A Quantitative Model for Analyzing IS Outsourcing Decisions

Abstract

In this research, we propose a quantitative model to systematically evaluate outsourcing decisions. Our model is unique in many ways. For instance, it takes the costs of insourcing, outsourcing, and coordination into consideration simultaneously. Further, the inter-related nature of tasks is addressed; and the performance of a vendor is also considered. The problem is formulated as a mixed integer programming model and is solved using a practical spreadsheet based optimizer. Finally, managerial implications from our model are discussed.

Keywords: Outsourcing, Information Systems, Quantitative Model, Optimization

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1. Introduction

Kodak outsourced their information systems functions in 1989. Since then, many firms have followed the practice (Hirshheim and Dibbern, 2002; Lacity and Willcocks, 1995). Although outsourcing has been widely adopted in the industry, many IT outsourced projects still fail. According to Maclnnis (2003), about one quarter of outsourcing contracts examined failed in the first year and half of the outsourcing companies renegotiated their contracts or simply switched to other vendors. Haubold (2000) also showed that only 16.2 percent of outsourcing projects were completed on time and within budget. In addition, more than 31 percent of them failed and were suspended.

Thus IS outsourcing deserves more research attention. In the literature, researchers have already started to examine outsourcing practices. For instance, Williamson (1979) developed the transaction cost governance structure with two factors – frequency of the transactions and investment specificity – to help understand outsourcing decisions. Venkatesan (1992) proposed a generic method to classify IS functions into commodity and strategic types. A firm should outsource the commodity operations and keep the strategic functions in-house (also called insourcing). According to Vacca (2000), firms adopting outsourcing have better control on cost, easier access to skilled personnel, higher-quality IS services, and a better mechanism to share risk with vendors. On the other hand, they may suffer from lack of control in performance, loss of data security and confidentiality, inability to revert back to in-house operations, and loss of critical skills.

Although these models increase our understanding of outsourcing practices, they have their limitations. Lacity and Hirschheim (1993) questioned the ability of managers to differentiate a strategic function from a commodity service. They believed that managers could mistakenly identify both critical services and strategic functions as commodities. Yang and Huang (2000) argued that outsourcing decision determinants such as transaction cost, and strategic or commodity functions were too narrow to determine whether the system could be outsourced. They further pointed out that most decision models were unable to identify the possible outsourcing risk and uncertainty that might arise during outsourcing. They also observed that many decision models ignored hidden costs in outsourcing and other related managerial concerns.

To address these limitations, we propose a new decision model to evaluate outsourcing decisions and determine the assignment of jobs taking risk into consideration. Our outsourcing model also considers various factors that may implicitly or explicitly influence the outsourcing cost. Specifically, we try to find an optimal solution to the assignment of jobs considering insourcing cost, outsourcing cost, additional manufacturing cost reflecting the performance of a vendor, and coordination cost.

Our solution methodology makes use of Excel Solver. Solver is a free add-in package for Excel. A more powerful version – Premium Solver – is commercially available for optimization on an industrial scale. The advantage of a spreadsheet is that the package is widely used by practitioners. This gives us an opportunity to show to managers how a computerized decision support tool, specifically linear programming on a spreadsheet, enhances efforts to convert managerial ideas into practice. For further reading on Excel Solver, see Moore and Weatherford (2001).

This paper is structured in the following manner. A literature review is provided in section 2. The problem definition and the formulation are presented in section 3. A mixed integer programming (MIP) model is formulated in section 4. In section 5, a numerical example is presented and solved with Excel Solver based on our formulation. Managerial implications are derived from the computational experience with our model and are discussed in section 6. Section 7 concludes the paper.

2. Literature Review

In the literature, most outsourcing research studies are descriptive and somewhat anecdotal. They provide only modest insights into the decision-making. Although some approaches are more systematic and use mathematical models, they often restrict themselves to evaluating outsourcing options such as vendor selection. Very few attempt to use a quantitative approach to evaluate this complicated decision. In this review, we focus only on these approaches.

Udo (1996) argued that the Analytic Hierarchy Process (AHP; Saaty, 1990) was a good analytical tool to handle complex outsourcing decisions systematically. Their AHP outsourcing decision model considers four categories of factors in the analysis: strategic importance, vendor issues, customer’s interests, employee’s interests. Other factors may be added to the hierarchy to address the special circumstances of a company.

Yang and Huang (2000) also used AHP to develop an outsourcing decision model that included five factors: management, strategy, economics, technology and quality. The model helps a user structure the outsourcing problem with all the elements or factors that may be important to the decision. It also provides the user with a systematic way to analyze factors or attributes, and to prioritize jobs to be outsourced.

Patterson and Rolland (2002) developed a bias-free decision model to aid the

E-business outsourcing process using linear programming. They defined the Capacitated Business Process Outsourcing problem (CBPO). The model finds the assignment of processes to providers such that the total operating expenses are minimized.

Most research models including Patterson and Rolland (2002) treated every outsourcing decision as an independent event and ignored the importance of the inter-dependence among the IS functions. Masten (1984) and Gulati (1995) argued that this “independent” treatment in modeling was inappropriate. Hence, we try to develop a model to address this limitation. Compared with the existing models, our model is unique in two ways. It not only considers the inter-related nature of jobs but also takes the performance of vendors into consideration.

3. Modeling Considerations

Before making an outsourcing decision, we have to analyze all the factors that may explicitly or implicitly influence the outsourcing cost. In other words, all relevant costs should be considered to ensure the quality of the decision. Our mathematical model includes the fixed costs for both insourcing and outsourcing jobs, and the additional manufacturing cost. The fixed cost for insourcing jobs includes all the setup costs for establishing a service such as the personnel cost, technology cost, and control cost. It also includes the coordination cost and monitoring cost for internal operations. However, the total resource usage for in-house production including labor, computer facilities and expertise cannot exceed the maximum capacity of the firm.

The fixed cost for outsourcing jobs is composed of the price quoted by a vendor, the cost of selecting and establishing a relationship with a vendor, and the contracting cost to handle the process. Nevertheless, the fixed cost for outsourcing does not necessarily reflect all of the actual cost. For instance, it may not include the additional manufacturing costs that may be required for governing the transaction.

The additional manufacturing costs are the transaction costs of bargaining and opportunism that arise in governing outsourcing activities. The bargaining cost may arise from negotiation and monitoring in the pre- or post-contractual stage. The opportunism cost may be incurred when a vendor wants to change the agreed terms of a transaction in bad faith. This behavior occurs when the vendor cannot achieve the expected level of performance (Vining and Globerman, 1999).

The expected additional manufacturing cost may be pre-estimated by the outsourcer using the vendor performance matrix. The methodology used is similar to that suggested by Soukup (1987). The matrix was designed to analyze the individual vendor's performance given an estimation of the additional manufacturing costs that may be generated under various operating conditions. The performance of the potential vendor is extremely important in the IS function and failure in achieving the expected level of performance would lead to an additional governing cost.

The vendor selection committee of an outsourcing company needs to judge if vendors will be able to fulfill the requirements of the contract and meet the expectations. In fact, the vendors will be "scored" on how well they would perform based on their track records. To execute the performance matrix, the managers would have to first estimate the relative additional manufacturing costs that may be generated if the vendors perform well, fairly and poorly. Then, the managers would forecast the possibility of all three performance levels and assign the probability to each level of performance. The expected additional manufacturing cost is the sum of the product of the estimated costs of all the performance levels and their associated probabilities.

Another important issue in IS outsourcing decision-making is the coordination among the jobs. Before deciding whether a job is outsourced or done in-house, we must consider its impact on another job. In general, an IS job (e.g., training), which is critically related to other important jobs (e.g., systems development and planning), is riskier to outsource. On the other hand, an IS job (e.g., PC maintenance), which is insignificantly related to other important jobs (e.g., system development), is more likely to be outsourced.

We adopt an idea from Stanfel (1983) to measure the inter-dependence between jobs. The goal of IS outsourcing is to determine the mode of production for a collection of jobs in a system. A system may be represented by an undirected graph, as suggested by Stanfel (1983). Figure 1 is a block diagram of the system, where the circles represent jobs and the edges represent the interaction between jobs. The inter-dependence matrix for Figure 1 is defined and shown in Figure 2. The cost of coordination between a pair of jobs may be estimated under different scenarios.

INSERT FIGURE 1 HERE.

INSERT FIGURE 2 HERE.

4. Quantitative Model

We consider two jobs at a time. Let k be the outsourcing/insourcing scenario index where $k = 1, 2, 3$, or 4. Thus we have four scenarios as follows

1. Both job i and job j are outsourced ($k = 1$);
2. Job i is outsourced and job j is done in-house ($k = 2$);
3. Job i is done in-house and job j is outsourced ($k = 3$);
4. Both job i and job j are done in-house ($k = 4$).

Also there is an additional manufacturing cost (h_i) in outsourcing due to the different performance levels of a vendor. This expected additional cost can be pre-estimated using the vendor performance matrix (see the last section for details). To formulate the model, we now define:

N = number of jobs to be outsourced/insourced
k = {1, 2, 3, 4} are the possible scenarios
M = number of types of resources available in the company;
c_i = fixed cost for insourcing job i;
d_i = fixed cost for outsourcing job i;
h_i = additional manufacturing cost of a vendor performing job i;
e_i = total outsourcing cost ($d_i + h_i$)
r_{ij}^{k} = inter-dependence cost between job i and job j under scenario k
(This helps determine the coordination cost required to achieve an identical standard level of performance under different scenarios)
Q_m = the maximum amount of resource m available in a company;
a_{im} = the amount of resource m required by job i when the job is done in-house;

Decision variables:
x_i = 1 if job i is done in-house, and 0 if job i is outsourced;
z_{ij} = the interdependence cost due to the specific insourcing/outsourcing combination of jobs i and j;

An MIP model is defined next to determine the assignment of all N jobs (either outsourcing or insourcing) such that the sum of all the costs is minimized.

$$\text{Minimize} \sum_{i=1}^{N} c_i x_i + \sum_{i=1}^{N} e_i (1 - x_i) + \sum_{i=1}^{N} \sum_{j>i}^{N} z_{ij} \qquad (1)$$

Subject to

$$\sum_{i=1}^{N} a_{im} x_i \le Q_m \qquad \text{for } m = 1, 2, \ldots, M \qquad (2)$$

$$z_{ij} \ge r_{ij}^{1} \lfloor 1 - x_i - x_j \rfloor \qquad \text{for } i<j,\ i, j = 1, 2, \ldots, N \qquad (3)$$

$$z_{ij} \ge r_{ij}^{2} \lfloor x_j - x_i \rfloor \qquad \text{for } i<j,\ i, j = 1, 2, \ldots, N \qquad (4)$$

$$z_{ij} \ge r_{ij}^{3} \lfloor x_i - x_j \rfloor \qquad \text{for } i<j,\ i, j = 1, 2, \ldots, N \qquad (5)$$

$$z_{ij} \ge r_{ij}^{4} \lfloor x_i + x_j - 1 \rfloor \qquad \text{for } i<j,\ i, j = 1, 2, \ldots, N \qquad (6)$$

$$x_i = \{0,1\} \qquad \text{for } i = 1, 2, \ldots, N \qquad (7)$$

The objective of the formulation (Equation (1)) is to minimize the total cost of assigning *N* jobs which may be dependent on one another. Equation (2) is the capacity constraint of each resource. The sum of the resources required for in-house production should not exceed the resource available in the company. Equations (3) to (6) determine the cost due to the inter-dependence between jobs. Notice that the cost changes as job *i* and job *j* are differently assigned under the four scenarios. Since only one scenario is possible, only one of the equations (3) to (6) is valid. For example, if job *i* is outsourced and job *j* is produced in-house, $x_i = 0$ and $x_j = 1$ and hence only equation (4) is valid with $z_{ij} \geq r_{ij}^2$. For the other constraints on z_{ij}, the right-hand-sides are all zero or negative under this particular combination of x_i and x_j. Equation (7) restricts all jobs to binary values (a job is either outsourced or done in-house).

5. Numerical Example

This example illustrates the decision model for a single vendor case. The model is formulated as an MIP problem and Solver is used to obtain the optimal solution. The mathematical model only requires modest computational effort and is easy to integrate in Excel. The worksheet for this example can be obtained by contacting the authors.

A company needs to decide the assignment of five IS related functions (jobs) - system development, training, maintenance, telecommunication and system integration. Table 1 shows the insourcing and outsourcing costs. The company may consider outsourcing all the five jobs to reduce production costs. However, production cost alone does not necessarily reflect the actual cost of outsourcing.

INSERT TABLE 1 HERE.

Therefore, our decision model must also consider the hidden costs that may arise in managing the outsourcing activities such as the expected additional manufacturing cost and the cost due to the inter-dependence between jobs. The expected additional cost is pre-estimated according to the vendors' performance level. As seen in Table 2, the expected additional cost is $240,000 for the particular vendor to perform job 1. Note that this is also based on the estimated probabilities of good, fair, and poor performance levels for that vendor. Table 3 shows the expected additional cost of all five jobs given that they are outsourced.

INSERT TABLE 2 HERE.

INSERT TABLE 3 HERE.

In addition to the expected additional manufacturing cost due to the variation in vendor performance, our decision model also considers the cost due to the inter-dependence between jobs. Table 4 shows the costs for each pair-wise combination of job i being outsourced and job j being done in-house (Scenario 2). For example the cost of the coordination required when job 1 is done in-house and job 2 is outsourced is $200,000.

INSERT TABLE 4 HERE.

Table 5 shows the resources required by each job if it is performed in-house. For example, job 1 requires 100 labor hours, 50 computers and 20 experts. However, the company cannot perform all the jobs as it is constrained by 200 labor hours, 100 computers and 50 experts. Therefore the resources required for all the insourced jobs have to be less than or equal to the maximum amount of the resources available in the company.

INSERT TABLE 5 HERE.

Decision variable x_i decides whether the job is insourced {1} or outsourced {0} and z_{ij} determines the interdependence cost for a particular assignment of jobs i and j under the four scenarios.

Table (6) shows the optimal solution that minimizes the total cost of assigning the five jobs. The solution has jobs 1, 4 and 5 outsourced and jobs 2 and 3 done in-house. The total cost of this strategy will be $28, 668, 000.

INSERT TABLE 6 HERE.

6. Managerial Implications

Our formulation based on an MIP determines the assignment of jobs with a more comprehensive cost analysis. The methodology is also useful in evaluating the importance of the IS functions. For example, we assume that the cost for in-house production equals the sum of the fixed outsourcing cost plus the expected additional manufacturing cost, i.e., $c_i = e_i$

In Equation (1) if total insourcing cost equals to total outsourcing cost, the outsourcing decision will rely on the critical parameter z_{ij} – the cost reflecting the inter-dependent nature of jobs. When a job is highly related to other jobs, it is obviously critical and strategic to the company and should be kept in-house. Venkatesan (1992) classified the IS function as commodity or strategic and suggested keeping strategic functions in-house. Our finding is consistent with Venkatesan (1992) in this aspect. Later, Lacity and Hirschheim (1993) questioned the ability of managers to differentiate a strategic function from a commodity service. A slight modification to our model (as demonstrated here) may provide a solution to address their concern.

On the other hand, when $c_i > e_i$, the model may suggest that the company could outsource all IS functions. In this case, the company will not have any in-house production and waste their resources. In the long run, the company would have to consider downsizing IS operations.

Our model may be modified to deal with the situation where the company wants to maintain some in-house production capability. The objective of our model is revised to include an additional penalty for unused resources. Equation (2) is modified to reflect that the resources available are either used or not used. To show the modification in the model, we let b_m be a penalty per unit of the unused resource *m* and y_m is the number of units of unused resource *m*.

Equation (1) will become

$$\text{Minimize } \sum_{i=1}^{N} c_i x_i + \sum_{i=1}^{N} e_i (1 - x_i) + \sum_{i=1}^{N} \sum_{j>i}^{N} z_{ij} + \sum_{m=1}^{M} b_m y_m$$

Equation (2) will become

$$\sum_{i=1}^{N} a_{im} x_i + y_m = Q_m \qquad \text{for } m = 1, 2, \ldots, M$$

To minimize the impact of the penalty cost, the model would suggest that the company maintains some in-house production. Table 7 shows the revised optimal assignment of jobs when this consideration is included. The resources used for the in-house production is shown in Table 8. The total outsourcing cost is $37,543,000.

INSERT TABLE 7 HERE.

INSERT TABLE 8 HERE.

7. Conclusion

Few research studies in the literature use a quantitative model to understand outsourcing decisions. Our work is to evaluate the decisions using an MIP model. The objective is to minimize all the possible insourcing and outsourcing costs considering the inter-dependence between jobs. A numerical example was also shown to illustrate the decision model with a single vendor approach. Managerial implications derived from our formulation are discussed.

Although our model is comprehensive, it still has its limitations. In practice, companies often deal with multiple vendors rather than a single vendor. Hence, our future work will introduce a multiple vendor situation into our model. In addition, in our existing model, the capacity of a vendor is not modeled. Thus it would be interesting to consider models with capacitated vendors.

The problem as formulated carries some features of a non-standard version of the knapsack problem. Interested readers may refer to Lin (1998) for a comprehensive bibliographical survey of these non-standard knapsack problems. One may take advantage of this problem structure in designing a solution method. Since our focus is not on computation, we decide to use a spreadsheet-based solution to illustrate our main ideas. Using a spreadsheet-based optimizer has the advantage of showing managers how to implement managerial ideas using optimization

In our model, we assume that a strategic function is highly inter-related to other functions. As a result, our managerial implications are consistent with Venkatesan (1992). Based on the assumption, we develop a procedure for differentiating strategic functions from commodity functions to address the concerns of Lacity and Hirschheim (1993). Although this assumption is generally true, it may not be applicable in some situations. For example IBM outsourced strategically critical components such as microprocessor and operating systems to Intel and Microsoft.

This could be explained based on the classical differences between resource-based theory and transaction-cost theory. Strategic perspectives such as resource-based theory and resource-dependency theory (Barney, 1986; Cheon et al., 1995; Wernerfelt, 1984) propose to formulate and implement the strategies in order to achieve the performance goal. They focus on maximizing the firm's internal resources and capabilities, and obtaining the critical external resources in order to survive and stay competitive. Economic views such as transaction cost theory and agency-cost theory (Hallen et al., 1991; Lacity and Hirschheim, 1993; Williamson, 1979) explains the characteristics of the transactions and examines the governance of economics agents in the transactions in order to achieve the economies of scale.

The behavior of IBM in the PC market may be explained by arguments following resource-based theory. At the time IBM entered the market, they were strong in mainframe hardware and systems software, application software, manufacturing logistics, and marketing. To shorten time to market, they outsourced microprocessors and operating systems and focused on their strengths. In our case, we focus on companies that have extensive experience in IS project development. They need a decision model to help make outsourcing decisions.

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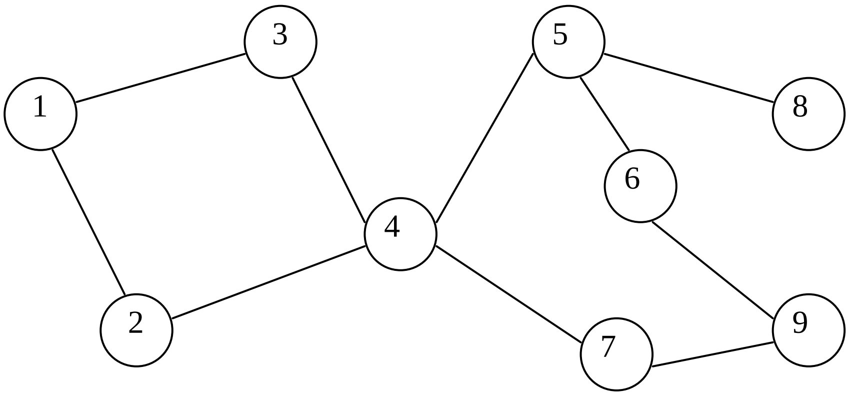

Figure 1. System represented as an undirected graph

	1	2	3	4	5	6	7	8	9
1		1	1						
2	1			1					
3	1			1					
4		1	1		1		1		
5				1		1		1	
6					1				1
7				1					1
8					1				
9						1	1		

Figure 2. Inter-dependence matrix

Table 1. Production costs for insourcing and outsourcing (in $ millions)

Jobs / Decision	1	2	3	4	5
In-house	10	9.9	1	3.2	6.8
Outsource	5.5	9.6	0.9	3	6.5

Table 2. Expected additional cost (in $ millions) for the vendor to perform job 1

Job 1			
Performance	Cost	Probability	Expected cost
GOOD	0.01	0.25	0.0025
FAIR	0.25	0.55	0.1375
POOR	0.5	0.2	0.1
Expected additional cost			0.24

Table 3. Expected total additional cost (in $ millions) of outsourced jobs

Jobs	1	2	3	4	5
Expected additional cost	0.24	0.319	0.04	0.164	0.124

Table 4. Costs (in $ millions) due to interdependence between jobs when job *i* outsourced and job *j* done in-house

Cost (Scenario 2)	**Outsource**				
In -house	1	2	3	4	5
1	0	**0.2**	0.2	0.3	0.1
2	0.5	0	0.5	0.3	0.2
3	0.2	0.1	0	0.1	0.12
4	0.4	0.3	0.2	0	0.3
5	0.3	0.2	0.25	0.4	0

Table 5. Resources required by each job and the maximum resources of the firm

Resources required	1	2	3	4	5	Max resources of the firm
Labor hours	100	150	50	150	180	200
Computers	50	30	20	30	40	100
Experts	20	25	10	30	20	50

Table 6. Optimal solution for the decision model

JOBS	1	2	3	4	5
Outsource ={0} **In-house={1}**	0	1	1	0	0

Table 7. The optimal solution for the decision model

JOBS	1	2	3	4	5
Outsource ={0} **In-house={1}**	1	1	0	0	1

Table 8. The resources used for in-house production

Resources used	Prior assignment of jobs	With the consideration of the penalty	Max resources of the firm
Labor hour	200	200	200
Computer	50	50	100
expertise	35	40	50