Evaluating Information Technology Investments:
A Fuzzy Activity-Based Costing Approach

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Abstract

This paper proposes a framework for evaluating information technology investments, integrating value chain analysis with activity-based costing and fuzzy logic. The proposed method should be particularly useful for businesses in emerging economies, where an uncertain economic environment is often combined with a lack of dependable, historical accounting data. The framework is illustrated by means of a hypothetical manufacturing company and a triangular fuzzy set membership function.
Keywords: activity-based costing, developing countries, emerging economies, fuzzy logic, value-chain analysis.

Introduction

The value chain model, which characterizes a company as a system of related activities [Porter and Millar, 1985] is perhaps one of the best known concepts in the business literature. The value chain model can serve management as a guide in identifying areas for improving profitability through lowering costs or increasing productivity. However, in practice, the value chain model is less frequently used than might be expected. Difficulties in reliably tracing costs to organizational processes appear to be the main obstacles [Hergert and Morris, 1989]. Traditional cost accounting methods, which fail to provide reliable cost information [Ness and Cucuzza, 1995], prevent broad, practical application of value chain analysis.

In essence, traditional cost accounting methods do not consider costs of processes but rather allocate the overhead based on direct labor hours, direct machining hours, or material costs. This simplification is satisfactory for the purpose of external financial reporting functions, such as inventory valuation [Kaplan, 1988]. However, for a systematic value chain analysis, traditional cost accounting methods are not very useful.

In order to address the shortcomings of traditional accounting systems and to more reliably estimate the cost of activities in the value chain, some authors propose the use of activity-based costing (ABC) [Dekker, 2003, Shank and Govindarajan, 1992]. ABC uses various activities and multiple cost drivers to trace overhead directly to cost objects such as products or services, and is thereby able to avoid the cost distortions generated by traditional volume based costing systems which use just a single driver, typically direct labor hours [Cooper, 1988, Cooper, 1989, Johnson, 1991].

One of the greatest challenges faced by business managers is the evaluation of investments in information technology (IT) [Dos Santos, 1991, Thatcher and Oliver, 2001]. The existence of numerous IT evaluation methods and techniques make an identification of appropriate procedure a difficult task [Renkema and Berghout, 1997]. In addition, the evaluation process is often lacking understanding and based on wrong assumptions, which leads many organizations to poor IT investments [Love et al., 2005].

Evaluating IT-related investments in emerging economies is an even more difficult task, due to generally less predictable changes in the social, political, and economic infrastructure. Recently, an integrated value chain model using ABC was developed for evaluating IT investments [Roztocki and Weistroffer, 2004]. Unfortunately, because companies in emerging economies often operate in a business environment characterized by uncertainty, evaluating IT investments using standard ABC may not always be practicable.

Fuzzy ABC, which combines ABC with fuzzy logic, is an extension of standard ABC, designed specifically for companies operating in an uncertain
business environment [Nachtmann and Needy, 2001]. For this reason it appears that the value chain model integrated with fuzzy ABC would be a promising tool for evaluating IT related investments in emerging economies. The purpose of this paper is to present a framework for such an evaluation method.

Theoretical Background

The framework presented in this paper synthesizes three concepts: value chain analysis, ABC, and fuzzy logic.

As stated above, the value chain model views a business as a collection of related activities [Porter and Millar, 1985], which allow the business to achieve its objectives. These activities feed into each other or support each other, and create business value. Activities directly involved in creating products or services are called primary activities, while those activities not directly involved in creating products or services, but necessary in order to effectively carry out the primary activities, are called support activities. The value created in the company is determined by three key factors: the price customers are willing to pay for end products or services; the cost of raw material; and the cost of activities in the value chain. In essence, a company is generating profit if the prices customers are willing to pay exceed the combined cost of raw material and costs of activities in the value chain. In theory, the value chain model should be very useful in helping management increase competitiveness by focusing on value activities and making these activities more efficient, thus reducing cost. As pointed out in the introduction though, in reality, traditional costing systems make it difficult for many companies to fully assess the cost of their value chain activities [Ness and Cucuzza, 1995].

ABC attempts to address shortcomings of traditional costing systems which typically allocate overhead to products and services based on direct labor hours [Cooper, 1988, 1989; Johnson, 1991]. In the ABC approach, overhead expenses, such as for example administrative salaries, are first traced to activities. Then, looking at multiple cost drivers, such as number of orders processed or shipping distance, costs are assigned from activities to cost objects. Examples of possible cost objects are products or services. Thus, ABC follows a two stage cost assignment procedure, where the first stage fits in very well with value chain analysis. In a recent paper, Peacock and Tanniru [2005] propose using ABC for justifying IT investments, though they do not specifically link it to value chain analysis.

Fuzzy logic or fuzzy set theory [Zadeh, 1965; Irani, Sharif, Love, and Kahraman, 2002] was introduced to represent vagueness and uncertainty prevalent in human reasoning. In contrast to traditional logic, fuzzy logic is less dependent on precise data. Since one of the biggest challenges during ABC implementation is the lack of precise and reliable accounting data, applying fuzzy logic concepts to ABC in companies operating in an uncertain
business environment seems to be a natural fit [Nachtmann and Needy, 2001].

Using fuzzy logic, statements or relationships are represented as fuzzy sets, where the imprecision and uncertainty of the statements are quantified via a fuzzy set membership function. These fuzzy set membership functions take on values between 0 and 1, specifying the degree of membership in the fuzzy set, corresponding to the strength of the statement or relationship represented. The closer the value of the membership function is to 1, the higher the certainty of the statement. A value of 1 indicates full membership, and a value of 0 indicates no membership.

Often decision-makers use a variety of techniques simultaneously for IT investment evaluation, to lessen the limitations of any one particular method. Thus, and for the reasons mentioned above, the synthesis of value chain analysis, ABC, and fuzzy logic concepts appears to be very promising to complement existing approaches for evaluating IT investments in emerging economies.

Proposed Framework

The proposed framework for evaluating IT-related investments requires four major steps:
1. Identify a company’s major activities and construct its value chain.
2. Estimate the cost for performing each of these activities.
3. Assess the potential impact of the IT investment on the costs of each activity in the value chain.
4. Evaluate expected changes in the cost structure.

Figure 1 gives an overview of the proposed framework, where the ovals represent the major steps in the framework, and the rectangular boxes represent essential inputs and outputs of these steps. The first step, identifying the major activities, makes use of the value chain model. These activities provide the input to the second step, assigning costs, based on ABC. Fuzzy logic may be used here, as well as in step 3, where the impact of the IT investment on the activity costs is estimated. The resultant projected cost structure serves as input to the last step, evaluating the new cost structure to determine the desirability of the proposed IT investment. A systematic approach to step 4 may involve a comparison between the projected costs for activities without the IT investment and with the IT investment, over a specific time period. The expected potential savings can then be compared to the additional expenses related to this IT investment.

The use of fuzzy logic in steps 2 and 3 allows the use of vague statements such as the IT investment has “greater impact” or “lesser impact” [Irani et al., 2002], which can be captured by an appropriate fuzzy set membership function. Usually, such imprecise statements can be elicited from a panel of experts more easily than firm numbers.
Figure 1: Four-Step Framework

1. Identify Activities
2. Assign Costs to Activities
3. Estimate Impact of IT on Activity Costs
4. Evaluate New Cost Structure

Figure 2: Trapezoidal and Bell Shaped Membership Functions
Membership functions can take many different forms and are not required to be symmetric. Figure 2 shows examples of trapezoidal and bell-shaped membership functions. The particular function used may depend on how well available data may be represented by such function, as well as the complexity of working with the function.

For purpose of illustration, a special membership function is used, called triangular fuzzy numbers (TFN) [Van Laarhoven and Pedrycz, 1983] which have the advantage of simplicity and are easier to handle than the more complex trapezoidal or bell-shaped membership functions or fuzzy numbers [Nachtmann and Needy, 2003]. As shown in Figure 3, the TFN are represented by three values: the smallest possible (SP), the most promising (MP), and the largest possible (LP) [Nachtmann and Needy, 2001]. Since TFN are relatively intuitive and easy to handle, they are commonly used for business related applications, such as capital budgeting [Chiu and Park, 1998].

Estimating the impact of planned IT investments on a company’s value chain in emerging economies is often based on imprecise and incomplete data. Therefore in many cases, decision-makers have only vague and often inconsistent assessments about the possible future outcomes of an investment. In such cases, the opinions of various experts, such as key personnel and outside consultants, can be combined to establish the three parameters of TFN for each activity in the value chain. As mentioned above, a different membership function may be employed if the input from these experts can be better represented by such. The required parameters would then be different: a trapezoidal function, for example, would require four parameters instead of three. Two parameters of a trapezoidal function may describe the range of most promising values while the remaining two parameters could specify lower and upper limits.

In essence, using TFN, the parameter MP represents the most likely activity costs after the IT investment, while the parameters SP and LP represent the optimistic and pessimistic view respectively. These values may be determined by combining high and low estimates of the various
Figure 4: Fuzzy Logic Estimation
The TFN function may be skewed toward SP or LP (as shown in Figure 3). The shape may reflect agreement or disagreement among the involved experts and serve as an indicator for their perception regarding the magnitude of the effect concerning the IT investment.

Figure 4 shows the use of fuzzy logic for assessing the potential impact of an IT investment on activities. Defuzzification, such as the “center of gravity” (COG) determination [Wang and Luoh, 2000], can be used to arrive back at a “crisp” cost structure, which may be more tangible and easier to work with. The COG, which is probably the best known defuzzification method, provides a single value by calculating the center of gravity for the area under the membership function. Other popular defuzzification methods include “mean of maxima”, which in effect calculates a center of gravity of the “core” of the fuzzy set, “center of mean”, and “midpoint of area” [Van Leekwijck and Kerre, 1999; Roychowdhury and Pedrycz, 2001]. Alternatively, the LP, MP, and SP numbers may be used directly in step 4, when evaluating the projected cost structure to make the investment decision.

The proposed framework for evaluating IT investments by using the value chain and fuzzy ABC is illustrated in the following section.

Illustration

The first major step in evaluating IT investments using the proposed framework is to identify a company’s major business activities. For purpose of illustration, a relatively basic value chain with ten major activities is constructed, keeping in mind though, that in many companies, the number of activities in the value chain could be substantially higher. Following the construction of the value chain, the current costs for performing all activities are estimated. For the purpose of simplification, only one estimate for current activity cost is provided in this illustration. This estimate can be obtained by using a standard ABC system (fuzzy logic may also be applied here, if necessary). Then in Step 3, Fuzzy ABC is used to estimate the cost of activities in the company’s value chain after the planned IT investment is conducted.

For simplicity, it is assumed that without the proposed IT investment the cost of activities over the years would remain constant. For each activity, three values (the smallest possible (SP), the most promising (MP), and the largest possible (LP)) are estimated as presented in Table 1. Interviewing key personnel and consultants may help derive these three estimation values for each activity [Nachtmann and Needy, 2001]. For example, the highest estimates given by any of the consultants or personnel may be used as the LP values; the lowest estimates may be used as the SP values, and overall averages may be used as the MP values. Individual consultants or personnel may arrive at their estimates based on available information and their past experiences. Rather than averaging estimates to arrive at the MP value, a Delphi technique [Dalkey and Helmer, 1963] could be used to get “consensus” estimates.
As shown in Table 1, the three expected costs may vary substantially, which mirrors the uncertainty related to the IT investment. For example, if the IT implementation turns out to be smooth, then the activity cost for job scheduling can be reduced to $20,000. On the other hand, it is also possible that the planned IT investment will not reduce the activity cost at all.

Table 1: Current and Projected Operating Costs One Year after IT Investment

<table>
<thead>
<tr>
<th>Activity</th>
<th>Current Activity Cost</th>
<th>Projected SP Activity Cost</th>
<th>Projected MP Activity Cost</th>
<th>Projected LP Activity Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receive Orders</td>
<td>$60,000</td>
<td>$40,000</td>
<td>$50,000</td>
<td>$70,000</td>
</tr>
<tr>
<td>Schedule Jobs</td>
<td>$50,000</td>
<td>$20,000</td>
<td>$30,000</td>
<td>$50,000</td>
</tr>
<tr>
<td>Purchase Materials and Subparts</td>
<td>$80,000</td>
<td>$50,000</td>
<td>$60,000</td>
<td>$100,000</td>
</tr>
<tr>
<td>Handle Inventory</td>
<td>$70,000</td>
<td>$50,000</td>
<td>$60,000</td>
<td>$70,000</td>
</tr>
<tr>
<td>Manage Production</td>
<td>$160,000</td>
<td>$120,000</td>
<td>$130,000</td>
<td>$160,000</td>
</tr>
<tr>
<td>Assure Quality</td>
<td>$30,000</td>
<td>$20,000</td>
<td>$30,000</td>
<td>$40,000</td>
</tr>
<tr>
<td>Ship Final Products</td>
<td>$100,000</td>
<td>$80,000</td>
<td>$90,000</td>
<td>$100,000</td>
</tr>
<tr>
<td>Administrate Payments</td>
<td>$40,000</td>
<td>$30,000</td>
<td>$40,000</td>
<td>$60,000</td>
</tr>
<tr>
<td>Perform Engineering Work</td>
<td>$110,000</td>
<td>$100,000</td>
<td>$110,000</td>
<td>$130,000</td>
</tr>
<tr>
<td>Manage Customers</td>
<td>$100,000</td>
<td>$90,000</td>
<td>$100,000</td>
<td>$120,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$800,000</strong></td>
<td><strong>$600,000</strong></td>
<td><strong>$700,000</strong></td>
<td><strong>$900,000</strong></td>
</tr>
</tbody>
</table>

Overall, the values in Table 1 suggest that the planned IT investment is expected to have a substantial impact on the company’s value chain, as can be seen in the variations of the activity costs. In addition, the estimates may reflect possible interactions among activities and their cost as a result of the IT investment. For example, if the IT investment runs less smoothly than expected, the costs of the activity “Purchase Materials and Subparts” may increase from the current level of $80,000 to $100,000. In addition, the problems in material procurement may negatively affect product quality and increase lead times, which may negatively impact customer satisfaction and create additional need for customer support. This may, in turn, increase the cost of the activity “Manage Customers.”

In order to better decide if the proposed IT investment will be cost effective, the three projected activity costs can be combined in a single value by using defuzzification. Wang and Luoh [2000] show that when using the triangular
membership function (or TFN), a “center of gravity” (or COG) defuzzification can be achieved simply by averaging the three numbers SP, MP, and LP. Precisely because of this simplicity, TFN together with COG are among the most commonly used approaches to fuzzy numbers and defuzzification. For an overview of other defuzzification methods refer to Van Leekwijk and Kerre [1999] and Roychowdhury and Pedycz [2001].

Note that COG defuzzification of TFN will generally produce different values than those resulting from simply averaging the single value predictions of various experts. The lowest and highest cost estimates from the experts will have a greater impact when using TFN with subsequent COG, as extreme SP or LP values will pull the COG value further down or up. Table 2 compares the current activity cost and projected activity cost after defuzzification.

Table 2: Current and Projected Defuzzified Operating Costs
One Year after IT Investment

<table>
<thead>
<tr>
<th>Activity</th>
<th>Current Activity Cost</th>
<th>Projected Activity Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receive Orders</td>
<td>$60,000</td>
<td>$53,333</td>
</tr>
<tr>
<td>Schedule Jobs</td>
<td>$50,000</td>
<td>$33,333</td>
</tr>
<tr>
<td>Purchase Materials and Subparts</td>
<td>$80,000</td>
<td>$70,000</td>
</tr>
<tr>
<td>Handle Inventory</td>
<td>$70,000</td>
<td>$60,000</td>
</tr>
<tr>
<td>Manage Production</td>
<td>$160,000</td>
<td>$136,667</td>
</tr>
<tr>
<td>Assure Quality</td>
<td>$30,000</td>
<td>$30,000</td>
</tr>
<tr>
<td>Ship Final Products</td>
<td>$100,000</td>
<td>$90,000</td>
</tr>
<tr>
<td>Administrate Payments</td>
<td>$40,000</td>
<td>$43,333</td>
</tr>
<tr>
<td>Perform Engineering Work</td>
<td>$110,000</td>
<td>$113,333</td>
</tr>
<tr>
<td>Manage Customers</td>
<td>$100,000</td>
<td>$103,333</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$800,000</strong></td>
<td><strong>$733,333</strong></td>
</tr>
</tbody>
</table>

The comparison between the current activity cost and the projected activity costs, as produced by defuzzification, provides valuable information about the expected payoffs and potential risks of the IT investment. For some activities, such as “Schedule Jobs” and “Manage Production,” the IT investment is expected to be cost effective. In contrast, for activities such as “Manage Customers” and “Perform Engineering Work,” the IT investment may, at least temporarily, increase their costs, which is a direct result of potential quality and delivery problems related to system implementation, as mentioned earlier.
In summary, the example shows that the overall cost of all activities in the company’s value chain is expected to be reduced. Therefore, the IT investment has good potential to be cost effective.

Conclusions and Limitations

In this paper, a conceptual framework for evaluating information technology investments, integrating value chain analysis with activity-based costing and fuzzy logic has been presented. The proposed approach appears to be particularly suited for businesses in emerging economies, where economic and political developments are particularly difficult to predict. A hypothetical manufacturing company was used to illustrate the application of the framework. The framework is a thought model, based on reasoning and experience, but no empirical validation has been carried out as yet.

In the framework presented here, the focus is only on the cost side and not on revenue side. Some of the IT investments may provide more value for customers and create more revenues, which should also be considered. Also, the complex issue of the interaction among activities and their costs is only briefly discussed. It is, however, possible that higher spending in one activity may result in a substantial cost reduction for another activity. Some IT investments may change the sequence of activities in the value chain and even eliminate particular activities. Furthermore, this illustrative example given here concentrates on the operating costs of activities. Direct costs, such as materials and direct labor, are not considered. However, possible changes in direct costs derived from an IT investment could be substantial and may also need to be accounted for. In addition, many investments and ensuing capital expenses tend to shift the company cost structure from variable toward fixed costs. Such a shift needs also to be considered, as an increase in fixed costs presents higher risk in case of fluctuations in revenues.

In our fuzzy logic cost estimation, we used triangular fuzzy numbers, which are quite intuitive and relatively easy to handle. Nevertheless, it is quite possible that other, more complex functions, may prove more appropriate for this kind of analysis. Finally, only the value chain of a single company is looked at. Most businesses in emerging economies are components of a larger global value chain. For this reason, when investing in IT, these companies often need to balance their own cost savings efforts with the requests from customers and suppliers.

Notwithstanding these limitations, the framework represents a valuable contribution to the existing body of knowledge, as it presents an IT evaluation method which can appreciably complement the currently used approaches, specifically in emerging economies. The concepts that form the basis for the framework, value chain, ABC, and fuzzy logic, have been validated in other contexts. Though, for the purpose of simplicity, the illustration of the framework is based on an example of a hypothetical company, the work presented here is based on wide-ranging experience in working with companies in emerging economies.
Future Work

The limitations of this framework, discussed briefly in the previous section, offer multiple avenues for future research. Field studies in a number of companies in emerging economies need to be conducted, to validate the proposed framework.

The five phases of action research proposed by Susman and Evered [1978] provide a suitable structure for conducting these studies. In the diagnosing phase, a suitable company needs to be identified. This company may be one which is notorious for protecting its cost leadership by heavily investing in IT, and which is not satisfied with its current IT evaluations methods. In the action planning phase, the management and key employees need to be familiarized with the proposed framework for IT investments evaluation, and the framework may need to be adapted and fine tuned to the particular characteristics of the company. In the action taking phase, the framework would be implemented to make IT investment decisions. Then, in the evaluating phase, the results of the investments made using the framework need to be examined. Finally, in the specifying learning phase, the experienced effectiveness of the framework needs to be examined, which may result in changes or refinements to the framework.

Case studies of other companies, not using the proposed framework, may be useful for comparisons. A longitudinal study may be used to assess potential implications over time. Further, the framework may be expanded to also consider the revenue side, direct costs, capital costs, and some interactions between different costs.

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