians working at the company, the EAD matrix in Table (4) is filled with check marks "✓" at entry (i,j) which denotes that the activity (i) generate expense in category (j) and is replaced by the proportion of contribution. If the actual data are available, these ratios are determined easily based on the respective cost drivers in Table (3). Since there is a lack or uncertainty of the actual data, Fuzzy Logic is employed.

In this situation, the ratios are estimated by using FL. The universe of discourse and the set of the grades of MF are developed within the existing knowledge and experience of ABC system using a subjective approach. This is in line with Zadeh's vision (1995), who indicated that the grades of MF are subjective in the sense that their specification is a matter of definition rather than experimentation. The shape of MF reflects the expert's knowledge, experience and preference of the importance of different relationships (Little, few, large…etc.). For the pervious example, the ratio of contribution of mixing and filling activities is determined by FL as follows:

a) Inputs, outputs and their universe of discourse are determined with the assistance of managers, experts and production documents.
b) The MFs and their scale of grade for each input and output are determined. The financial/production managers are asked specific questions in order to determine the MFs; such as, "what was the total number of maintenance work for filling machines compared with mixing machines?" "What was the total time for maintenance mixing machines compared with filling machines?" "What was the most and least time of maintenance? During which activities? And how much was it?"

The answers to these questions are translated into fuzzy numbers as shown in Figure (3). The financial/ production managers are also asked to determine the set of rules. For maintenance expenses for example, the following rules are decided:

- *If the maintenance criteria are min. or accuracy is med. then CD is min.*
- *If the maintenance criteria are med. or accuracy is med. then CD is min.*
- *If the maintenance criteria are max. or accuracy is med. then CD is med.*

c) The rules are fired for each activity that consumed maintenance expenses and the result or defuzzification is obtained. The output is the estimated value of consumed maintenance expenses by the activities. Figure (4) shows the active rules for mixing activity consumed maintenance expenses with the output result.

After determining the entire required ratio for consuming all variable overhead expenses by the activities in the company, the "✓" check marks in EAD matrix are replaced by the output of FL as shown in Table (4). After mapping the ratios obtained from using FL for every entry in EAD matrix, the cost of each activity is calculated by multiplying the cost of variable overhead expenses' category (j) with the obtained ratio value (i,j). The total cost for each activity is obtained by using equation (1). Table (5) depicts the new EAD matrix for the company with the resulting value resource consumption of each activity in JD.

Relating Activities to Production Lines

By determining the total cost of each activity, activities costs are correlated with each production line instead of each product. Since SMMEs companies consist of short production lines, which have small and similar operations to produce similar products, the procedure for relating activities to production lines is the same as the one used for correlating cost of expenses with activities where the AP_LD is established. AP_LD matrix for the company is shown in Table (6). As in EAD matrix, a "✓" sign at entry (i,j) denotes that production line (i) consumes activity (j), then, all the check marks are replaced by the corresponding ratios which result from using FL. For example, to allocate the mixing activity to powder line, the following procedures are followed:

a) The financial/production managers are asked to determine the inputs and the outputs for each activity. For mixing activity, the different criteria which are used to determine the CD are machine hours as the main criterion, labor hours and the operation complexity. Labor hours and operation complexity are integrated in one input called "other consideration" since these two criteria have less impact than the machine hours in determining the multi criteria CD for mixing activity. Figure (5) shows that two inputs and one output are needed to allocate mixing activity to powder line.

b) The financial/production managers also assist through their experiences in determining the grades of MF for each input and output. Figure (6) (a and b) shows the MF which is determined by experts for the inputs and the output for mixing activity consumed by the powder line as an example.

The financial/ production managers also determine the set of rules for each activity consumed by each production line. For instance, the mixing activity which is consumed by all the production lines follows some rules:

- *If the machine hr is min. or the other consideration is min. then CD2 is min.*
- *If the machine hr is min. or the other consideration is med. then CD2 is min.*
- *If the machine hr is min. or the other consideration is max. then CD2 is med.*
- *If the machine hr is med. or the other consideration is min. then CD2 is min.*
- *If the machine hr is med. or the other consideration is med. then CD2 is med.*
- *If the machine hr is med. or the other consideration is max. then CD2 is med.*
- *If the machine hr is max. or the other consideration is min. then CD2 is med.*
- *If the machine hr is max. or the other consideration is med. then CD2 is max*

c) The rules are fired for each production line that consumed a mixing activity and the result or defuzzification is obtained. The output is the estimated value of the consumed mixing activity. Figure (7) shows the active rules for Powder line that consumed mixing activity and the output result.

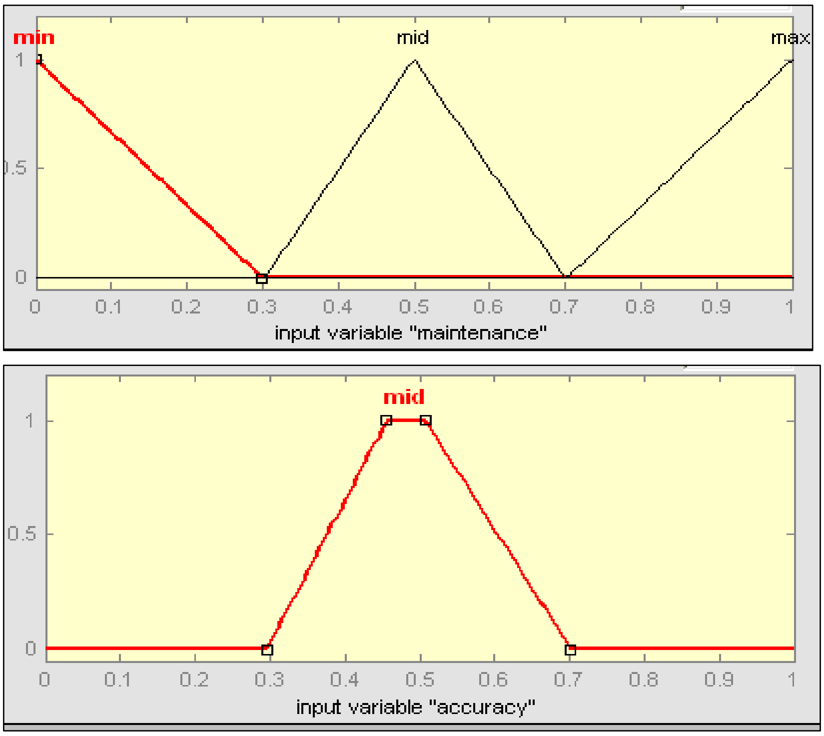

Figure 3. MF for the Maintenance Inputs.

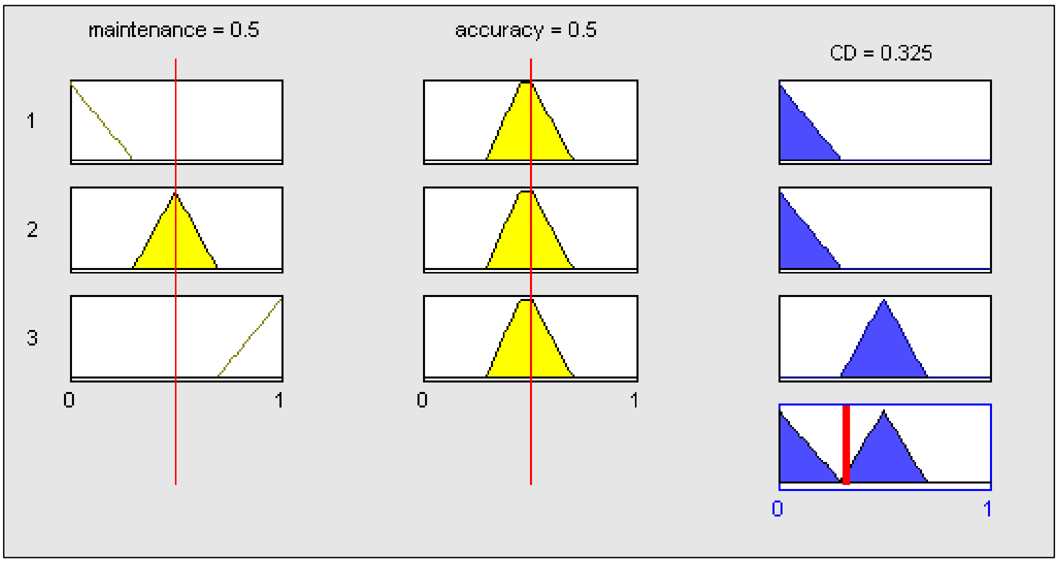

Figure 4. The Active Rules for Mixing Activity, Consumed Maintenance Expenses and the Output CD.

No.	Inputs
1	Machines hours
2	Other consideration

Output
The output is the estimated ratio of consumed mixing activity by Powder line. Multi criteria CD (CD2).

Figure 5: Inputs and Output to Allocate Mixing Activity to Powder Line.

Table (5): EAD Matrix for the Company (X1000JD).

Expenses / Activities	Depreciation of tools	Cars depreciation Expenses	Maintenance	Depreciation of production materials	Depreciation of machines	Sample analysis
X1000JD	8.804	3.512	6.086	8.834	11.780	0.561
Raw material stores	0.986	2.153				
Inspection						0.561
Mixing	2.853		1.978	2.270	3.028	
Filling	4.877		4.108	6.564	8.753	
Finished goods stores	0.088					
Freight & distribution		1.359				

Table (6): The AP$_L$D Matrix for the Company.

Activities / Productions Lines	Raw Material Stores	Inspection	Mixing	Filling	Finished Goods Stores	Freight and Distribution
Powder line	✓	✓	✓	✓	✓	✓
Cream line	✓	✓	✓	✓	✓	✓
Liquid line	✓	✓	✓	✓	✓	✓

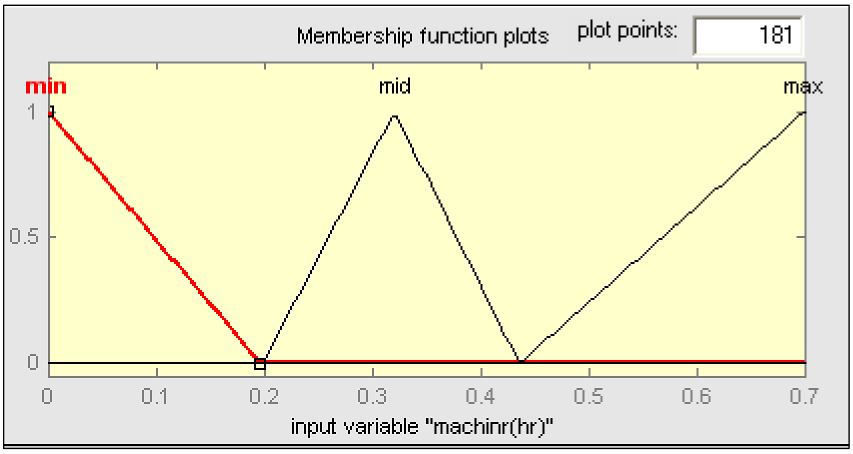

Figure 6(a). MF for the Machine Hours as Input 1 for Mixing Activity.

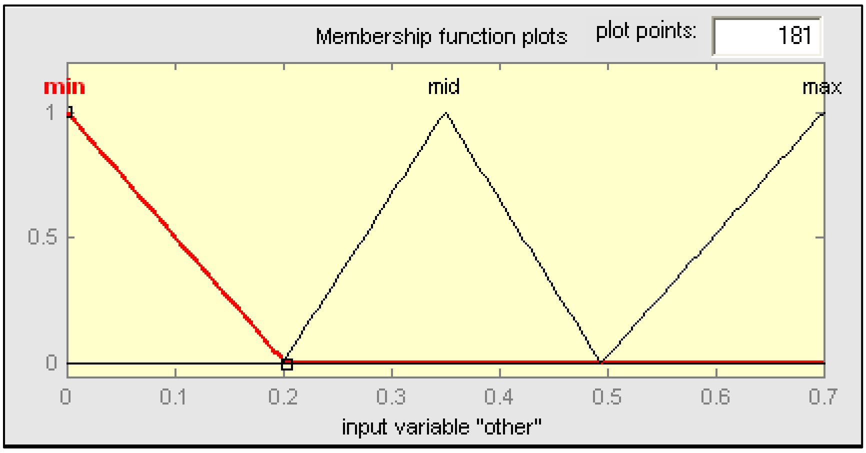

Figure 6(b). MF for the Other Consideration as Input 2 for Mixing Activity.

After determining all required ratios, the ratios are filled in AP_LD matrix as shown in Table (6). When the sum of any column in the AP_LD matrix is more or less than one, the normalization procedure is used. For example, the sum of ratios results from FL for allocation raw material stores activity to all production lines is 1.39, so it is normalized to 1. Table (8) shows ratio results from using FL with and without using normalization.

After replacing check marks, every entry (i,j) of AP_LD Matrix is replaced by cost value which is calculated by multiplying the cost of activity category (j) with the ratio, which results from using FL at entry (i,j). The new matrix gives the cost for each production line, and the total variable overhead cost for each Production line is obtained by adding each row. Table (9) depicts the new AP_LD Matrix for the company.

Table (9) shows that the variable overhead contributed ratios for each production line (PLCD) are 8.7%, 38.8% and 52.5%, respectively. Using PLCD means that only one cost driver is used for each production line. The overall cost for each product is calculated after determining the variable overhead costs for each PL. Based on these data, the total cost per unit for each product is calculated by:

Total product cost per unit = Overhead cost/kg X product unit size+ equally distributed costs + Direct labor + Direct materials.

Table (10) shows some examples for the total product's cost per unit for some products.

Currently, the traditional cost system is used to find the product's cost which depends on sales volume as a basis for allocating the overheads. As a result of such system, inaccurate cost allocation affects the actual cost of a product. Some get over-costed while the remainders are under-costed. Table (11) shows the ABC-FL Model total cost and the traditional total cost. Comparing these results asserts a deviation in some product's costs. For example, there is a very small difference between both costs for cream 1 product. Based on traditional methods, the total cost of cream 1 product is 1.278 JD, while it is 1.267 JD according to ABC-FL model. Another example is Baby Shampoo 1 where its traditional total cost is 1.098 JD and its ABC-FL model cost is 1.237 JD. This shows that this product is under its actual cost. Thus, this difference in total cost gives the managers a hint to modify Product's selling price.

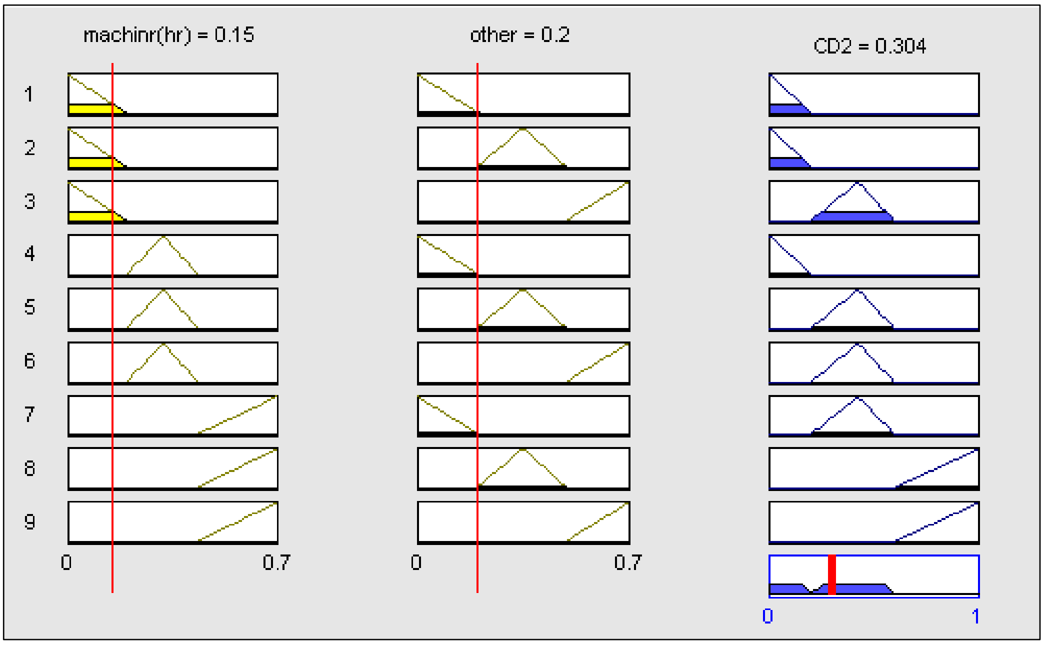

Figure 7. The Active Rules for Powder Activity Consumed by Mixing Activity.

Table (7): The AP$_L$D Ratio Matrix (%).

Production Lines \ Activities	Raw material Stores	Inspection	Mixing	Filling	Finished Goods Stores	Freight and Distribution
Powder line	0.05	0.078	0.17	0.1	0.107	0.07
Cream line	0.34	0.594	0.43	0.37	0.366	0.37
Liquid line	0.61	0.328	0.4	0.53	0.527	0.56
Total	1	1	1	1	1	1

Table (8): The Normalization for Raw Material Activity vs. Production Lines.

Before normalizing		**After normalizing.**	
Powder line:	0.07	Powder line:	0.05
Cream line:	0.47	Cream line:	0.34
Liquid line:	0.85	Liquid line:	0.61
Total:	1.39	Total:	1

Table (9): The AP_LD Cost Value Matrix (X000JD).

Activities	Raw material Stores	Inspection	Mixing	Filling	Finished Goods Stores	Freight and Distribution	
Production Lines							**Total**
The total cost for each activity	3.139	4.678	10.128	24.302	0.088	55.986	
Powder line	0.157	0.365	1.721	2.430	9.42 E-3	3.919	8.702
Cream line	1.067	2.778	4.355	8.992	0.0322	20.714	38.819
Liquid line	1.915	1.534	4.051	12.880	0.0459	31.352	52.479

Table (10): Total Cost per Unit.

Product	Variable overhead cost (unit/JD)	Labor cost Unit/JD	Material cost Unit/JD	Equally distributed cost unit /JD	Total cost Unit/JD
Cream 1	0.328	0.403	0.38	0.156	1.267
Cream 2	0.328	0.403	0.37	0.156	1.257
L.h. cream	0.213	0.403	0.19	0.156	0.962
Lotion 1	0.492	0.403	0.61	0.156	1.661
Lotion 1a	0.984	0.403	0.75	0.156	2.293
Lotion 2	0.492	0.403	0.67	0.156	1.721
Lotion 2a	0.984	0.403	0.89	0.156	2.433
Lotion 3	0.492	0.403	0.7	0.156	1.751
Lotion 3a	0.984	0.403	1.02	0.156	2.563

Table (11): Comparison between the New Model and Traditional Costing.

Product	New model Total cost (JD)	Traditional Total cost JD	Change (%)
Cream 1	1.267	1.278	1.1
Baby shampoo1	1.237	1.098	-13.9
Cream 2	1.257	1.268	1.1
Conditioner 3	2.499	2.01	-24.3
Baby oil	1.158	1.094	-6.4
Lh. Cream	0.962	0.973	1.1
Baby shampoo2	1.237	1.098	-13.9
Lotion 1	1.661	1.672	1.1
Shampoo 1a	1.523	1.334	-18.9
Lotion 1a	2.293	2.304	1.1
Shampoo 1b	1.533	1.344	-18.9
Lotion 2	1.721	1.732	1.1
Shampoo 1c	1.533	1.344	-18.9
Shampoo 1d	1.553	1.364	-18.9

Table (11) shows that some of the proposed model products' cost values are found to be over the traditional values, whereas others are found to be under the traditional ones. These mismatch values lead to problems in the company's products costs and act in accordance with selling price.

In order to make a right judgment about the model, the actual costs of production lines in the company for the last three years are compared with the model results. Table (12) shows the actual production lines proportions in three production lines for these years. Table (13) and Figure (8) compare the average proportions of the actual years, ABC-FL model proportions and traditional cost accounting proportions. The curve shows that the developed model is very close to actual costs, while the traditional one is far from both. This means that by using the traditional method in calculating the total cost of products, some products will have underestimated costs while others will have overestimated ones. This causes wrong allocation of costs for these products.

Accordingly, the new model affirms very close values to real ones, and this reflects the importance of considering such criteria for further future calculations. Implementing the proposed model in the selected company provides the managers with a lot of data to reevaluate products' prices in all production lines. This model presents more accurate costs of their products by allocating correctly the overhead costs. Also, the data calculated through the proposed model can be supportive in deciding whether to discontinue or expand producing a product.

Table (12): Actual Production Lines Proportions in Three Production Lines for 3 Years.

	Contributed proportion in 2000	Contributed proportion in 2001	Contributed proportion in 2002
Cream line	39.8%	38.9%	38.3%
Liquid line	53.7%	56.4%	56.6%
Powder line	6.5%	4.7%	5.1%

Table (13): Actual Average Proportions, ABC-FL Model and Traditional System Proportions.

	Traditional cost proportions	Actual average proportions	ABC-FL model proportions
Cream Line	45%	39%	38.80%
Liquid Line	40%	55.57%	52.50%
Powder Line	15%	5.43%	8.70%

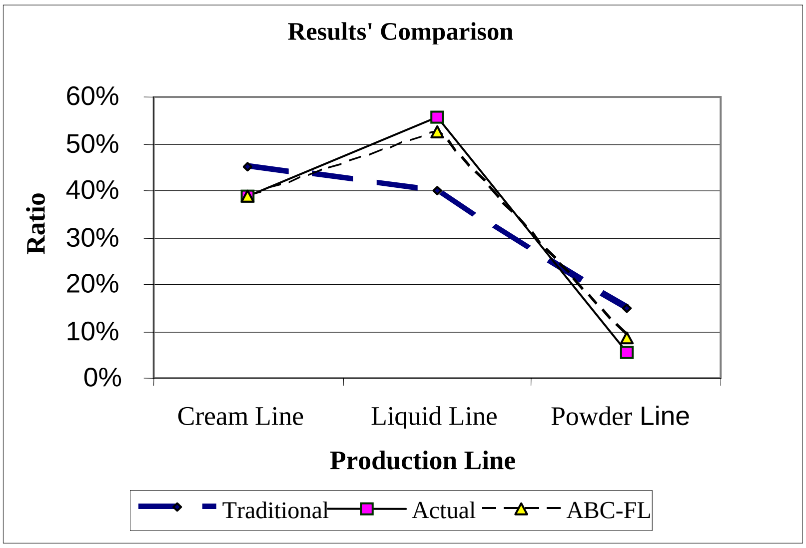

Figure 8. Comparison Curve between Traditional System, Actual and New Model Proportions.

5. CONCLUSIONS

Using traditional cost system as the only cost accounting approach implemented in SMMEs, with the current high degree of variation among the products in terms of the manufacturing requirements and overheads, to estimate the final product costs may give misleading information about the profitability of products. ABC is a better alternative to the traditional cost system in such enterprises. However, implementing ABC is limited due to the need for huge efforts and to the high level of uncertainty and complexity in selecting the cost drivers. That is why FL is used for the first time to overcome this problem. The new model is more suitable for small and medium enterprises; because this type of enterprises consists of short and similar production lines and it does not require a high investment for its application.

The new model solves the problem of selecting cost drivers by combining two approaches; ABC and FL. FL assists in incorporating all the related cost drivers' considerations with an enterprise experiences to emerge the optimum multi criteria cost drivers. Multi criteria cost drivers increase ABC system reliability and decrease uncertainty. Using FL to select the cost drivers plays a major role in bringing the idea of production line cost driver into existence. Thus, the complexity is obviously reduced since FL is keeping the system as simple as possible by limiting the number of cost drivers and by running it in a reasonable amount of time. The implemented model shows that the new production line costs are very close to reality in comparison with three previous years, and this reflects the importance of considering such criteria for further future calculations.

Nevertheless, the new proposed model has some limitations; including first, the time needed by financial/production managers to determine the required input, and to put the rules to select the cost drivers by using FL. Second, the new model does not show the differences in overhead costs distribution per product, since it gives the same contribution for all products in the same production line. Finally, the new model is suitable for the small and medium manufacturing companies and not applicable to large ones. By applying and modifying the model and getting real data, a neuro-fuzzy modeling can be built as a future work.

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تطبيق المنطق المضبب في نظام التكاليف المعتمد على النشاط في الشركات الصناعية الصغيرة والمتوسطة

*سهى وريكات وابراهيم الروابدة**

ملخـص

لاقى نظام حساب التكاليف المعتمد على النشاط اهتماما في الآونة الأخيرة لما حققه من تحسينات واضحة على أنظمة المحاسبة التقليدية؛ اذ يعتمد نظام حساب التكاليف المعتمد على النشاط على استخدام اكثر من محرك كلفة لربط الأنشطة والمنتجات المعتمدة عليها. لكن، وبالرغم من الفوائد الجلية لنظام المحاسبة المعتمد على التكاليف إلا انه يعاني من بعض الصعوبات في تطبيقه. وتتمثل هذه الصعوبات في صعوبة تحديد محركات الكاف المناسبة وكثرتها مما يصعب تطبيق نظام المحاسبة المعتمد على النشاطات. يوضح هذا البحث إمكانية استخدام المنطق المضبب في حل مشاكل نظام حساب التكاليف المعتمد على النشاط في الشركات الصغيرة والمتوسطة؛ إذ إن المنطق المضبب يعالج الحالات التي يظهر فيها عدم الوضوح وعدم التأكد التام. لقد أوجد هذا البحث مفهومين جديدين في تطبيق نظام حساب التكاليف المعتمد على النشاط؛ محرك الكلفة ذا الاعتبارات المتعددة ومحرك كلفة خط الإنتاج. في محرك الكلفة ذي الاعتبارات المتعددة تؤخذ كل الاعتبارات ذات العلاقة في تحديد محركات الكاف كمداخل إلى المنطق المضبب لإنتاج محرك كلفة مناسب. أما محرك كلفة خط الإنتاج فيهدف إلى استخدام محرك كلفة واحد لكل خط إنتاج بدلا من محرك كلفة لكل منتج، وذلك لما للشركات الصغيرة والمتوسطة من ميزة في صغر وتشابه خطوط الإنتاج فيها، مما يساهم في تقليل صعوبة تطبيق نظام حساب التكاليف المعتمد على النشاط بشكل واضح. أظهرت النتائج أن المنطق المضبب حسن نظام حساب الكاف المعتمد على النشاط وأوجد أساساً منطقياً ومقبولاً وشاملاً لأنظمة الكاف، حيث اندمجت خبرة المديرين والمعنيين في أسس اختيار محركات الكاف وتم التقليل من عدم الثقة ومن الصعوبة في نظام حساب الكاف المعتمد على الأنشطة وزاد من وثوقيته.

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