Make-or-Buy Dilemma: Software Sourcing by Combining Analytic Hierarchy Process with Linear Programming Methods

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Abstract — Supplier selection for custom software development is difficult because the role that quantitative and qualitative factors play in making a purchasing decision. Qualitative factors are based on conflicting requirements governed by different viewpoints. Decision support models are used to assimilate and organize this information. By integrating three decision support models specifically designed to analyze each factor; work can be optimally allocated across suppliers. This paper describes using a multi-criteria decision process to determine each software supplier's utility rating, cost modeling to provide cost of the labor estimate, and integer linear programming to optimize allocation of labor between highest rated suppliers. Modeling tools available on the internet were used and an Excel model was developed to produce the allocation results.

Key Words — Outsourcing, Software Development Estimation, Linear Programming, Cost Modeling, Multi-Criteria Decision Making, Analytic Hierarchy Process.

I. Introduction

THE objective of this research is to develop a decision support model to give insight into make-or-buy decisions focusing on software development. A make-or-buy decision is a strategic decision companies make to determine the benefits of making a product or providing a service. Research indicates there are various names for make-or-buy decisions. The concept is expressed in the terms: *sourcing, outsourcing,* and *sub-contracting,* along with the lesser known term *insourcing* (Eilam, 1991; Hwang, 2003). Throughout this paper, make-or-buy and outsourcing will be used interchangeably to express the main theme of this discussion.

Government contractors face a dilemma when deciding on using an in-house product development group or outsourcing the development work to vendors. Contract proposals are written that include delivery of products and services that may not be core competencies of the bidding firm. The prime contractor may prefer outsourcing work to a sub-contractor. In this case, insourcing is not an option; the decision of outsourcing is made with regards of selecting a sub-contractor to provide the work package or fulfill the statement of work (SOW).

The scope of this project is limited to four software development sourcing options with one of the options being in-house sourcing. The winning bidder will be awarded all the work within one work package. There will be 30 standardized work packages containing all requirements and specifications for the software development effort. The work packages will be optimally allocated to each supplier as defined in the Integer Linear Programming (ILP) model developed in this paper.

Literature on organizational behavior and the history of outsourcing was reviewed. The review presented insight into a firm's motivation to seek an outside supplier and less obvious effects outsourcing has on a business. Secondly, software development estimating models were reviewed. An examination of the Analytic Hierarchy Process (AHP) proved it to be a valuable method to rank the importance of one variable to another. Structuring the problem using AHP was suggested as a way to make comparative judgments and priority (Hwang, 2003). Thirdly, Linear Programming (LP) models were investigated and a specific case where a combination of AHP and LP is used to provide tangible cost benefit in a capacity planning application was considered (Gurgur & Morley, 2008).

II. Literature Review

A. *Perspectives on Outsourcing*

Standard cost accounting methods have traditionally been used in make-or-buy decisions (Balakrishnan, 2005). It has been suggested that instead of comparing total cost, a differential cost perspective should be taken (Michel, 2004). Unrelated fixed costs may be included into the financial model due to pre-existing obligations that weight favorably to outsourcing. Michel reasonable argues that analysis should cover multi-year periods using discounted future cash flows to their present value. Others support this theory by demonstrating that short-term contractual time horizons often result in lost profit by using LP models (Sopariwala & Koste, n.d.).

A study of the benefits, risks, motivations and other factors associated with outsourcing reveals that outsourcing decisions involve input from multiple interested parties both internal and external to a business. Each party considers outsourcing from a different viewpoint. An interested party may be a labor union or other peripherally joined entities that may constrain the decisions. The make-or-buy decision can be analyzed using various viewpoints, each adding a unique dimension to

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the problem. In discussing the different approach companies take towards their outsourcing decision, Canez, Probert and Platts (2001, p. 1) explain:

> Existing approaches address make-or-buy from different perspectives such as *economics* (Poppo et al., 1995), *purchasing* (Shore, 1970), *accounting* (Bassett, 1991) and *strategic management* (Venkatesn, 1992). However, two main streams were identified in the literature. The first aims at answering the make-or-buy question from a cost viewpoint (Raunick and Fisher, 1972; Levy and Sarnat, 1976; Meijboom, 1986; Bassett 1919?; Ellis (1992, 1993); Balkrishnan, 1994; Poppo et al., 1995; Poppo, 1998; Padillo-Perez, 1995; Padillo-Perez, et al., 1999). The concept of *transaction cost* often plays an important role in many of the models mentioned above. The second approaches make-or-buy from a strategic perspective, acknowledging other factors in addition to cost [italics added].

Multi-disciplinary knowledge domains within an organization attempts to solve the make-or-buy problem from various viewpoints (Canez et al., 2001). This is supported by a survey of over 200 publications dealing with outsourcing that were analyzed (Kremic, Tukel & Rom, 2006 p. 460-82).

The main contribution of this paper is in identifying that the breath of literature lacks a practical approach to address the make-or-buy decision at an operational level when software development is concerned as opposed to outsourcing many low cost products for mass consumption.

B. *Prior Literature and Industry Practices*

One of the earliest discussions of outsourcing is derived from a paper on economic theory applied to business organization (Coase, 1937). The concept of outsourcing is used in a broad context as the author discusses how firms orchestrate partnerships with suppliers rather than integrate vertically. Vertically integrated companies are united through a common business owner that forms a supply chain. Vertical integration refers to insourcing as opposed to outsourcing.

Some companies strategically incorporate outsourcing into their business model (Klien, 2004). Klien contrasts IBM's highly integrated model which produces components and software and maintains a sales force to Dell Computers and Reebok Shoe Company. Dell outsources hardware and software components to focus on quickly customized production through internet sales. He observes that Reebok relies on outside suppliers completely as it owns no manufacturing plants. It is apparent by his examples that companies can remain successful regardless of the decision to outsource functions or integrate vertically.

Transaction Cost

Economists warn that outsourcing generates a hold-up problem that interferes with mutual success and profitability (Lee, 2008). The hold-up problem refers to the loss of bargaining power the supplier has after it makes investments to fulfill its obligations. In the 1970s and 1980s, literature emerged explaining the make-or-buy decision using transaction cost reasoning (Klein, 2004). Transaction cost is important to make-or-buy decisions because it consists of the cost incurred in searching for the best supplier and the cost of establishing a relationship.

Production cost is composed of raw materials and labor. Transaction costs are incremental costs incurred in bringing the product to market or making an economic exchange. They contain the cost related to monitoring and enforcing the implementation of the contract. Poor decisions could result in the absence of evaluating a firm's production capacity using Transaction Cost Economics (Cheng, 2005). Since software development has very few raw materials costs, a substantial cost component is transactional in nature from the viewpoint of the contractor.

C. *Outsourcing Software Development*

Special attention needs to be given when outsourcing software projects because "... developer effort may be hard to monitor and product quality cannot be verified immediately after the software is delivered" (Dey et al., 2009, p. 16). Their work examines outsourcing through the viewpoint of structuring a software development contract and the important dimensions that must be considered. Dey et al. summarize by stating "We find that, if a client has an effective and efficient process of monitoring and auditing, a time-and-materials contract may perform better than a fixed-price contract" (2009). They identify important factors a typical software development contract must address. Suggested factors are quality, timeliness, transactions cost, payment structure and post delivery support (2009).

D. *Cost Estimation and Hierarchy Analytical Process*

Producing software in-house is an option that is being considered for this project; however no favorable bias is given to insourcing. Software development cost estimation presents unique challenges and many estimation models have been developed (Boehm & Abts, 2000). Contracting for custom software does not permit competitive price evaluations on the open marketplace. Literature was surveyed on different models used for software cost estimation.

Cost Estimation

Constructive cost model II (COCOMO II) was researched for cost estimation and is suitable to obtain baseline cost estimates for this project. It allows estimation of cost and schedule for software development activity. Additionally, it is easily obtainable on the internet without cost. Boehm et al. conclude that that no one method or model should be preferred over others (2000). The interpretation of their finding suggest that if one can justifiably explain the reasons behind the cost decisions and risk factors one has a good grasp of the factors driving cost. As stated earlier, the transactional cost whether incurred internally or externally is important to consider. A staffing formula used by the U.S. Office of Management and Budget indicates that projects with seventy to one-hundred employees require four contract administrators full time (Michel, 2004).

Analytic Hierarch Process

The Analytic Hierarchy Process (AHP) was developed by Thomas Saaty (Saaty, 1999) in the late 1970s as an approach to Multi-Criteria Decision Making (MCDM). His structured technique to complex decisions forms a hierarchy of essential relationships. Decision problems that contain quantitative factors as well as qualitative factors can be incorporated into the decision space. The structure is put into matrix form and using pairwise comparisons the relative importance of one criterion over the other can be expressed. The top level of the hierarchy has the single goal element. The other intermediate levels depict interconnecting decision criterion. The bottom level lists the connecting alternatives.

There are importance internet sources of information to aid in the understanding of the Analytic Hierarchy Process (Teknomo, 2006). Teknomo provides a very simple yet informative tutorial on the basics of problem decomposition into a hierarchy of criteria and alternatives. Figure 1 shows a generic form of the hierarchy structure.

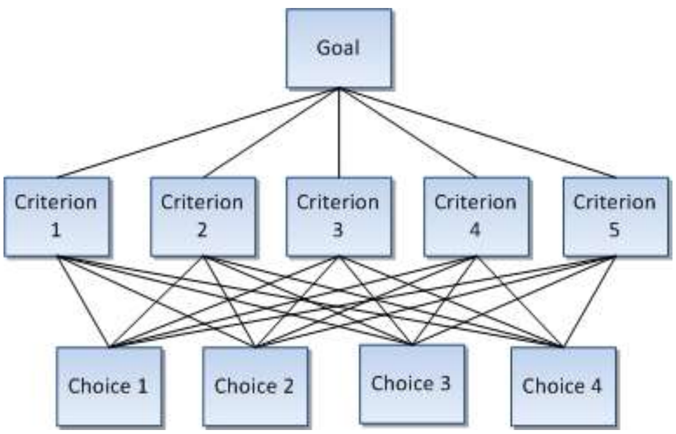


Figure 1: Generic Hierarchy Structure
(Adapted from Teknomo)

Make-or-Buy decisions are often used as LP examples using capacity constraints and schedule constraints (Anderson, Sweeney, Williams & Martin, 2008). The problem can be formulated into a capacity constraint problem without pairwise evaluation of AHP. Gurgur and Morley (2008) describe using both methods to solve a complex project-portfolio selection all within an Excel spreadsheet. Their study proved that the combination of AHP and LP can provide a valuable tool when handling quantitative and qualitative information.

E. Review Summary

Providing decision makers with the tools and techniques to craft low cost and risk aversive agreements are important in this discussion. Government contractors face mounting pressure to reduce spending (Potter, 2005). In contractual settings, software development is hard to monitor and control quality. Software development has low raw material acquisition costs. A large expense is incurred from transactional cost within a firm or on the open market. Contract should be structured to promote sub-contractor investments without fear of diminished bargaining power. Multiple techniques can be applied to software sourcing decision making under uncertainty. No one domain of knowledge is complete in helping the decision maker. A review of relevant literature has shown that an outsourcing decision is best made using a multi-disciplinary approach. The benefits of blending both operational research (OR) techniques and human factors in decision making is discussed in following sections.

III. Process Overview

Figure 2 shows the quantitative and qualitative inputs that are supplied to the decision support models that result in optimized output. The quantitative inputs are objective non-judgmental facts used in the models supplied by vendors or derived internally. Qualitative inputs are judgments or subjective interpretations that are transformed into quantitative information to be used in the LP model.

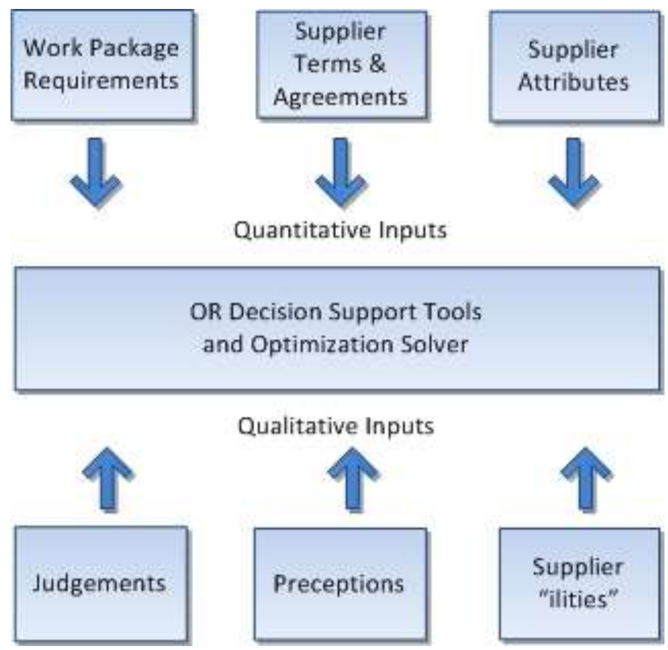


Figure 2: Decision Tools and Inputs

System Engineers evaluate system parameters in terms of 'illities' that are system wide requirements (Buede, 2000). Examples related to software development outsourcing are *on-time delivery* and *production reliability*, *modification flexibility*, and *software supportability*. These are important attributes that must be taken into consideration in the decision process. They could be qualified by specific requirements such as; "*the software shall not have more than one defect per 10,000 lines of code*," however, it is difficult to measure in complex systems and often discovered after delivery and installation of the work package. Therefore, these model parameters are evaluated using AHP pairwise method.

IV. Criteria and Problem Formation

Three different model types are used in this paper that forms the solution to the vendor selection problem as related to software outsourcing. The models provide proven implementation of methodologies to determine decision criteria weights, software cost estimates, and optimization of work allocation. The implementations of these methodologies selected for use are Web-HIPRE, COCOMOII and Microsoft Excel. Suitable web based implementations are readily available for AHP and software estimating. Microsoft Excel has proved to be widely excepted interface with a LP solver. Familiarity of Excel by many engineers and managers promoted process credibility and acceptance while controlling common units of measurement that can introduce errors.

Figure 3 illustrates the human decision and automated processes along with artifacts that result from each process. We can see that the output of AHP and COCOMOII models are used as input into the LP model.

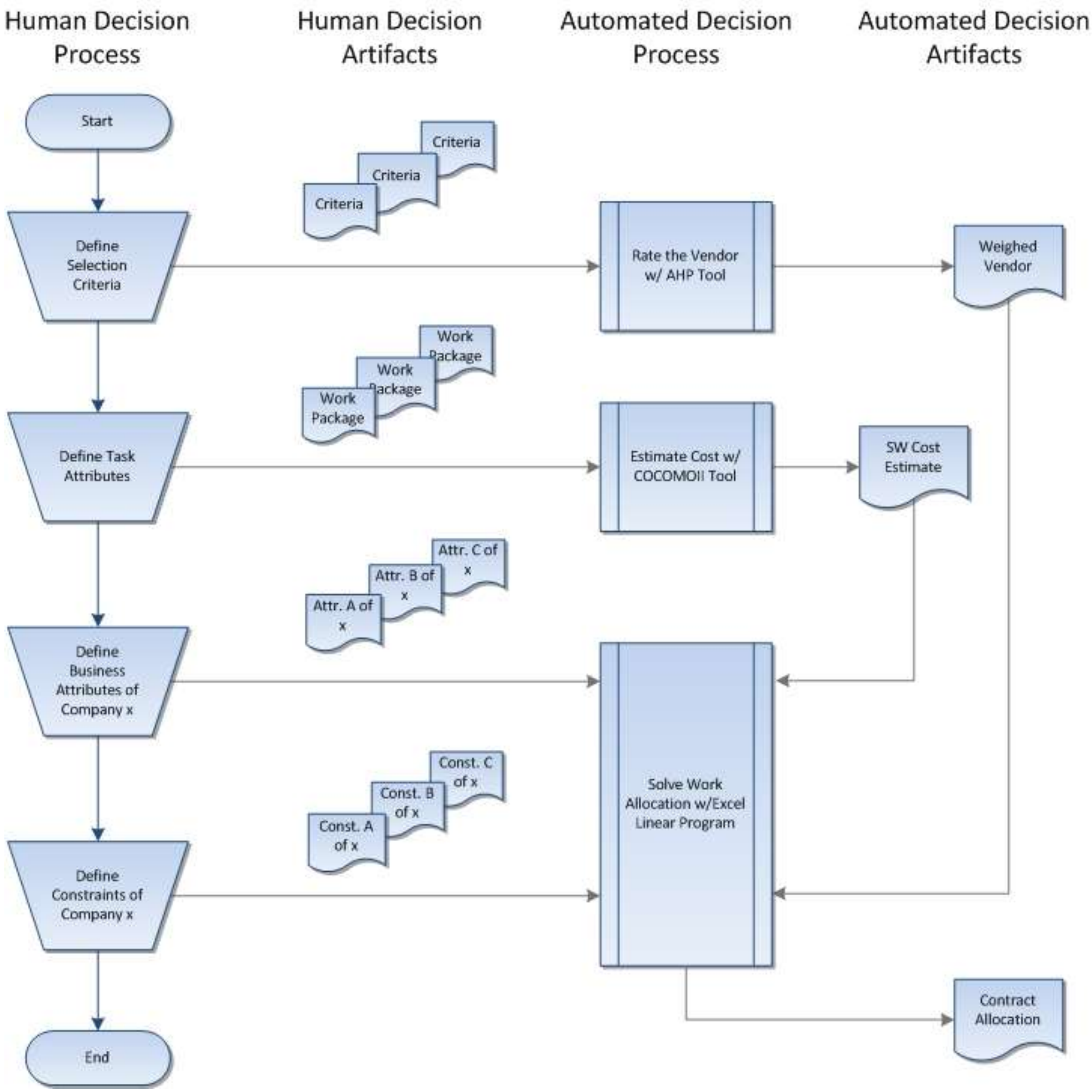


Figure 3: Process Flowchart and Decision Artifacts

A. Define Selection Criteria

AHP provides a method of capturing qualitative human decision factors that must be represented. Some decision criteria are judgments of technology readiness and perception of a particular vendor's reliability, supportability, and flexibility. The model with goal, criterion, and choices are shown in figure 5. Web-HIPRE implements the generic hierarchy with the goal being placed at the far left. The criteria can have multiple levels moving to the right. The alternative choices are shown on the right hand side of the figure. The lines show a relationship between nodes that are evaluated pairwise.

A pairwise comparison allows for trade-offs between qualitative factors which calculate a rating for each supplier. Saaty's 1-9 scales are used to evaluate qualitative criteria. The assumption follows that if A is 9 times as good as B, then B is 1/9 as good as A. The final ratings are applied as coefficients to an objection function in a linear programming model.

Web-HIPRE calculates the consistency ratio (CR) to indicate inconsistent pairwise rating above 10 percent. All ratings were at or below the CR rating threshold.

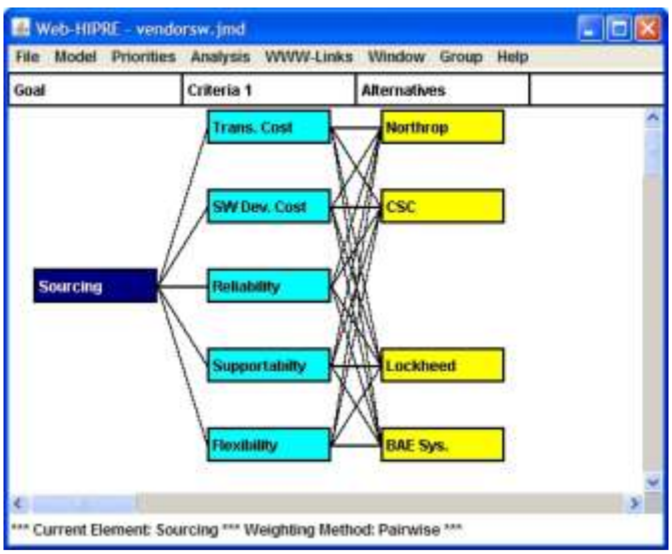


Figure 5: AHP Model

B. Supplier Rating

The software development sourcing choices are Northrop Grumman, Computer Science Corporation (CSC), Lockheed Martin (in-house), and BAE Systems. Figure 6 depicts the final weights after comparison. The results show that CSC and Lockheed are most favored using the AHP process alone. Northrop and BAE Systems fall into third and fourth place respectively.

The color coding provided by Web-HIPRE provides insight into criteria weights. We can see that reliability on the top of each bar in the graph is considered very important in relation to other criteria. Secondly, software development cost is heavily weighted.

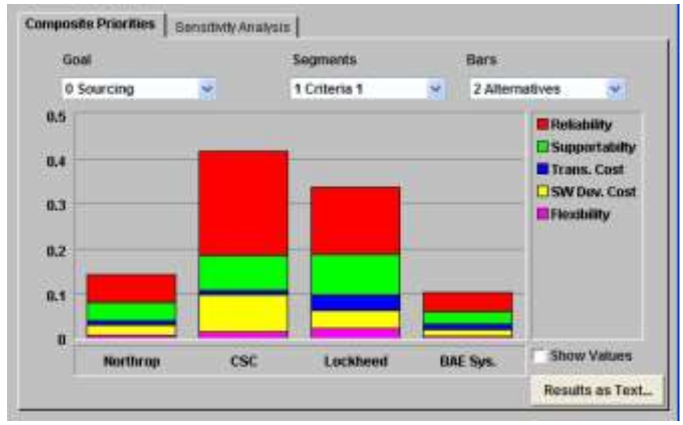


Figure 6: AHP Summary

Table 1 displays the same information presented in numeric form for input into our LP model. The text values are summed to give exact utility rating for each supplier. The total percentages may not equal exactly one due to computer round off error.

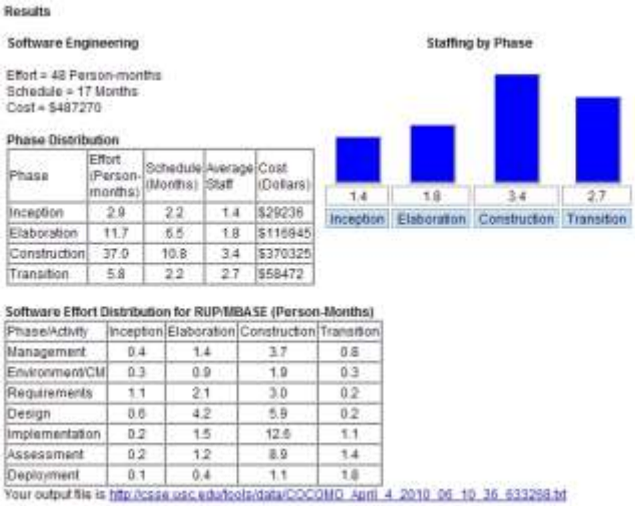
Transaction cost is less important with the in-house vendor due to common management oversight between parties. Furthermore, internal sourcing mitigates the hold-up problem that can affect mutual trust of the negotiating parties.

Table 1: Numeric Results

Criteria	**Northrop**	**CSC**	**Lockheed**	**BAE Sys.**
Reliability	0.031	0.234	0.099	0.035
Supportability	0.071	0.031	0.047	0.01
Trans.Cost	0.013	0.017	0.045	0.015
SWDev.Cost	0.029	0.123	0.119	0.04
Flexibility	0.023	0.008	0.005	0.005
Overall	**0.167**	**0.414**	**0.315**	**0.104**

C. Define Task and Estimate Cost

Software development cost is estimated by a cost model that provides a basis to evaluate vendor proposals. Variation from the estimate will reward or penalize the vendor in the LP model. COCOMOII is a cost model that allows one to estimate the cost, effort, and schedule when planning a new software development activity. A Basis of Estimate (BOE) is provided by past experience of estimating software development. The BOE defines expected software development attributes that are inputs into the cost model. Information, such as, the expected volume in terms of lines of code (SLOC), number of interfaces, and other information are used for cost modeling. The output provides a basis of the expected labor cost for a work package. Figure 7 show an example of a work package being evaluated in COCOMOII.


Results

Software Engineering

Effort = 48 Person-months
Schedule = 17 Months
Cost = $487270

Phase Distribution

Phase	Effort (Person-months)	Schedule (Months)	Average Staff	Cost (Dollars)
Inception	2.9	2.2	1.4	$29236
Elaboration	11.7	6.5	1.8	$116945
Construction	37.0	10.8	3.4	$370325
Transition	5.8	2.2	2.7	$58472

Software Effort Distribution for RUP/MBASE (Person-Months)

Phase/Activity	Inception	Elaboration	Construction	Transition
Management	0.4	1.4	3.7	0.6
Environment/CM	0.3	0.9	1.9	0.3
Requirements	1.1	2.1	3.0	0.2
Design	0.6	4.2	5.9	0.2
Implementation	0.2	1.5	12.6	1.1
Assessment	0.2	1.2	8.9	1.4
Deployment	0.1	0.4	1.1	1.8

Your output file is http://csse.usc.edu/tools/data/COCOMO_April_4_2010_06_10_36_633298.txt

Figure 7: Cost Estimation Example

The cost consequence results are shown in figure 8. These rating are a consequence of being higher or lower than the cost model's estimate. Note that the differences are relatively small between suppliers. This can be partially explained since the bids across all work packages are averaged. A vendor bidding higher than the estimate on one package and lower than the estimate on another would tend to balance the consequence. Therefore, a vendor that is very expensive and very inexpensive 50 percent of the time will appear equally as a good as a vendor that is very close to the estimate on each work package.

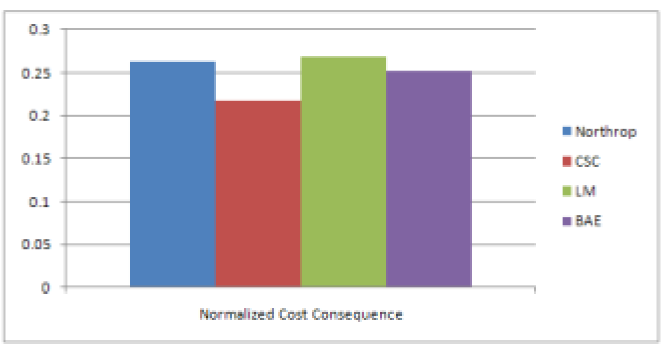


Figure 8: Cost Consequence

D. *Define Business Attributes and Constraints*

All suppliers are considered capable of producing the software work packages. Each supplier has a limited number of software developers and support personnel that is directly related to the number of work packages that can be produced.

V. Model Formation

The standard LP model is used by defining the objective function and the constraints that bound the problem. The deviation of expected cost versus the actual cost is used to penalize the more expensive supplier and reward the less expensive supplier.

A. *Objective function*

Ghodsypour & O'Brien referred to the optimal allocation of order quantity as the Total Value of Purchase (TVP) (1998). They describe using two methodologies in an integrated approach of applying AHP and LP models to vendor selection. We borrow the Total Value of Purchase concept for use in our objective function. The optimal allocation of work package quantity is the objective of this project. Maximizing the TVP is the optimization component of the problem. The objective function and constraints are described in more detail below.

B. *Model Notations*

R_i Utility rating of the *i*th supplier from AHP
C_i Cost consequence of *i*th supplier proposal
X_i Number of work packages assigned to *i*th supplier
V_i Capacity of *i*th supplier
n Number of possible suppliers
wp Number of work packages

The objection function of the model is to maximize the Total Value of Purchase (TPV). The sum product of the utility rating, cost consequence, and the unknown number of assigned work packages. Four vendors were used in the evaluation. The formula is shown below.

$$Max(TPV)\sum_{i=1}^{n} R_i C_i X_i \qquad \textbf{(1)}$$

C. *Utility Rating*

The utility rating coefficient corresponds to the normalized output generated from the AHP model. This input represents the qualitative input into the LP model.

D. *Cost*

The cost consequence coefficient is derived by averaging the vendor's proposal for each package and computing a ratio based on the estimated cost from COCOMOII. The average estimated cost for each work package is divided by the vendor's average bid cost. The weights are normalized. There are 30 work packages evaluated in this study.

A higher bid than the estimate produces a lower rating. A lower bid than the estimate produces a higher rating.

$$\sum_{j=1}^{wp} \frac{Estimate(C_j)}{C_j} \qquad \textbf{(2)}$$

E. *Constraints*

The maximum number of work packages produced by all vendors must equal the total number of work packages. This assures that all work packages are allocated.

$$\sum_{i=1}^{n} X_i = 30 \qquad (3)$$

A supplier cannot produce more work packages than their capacity. Equation 4 shows this constraint.

$$\sum_{i=1}^{n} X_i \leq V_i, \qquad i = 1,2,\ldots,n \qquad \textbf{(4)}$$

Only full work packages can be allocated to a supplier, therefore the number must be an integer. Also, the number of work packages must not be negative. The integer and non-negativity constraints are shown in equations 5 and 6 respectively.

$$\forall\, X_i = int \qquad \textbf{(5)}$$

$$\sum_{i=1}^{n} X_i \geq 0, \qquad i = 1,2,\ldots,n \qquad \textbf{(6)}$$

VI. Spreadsheet Implementation

An Excel spreadsheet was created to optimize the allocation of work packages by maximizing the TVP. Figure 9 shows the model developed in Excel. The Web-HIPRE AHP rating data was imported into Excel from a text file onto a separate worksheet. Another worksheet contains each vendor's cost proposals for each of the 30 work packages. The average cost for all work packages are calculated on the worksheet along with the average estimates provided from COCOMOII. AHP is automatically normalized from the tool's output. Cost data was normalized by dividing each average by the sum of all averages. Using Excel's built-in solver the results were calculated based on the objective function and the constraints. The capacity constraints are shown on the right hand side of the model.

		Northrop	CSC	LM	BAE		
Demand Constraint		1	1	1	1		30
Northrop capacity Const.		1					30
CSC capacity Const.			1				15
LM capacity Const.				1			10
BAE capacity Const.					1		30
Max(TVP)	2.415						
Objective Function		5	15	10	0		
Cost Consequence Ratings		0.262	0.218	0.268	0.252		
AHP Utility Ratings		0.167	0.414	0.315	0.104		
Subject To:		30				=	30
Northrop		5				<=	30
CSC		15				<=	15
LM		10				<=	10
BAE		0				<=	30

Figure 9: Excel Implementation

Cost consequence and AHP utility rating data are referenced from the Web-HIRE and cost estimate worksheets. The cell variables changed by the solver are outlined in green.

The Answer Report is shown in figure 10.

Microsoft Excel 12.0 Answer Report
Worksheet: [WorkingModel4-24.xlsx]LP Model
Report Created: 4/24/2010 5:10:25 PM

Target Cell (Max)

Cell	Name	Original Value	Final Value
C16	Max(TVP)	0.000	2.415

Adjustable Cells

Cell	Name	Original Value	Final Value
D18	Northrop	0	5
E18	CSC	0	15
F18	LM	0	10
G18	BAE	0	0

Figure 10: Excel Implementation

VII. Results Interpretation and Analysis

In this study, results indicate that work packages should be allocated between CSC, LM, and Northrop. The cost incurred with managing three difference sources is considered too expensive from a management prospective. Since capacity is undersupplied for only five work packages, direction was given to find ways to increase capacity at the two most desirable sources, CSC and LM.

This decision was further supported by examining the product of the AHP and cost consequence ratings for the two most favored suppliers; CSC and LM. Both CSC and LM are rank closely higher and Northrop and BAE rank markedly lower as shown in figure 11. We can see that the AHP rating played a significant role in supporting CSC as the more favorable sourcing option while a lower cost rating somewhat mitigated the higher AHP rating benefit.

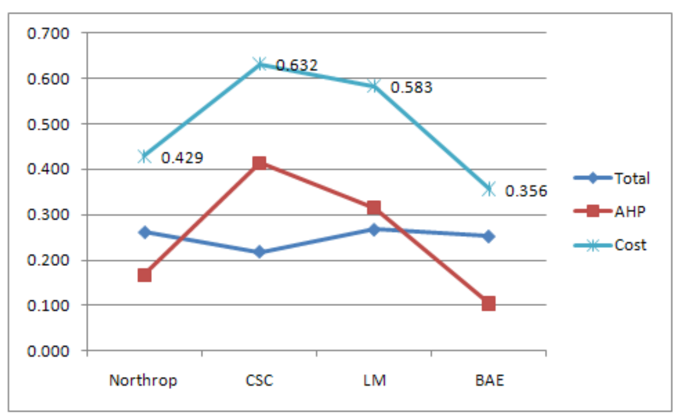


Figure 11: Excel Implementation

Once the maximum work package capacity has been reached for the highest rated supplier the next highest supplier is assigned work packages. This continues until all work packages have been allocated.

VIII. Conclusions and Future Work

Using the LP relaxation technique of dropping the integer requirement for the variables the model was explored without any effect on the results. Additionally, dual prices cannot be used for integer programming sensitivity analysis since they are for linear programs (Anderson et al., 2008). Excel defaults to five percent tolerance and it has been suggested to lower the tolerance to one percent when working with mixed integer linear programming. None of these techniques affected the model's output. However, it is important to recognize that integer optimization is only a close approximation of optimal solution space since the feasible region may extend closely to an adjacent integer.

A. Sensitivity

Small changes in AHP or cost coefficients can have a large affect on the allocation outcome. The sensitivity of these variables dictates the winning bidders and losers absolutely. Therefore, it is necessary to understand the underlying reasons that justify the decision. Although the results indicate CSC is the preferential supplier, it could be disregarded since management may feel that the combined rating variation between CSC and LM (0.632, 0.583) is relatively small. The management decision must take into account the legal complexity of entering into an outsourcing contract rather than keeping full software development control in-house. This is especially important in light of the small difference discovered with this study. Alternate methods to increase in-house sourcing capacity should be explored and evaluated.

B. Cost

The integration of models does pay particular attention to cost. Cost is evaluated from a qualitative aspect and again from a quantitative perspective. This was done because cost was perceived to have considerable overall importance an influence on the decision. A significant amount of time was spent on developing cost inputs, cost modeling, and analysis of proposals. The cost variation between various suppliers has little overall importance in the decision results as shown in figure 11. This was somewhat disappointing, although the exercise reinforced understanding that vendor cost proposals are strongly correlated to the estimated cost.

C. Future Enhancement

In addition to the quantity of work packages assigned to a supplier, specific work packages could be assigned to specific suppliers. This might be accomplished by matching attributes of work packages, such as, amount of code reuse or complexity factors to the best suited supplier. In this case, each work package would have to be scrutinized and each supplier must permit discovery of internal operations and special abilities. While this is a highly desirable objective it may be difficult to implement due to disclosure restriction on proprietary information held by each supplier.

Employing three different models, such as, Web-HIPRE, COCOMOII, and Excel proved difficult to manage and integrate. Two of the models, Web-HIPRE and COCOMOII are web based implementation and storing these models while they were being developed proved to be a serious distraction. Although the tools provided good insight and worked well, forcing in-progress model storage on remote web servers is too great of a risk for data security and potential loss of information. The fear of losing input data and the lack of control would prevent reoccurrence of using web based products again on a similar study.

A decision support tool or combination of tools as described in this study should have an interactive design. To improve usability the models could be combined into one Excel model. Visual Basic for Application (VBA) is included with Excel. A VBA interface would improve usability and limit the need to import data into Excel for each separate model.

D. Conclusion

The model development process created insights into the decision that are equally important as the model's results. The development effort forces understanding and consideration of cost weight factors and system wide factors, such as, reliability, flexibility, and supportability. Additionally, it compared cost proposals to estimated cost that over time can be studied to improve the estimation process. When actual cost is known the costing model can be changed slightly to produce more accurate cost projection for future projects.

By arming a decision making team with valuable make-or buy insight through the use of decision science models key drivers are unveiled that shape the solution of the work allocation problem.

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BIOGRAPHY

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